Vestibular Neuritis

Michael Strupp, M.D.,[1] and Thomas Brandt, M.D., F.R.C.P.[2]

ABSTRACT

The key signs and symptoms of vestibular neuritis are rotatory vertigo with an acute onset lasting several days, horizontal spontaneous nystagmus (with a rotational component) toward the unaffected ear, a pathologic head-impulse test toward the affected ear, a deviation of the subjective visual vertical toward the affected ear, postural imbalance with falls toward the affected ear, and nausea. The head-impulse test and caloric irrigation show an ipsilateral deficit of the vestibuloocular reflex. Vestibular neuritis is the third most common cause of peripheral vestibular vertigo. It has an annual incidence of 3.5 per 100,000 population and accounts for 7% of the patients at outpatient clinics specializing in the treatment of vertigo. The reactivation of a latent herpes simplex virus type 1 (HSV-1) infection is the most likely cause, as HSV-1 DNA and RNA have been detected in human vestibular ganglia. Vestibular neuritis is a diagnosis of exclusion. Relevant differential diagnoses are vestibular pseudoneuritis due to acute pontomedullary brainstem lesions or cerebellar nodular infarctions, vestibular migraine, and monosymptomatically beginning Ménière's disease. Recovery from vestibular neuritis is due to a combination of (a) peripheral restoration of labyrinthine function, usually incomplete but can be improved by early treatment with corticosteroids, which cause a recovery rate of 62% within 12 months; (b) mainly somatosensory and visual substitution; and (c) central compensation, which can be improved by vestibular exercise.

KEYWORDS: Peripheral vestibular vertigo, dizziness, nystagmus, herpes simplex virus type 1, glucocorticoids, vestibular rehabilitation

What can you learn about the vestibular system itself when you take a closer look at vestibular neuritis, a disorder that leads to an acute unilateral vestibular deficit? You can get answers to the following questions: What are the features and the cause of a spontaneous nystagmus? What is the head-impulse test and why is it so useful? What are Alexander's law and Ewald's second law? How do three-dimensional eye movement analyses show that vestibular neuritis does not involve all semicircular canals? What is an incomplete ocular-tilt reaction? What is the bucket test for determining the subjective visual vertical? What is vestibular pseudoneuritis?

To answer these and other questions, we first address the patient history and clinical features of vestibular neuritis, its assumed etiology, epidemiology, spontaneous course, and recurrence rate. Then we discuss the differential diagnoses and finally the current management of vestibular neuritis, which includes symptomatic, causative, and physical therapy.

CLINICAL FEATURES

Patient History

The main symptoms of acute unilateral vestibular deficit are sustained violent rotatory vertigo, apparent movement of the visual surrounding (oscillopsia), gait and postural imbalance with a tendency to fall toward the

[1]Department of Neurology and [2]Institute of Clinical Neurosciences, University of Munich, Munich, Germany.

Address for correspondence and reprint requests: Michael Strupp, M.D., Professor of Neurology and Clinical Neurophysiology, Department of Neurology, University of Munich, Klinikum Grosshadern, Marchioninistrasse 15, 81377 Munich, Germany (e-mail: Michael.Strupp@med.uni-muenchen.de).

Neurotology; Guest Editor, Robert W. Baloh, M.D.

Semin Neurol 2009;29:509–519.

DOI 10.1055/s-0029-1241040. ISSN 0271-8235.

side of the affected ear, as well as nausea and vomiting. All of these symptoms have an acute or subacute onset and last for several days to a few weeks. To make the diagnosis, you must first exclude the possibility of other neurologic deficits, in particular those originating from the brainstem or cerebellum, or acute hearing disorders. Therefore, it is important to note that you have to explicitly ask the patient for symptoms that may arise from the inner ear, brainstem, or cerebellum.[1] There are no typical antecedent signs or triggers, although some patients have occasional spells of vertigo a few days before.[2] Because the patients' complaints are exacerbated by any movements of the head, they intuitively seek peace and quiet.

Clinical Signs

Key signs and symptoms of vestibular neuritis (Fig. 1) are (a) an acute/subacute onset of sustained rotational vertigo with pathologic adjustments of the subjective visual vertical toward the affected ear; (b) horizontal spontaneous nystagmus toward the nonaffected ear with a rotational component associated with oscillopsia; (c) a pathologic head-impulse test (see below)[3]; (d) postural imbalance with a fall toward the affected ear (positive Romberg test); and (e) nausea and vomiting.[4,5] Ocular motor evaluation reveals an incomplete ocular tilt reaction (see below), apparent horizontal saccadic pursuit, and a gaze-evoked nystagmus toward the fast phase of the spontaneous nystagmus. All of these symptoms are secondary to the spontaneous nystagmus, which indicates a vestibular tone imbalance in the yaw (horizontal) and roll (torsional) planes between the two labyrinths.

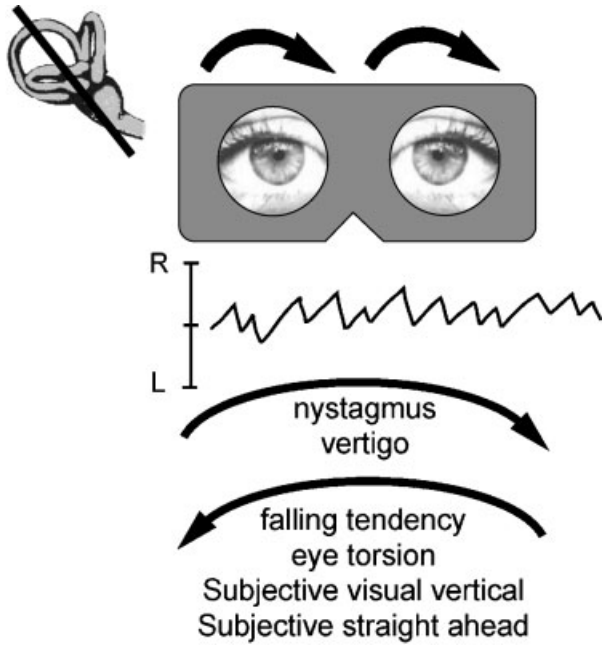

Figure 1 Ocular signs, perception (vertigo, subjective visual vertical, and subjective straight ahead), and posture in the acute stage of right-sided vestibular neuritis. Spontaneous vestibular nystagmus is always horizontal-rotatory away from the side of the lesion (best observed with Frenzel's glasses). The initial perception of apparent body motion (vertigo) is also directed away from the side of the lesion, whereas measurable destabilization (Romberg fall) is always toward the side of the lesion. The latter is the compensatory vestibulospinal reaction to the apparent tilt.

SPONTANEOUS NYSTAGMUS IN VESTIBULAR NEURITIS AND WHAT WE CAN LEARN FROM IT

The nystagmus in vestibular neuritis is horizontal due to an involvement of the horizontal semicircular canal, and has a torsional component due to involvement of the vertical superior canal (beating counterclockwise-left or clockwise-right from the patient's point of view). This peripheral vestibular spontaneous nystagmus is typically reduced in amplitude during fixation because visual fixation suppresses the vestibuloocular reflex. This occurs only when the relevant central structures in the brainstem and cerebellum are intact. The intensity of spontaneous nystagmus is enhanced by eye closure (you can see the nystagmus when looking at the eyelids or even feel it when you touch the eyelids with your fingertips), Frenzel's glasses (+16 diopters), and during convergence. From a clinical point of view this means that if there are no significant differences of the intensity of nystagmus with or without fixation (typical for a "fixation nystagmus"), this indicates a central origin and lesion and excludes vestibular neuritis. According to Alexander's law, amplitude and slow-phase velocity are increased with gaze shifts in the direction of the fast phase, and decreased with gaze shifts in the direction of the slow phase of the nystagmus. This may mimic unilateral gaze-evoked nystagmus in a patient with moderate spontaneous nystagmus that is completely suppressed by visual fixation straight ahead, but it is still present with the gaze directed toward the fast phase.

WHAT CAUSES THE SPONTANEOUS NYSTAGMUS?

Normal vestibular end organs generate an equal resting-firing frequency of the axons, which is the same on both sides. This continuous excitation (resting discharge rate in the monkey ≈100 Hz,[6] 1800 vestibular afferents for each labyrinth,[7] i.e., 180,000 action potentials per second) is transmitted to the vestibular nuclei via vestibular nerves. Pathologic processes affecting an end organ or vestibular nerve alter its firing frequency, thereby creating a vestibular tone imbalance. This causes a spontaneous nystagmus with the slow phase (the pathologic component of the nystagmus) of the eye movements in the direction of the impaired labyrinth. This imbalance is also the cause of the other manifestations on different levels, i.e., perceptual (rotatory vertigo, displacement of the subjective vertical),

ocular motor (besides a spontaneous nystagmus an ocular torsion), postural, and vegetative signs (nausea).

The three-dimensional features of the spontaneous nystagmus in vestibular neuritis, the horizontal, vertical, and torsional components as well as the dynamic deficit of the vestibuloocular reflex of the horizontal, anterior, and posterior semicircular canals (see below), were measured by means of the scleral-coil technique and analyzed by a vector analysis.[8] These measurements support the earlier view[9] that vestibular neuritis is a partial, rather than a complete, unilateral vestibular lesion (see below). It affects the superior division of the vestibular nerve (innervating the horizontal and anterior semicircular canals, the maculae of the utricle, and the anterosuperior part of the sacculus), which has its own path and ganglion,[10,11] whereas the inferior vestibular nerve (innervating the posterior semicircular canal and the posteroinferior part of the sacculus) is spared.[8] This has two implications: the first with respect to clinical findings because it explains why patients with vestibular neuritis can suffer from benign paroxysmal positioning nystagmus of the posterior canal[9]; the second implication is with respect to the pathophysiology and etiology because any such theory has to explain this fact.

HEAD-IMPULSE TEST INDICATES A HIGH-FREQUENCY DEFECT OF THE VESTIBULOOCULAR REFLEX

A suspected diagnosis of vestibular neuritis is supported by demonstrating a unilateral deficit of the vestibulooocular reflex by the head-impulse test.[3,12] When the head is rapidly rotated toward the side with the lesion, the eyes move with the head and the patient has to make a compensatory refixation saccade (Fig. 2). This indicates a dynamic unilateral high-frequency deficiency of the vestibuloocular reflex, which persists if the peripheral vestibular function does not recover.

But we have two labyrinths. Thus, why can't the intact one substitute for the deficient one? The direction of head rotation is sensed by corresponding on-and-off modulation of the resting activity (~100 Hz) of the right and left vestibular nerves and semicircular canals, which corroborate in pairs for the particular plane of motion. The horizontal and vertical canals are activated in the direction of the head movements (for instance, turning the head to the right causes an excitation of the right horizontal canal), which is an easy way to remember this. In parallel, there is an inhibition of the corresponding canal in the same plane. In the on-direction an increase from 100 Hz to ~500 Hz; i.e., by 400 Hz is possible, whereas in the off-direction a decrease from ~100 Hz to 0 Hz is only possible and is therefore limited. This asymmetry between on and off directions is the basis for Ewald's second law.[13,14] This deficit cannot be compensated for by any other system, and leads to the permanent dynamic vestibuloocular reflex deficit if the function does not recover.

INCOMPLETE OCULAR TILT REACTION AND THE BUCKET TEST

An incomplete ocular tilt reaction with ocular torsion and perceived tilts of the subjective visual vertical has been described in most patients with vestibular neuritis.[15] Today, a simple bedside device, the so-called bucket test[16] can be used to easily measure the subjective visual vertical, which is the most sensitive parameter for an acute lesion of the vestibular system (Fig. 3).

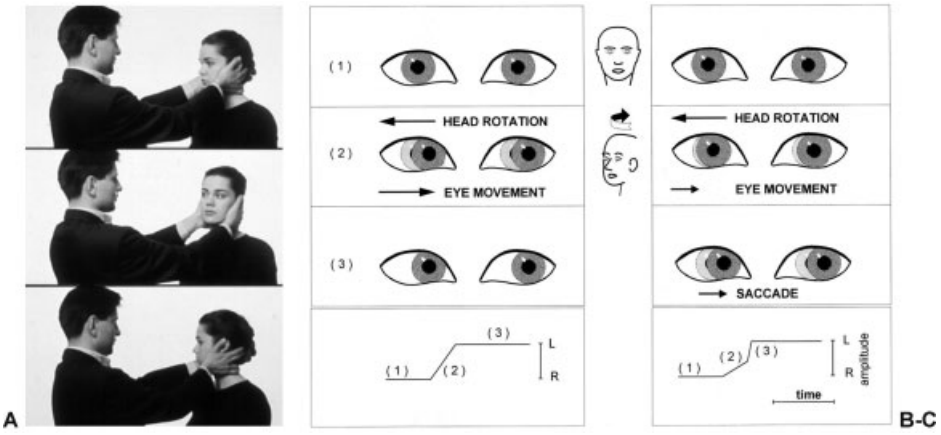

Figure 2 Clinical examination of the horizontal vestibuloocular reflex (VOR) by the head-impulse test by Michael Halmagyi and Ian Curthoys in 1988.[3] To test the horizontal VOR, the examiner holds the patient's head between both hands, asks him or her to fixate a target in front of his or her eyes, and rapidly and arbitrarily turns the patient's head horizontally to the left and then to the right. (A) This rotation of the head in a healthy subject causes rapid compensatory eye movements in the opposite directions. (B) In cases of unilateral labyrinthine loss, the patient is not able to generate the VOR-driven fast contraversive eye movement and has to perform a corrective (catch up) saccade to refixate the target. (C) Shown is an explanation of the findings in a patient with a loss of the right horizontal canal function. During rapid head rotations toward the affected right ear, the eyes move with the head to the right and the patient has to perform a refixation saccade to the left; the latter can be easily detected by the examiner.

Figure 3 The bucket test for determining monocular and binocular visual vertical. (A) Patients sit upright looking into a translucent plastic bucket so that the bucket rims prevent any gravitational orientation clues. (B) On the bottom inside the bucket, there is a dark, straight, diametric line. On the bottom outside (A), there is a perpendicular that originates from the center of a quadrant divided into degrees with the zero line corresponding to the true vertical. For measurement, the examiner rotates the bucket clockwise or counterclockwise to an end position and then slowly rotates it back toward the zero degree position. Patients indicate the position where they estimate the inside bottom line to be truly vertical by signaling stop. The examiner reads off the degrees on the outside scale. Ten repetitions have to be performed. An eye patch is used for monocular testing. In a group of 30 healthy subjects, the range of absolute deviations of binocular subjective visual vertical (from true verticality) was $1.1 \pm 0.9^{\circ}$ (mean $\pm$ SD). Therefore, the bucket test is an easy reliable test to determine the subjective visual vertical. (From Zwergal et al.[16])

Although mentioned in the literature before,[17,18] patients with vestibular neuritis do not have a skew deviation. This typically occurs in vestibular pseudoneuritis[19] and can also be found in a complete deafferentiation as occurs in zoster oticus.[20] An ocular tilt reaction indicates a vestibular tone imbalance in the roll plane induced by involvement of the anterior semicircular canal, otolith function, or both.

Laboratory Examinations

CALORIC TESTING

The principal diagnostic marker of vestibular neuritis is a peripheral vestibular deficit on the affected side. Caloric testing shows a hypo- or unresponsiveness of the tested and affected horizontal canal in vestibular neuritis. Because there is a large intersubject variability of the nystagmus induced by caloric irrigation and a small intraindividual variability of the response of the right and the left labyrinths in healthy subjects, Jongkees' vestibular paresis formula[21]:

$$(((\mathrm{R30\,deg} + \mathrm{R44\,deg}) - (\mathrm{L30\,deg} + \mathrm{L44\,deg}))/ (\mathrm{R30\,deg} + \mathrm{R44\,deg} + \mathrm{L30\,deg} + \mathrm{L44\,deg})) \times 100$$

should be used to determine vestibular paresis, where, for instance, R30 deg is the mean peak slow phase velocity during caloric irrigation with 30°C water. Vestibular paresis is usually defined as >25% asymmetry between the two sides.[22] This formula allows a direct comparison of the function of the horizontal semicircular canals of both labyrinths, which is important due to the large interindividual variability of caloric excitability.

VESTIBULAR-EVOKED MYOGENIC POTENTIALS AND GALVANIC STIMULATION

In response to loud clicks, vestibular-evoked myogenic potentials (VEMPs) can be recorded from the sternocleidomastoid muscles.[23,24] There is good evidence that VEMPs originate in the medial (striola) area of the saccular macula.[25] VEMPs allow examination of the function of the sacculus, and thereby of the inferior vestibular nerve. Vestibular-evoked myogenic potentials are preserved in two-thirds of the patients with vestibular neuritis.[26] This is because the inferior part of the vestibular nerve is spared in most patients (see above), and it supplies the posteroinferior part of the sacculus and posterior canal.

ETIOLOGY

The most popular theory supports a viral etiology, but the evidence for it remains circumstantial.[27–29] The following arguments are presented to support a viral etiology.[1] Vestibular nerve histopathology in cases of vestibular neuritis[30] is similar to that seen in single cases of herpes zoster oticus, when temporal bone histopathology was available.[2] An animal model of vestibular neuritis was developed by inoculating HSV-1 into the auricle of mice.[31] HSV-1 DNA was repeatedly detected in about two-thirds of autopsied human vestibular ganglia by polymerase chain reaction (PCR) (Fig. 4).[32,33] Furthermore,

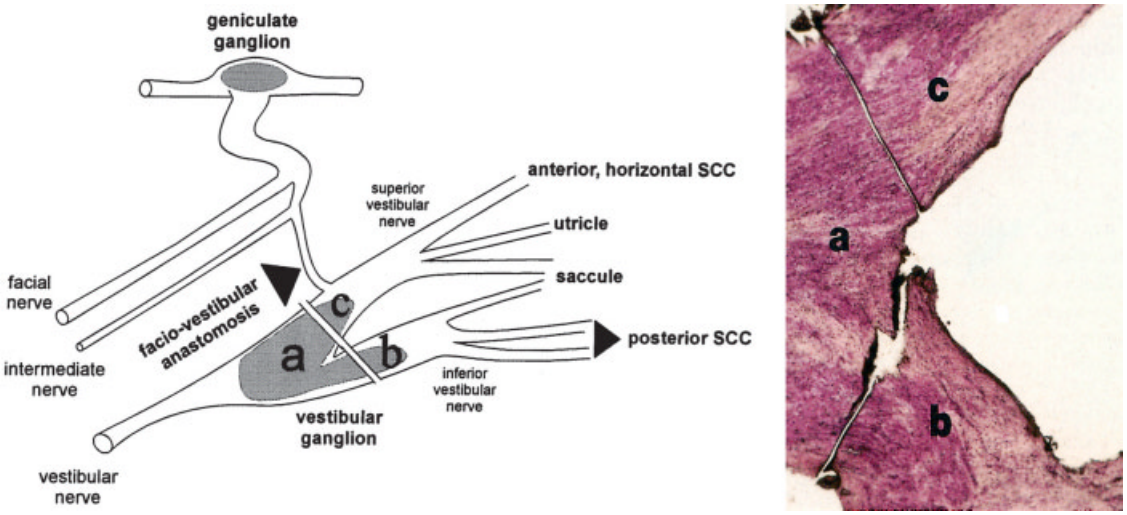

Figure 4 Schematic drawing of the vestibular and facial nerves, the facio-vestibular anastomosis, the geniculate ganglion, and different sections of the vestibular ganglion (a stem, b inferior portion, and c superior portion). Right: Longitudinal cryosection of a human vestibular ganglion, in which the individual portions are separated. Using polymerase chain reaction (PCR), herpes simplex virus 1 (HSV-1) DNA was found in ~60% of the examined human vestibular ganglia. Moreover, the double innervation of the posterior canal, which led to the preservation of its function during vestibular neuritis, is visible. SCC, semicircular canal. (From Arbusow et al.[33])

the latency associated transcript was found in ~70% of human vestibular ganglia.[34] All these findings indicate that the vestibular ganglia, like other cranial nerve ganglia, are latently infected by HSV-1.[35–37] A similar etiology is also assumed for Bell's palsy and strongly supported by the demonstration of HSV-1 DNA in the endoneural fluid of affected subjects.[38]

If HSV-1 is the most likely candidate, it can be assumed to reside in a latent state in the vestibular ganglia; e.g., in the ganglionic nuclei as has been reported in other cranial nerves.[35,39,40] As a result of intercurrent factors, it suddenly replicates and induces an inflammation and edema, causing secondary cell damage of the vestibular ganglion cells and axons in the bony canals. The canal of the superior vestibular nerve is longer and has more speculae,[41] whereas the posterior semicircular canal is innervated by an additional anastomosis,[42] which may explain why the posterior canal is often spared.

Epidemiology, Spontaneous Course, Recurrences, and Complications

EPIDEMIOLOGY

Vestibular neuritis has an incidence of ~3.5 per 100,000 population.[43] In our Dizziness Unit, vestibular neuritis is the third most common cause of peripheral vestibular disorders. The most common cause is benign paroxysmal positioning vertigo, and the second most common cause is Ménière's disease. Vestibular neuritis accounts for ~7% of the patients.[4] The usual age of onset is between 30 and 60 years,[44] and age distribution plateaus between 40 and 50 years.[43] There is no significant sexual difference.

SPONTANEOUS RECOVERY

There is usually a sudden onset of the disease. Patients feel severely ill and prefer to stay immobilized in bed for about 1 to 3 days. After 5 to 7 days, spontaneous nystagmus is largely suppressed by fixation in the primary position, although depending on the severity of the canal palsy, it is still present for 2 to 3 weeks with Frenzel's glasses and during lateral gaze directed away from the lesion. After recovery of peripheral vestibular function, spontaneous nystagmus transiently reverses its direction in some patients ("Erholungsnystagmus"); that is when the centrally compensated lesion regains function. "Erholungsnystagmus" then reflects a tone imbalance secondary to compensation. Bechterew's phenomenon, a reversal of postunilateral labyrinthectomy spontaneous nystagmus occurring after contralateral labyrinthectomy in animals or humans,[45,46] is produced by a similar mechanism. After 1 to 6 weeks most of the patients feel symptom-free, even during slow body movements, but actual recovery depends on whether and how quickly functional restitution of the vestibular nerve occurs during central compensation,[47] and possibly on how much physical exercise the patient has done. Rapid head movements, however, may still cause slight oscillopsia of the visual scene and impaired balance for a second in those who do not regain normal labyrinthine function (see above). This explains why only 34 of 60 (57%) patients with vestibular neuritis reported complete relief from subjective symptoms at long-term follow-up,[48] a figure that roughly corresponds to the 50 to 70% complete recovery rate of labyrinthine function assessed by caloric irrigation.[48–50]

There are numerous retrospective, rather than prospective, studies on the rate of complete or incomplete

recovery of vestibular function as measured by the nystagmus response to caloric irrigation.[51] These studies are very difficult to compare because of their different study design, the number of patients included, diagnostic criteria, definition of recovery, and duration of follow-up. This explains the great divergence in the numbers of complete or incomplete vestibular recovery following acute vestibular neuritis. The average recovery, which is based on 10 studies (Fig. 5), shows a tendency to functional improvement not only in the first few months but up to 10 years afterwards.[51] Tests for ocular torsion, subjective visual vertical, and vestibular evoked myogenic potentials revealed that otolith function appears to improve more rapidly than canal-related test abnormalities at the short-term follow-up.[52]

RECURRENCE RATE

In a recent long-term follow-up study (5.7–20.5 years, mean 9.8 years) on 103 patients with vestibular neuritis, only two patients (1.9%) had developed a second vestibular neuritis, 29 to 39 months after the first.[53] It affected the contralateral ear in both patients and caused less severe, distressing vertigo and postural imbalance. Thus, unlike Bell's palsy and sudden hearing loss, a relapse in the same ear does not occur.

Complications In 10 to 15% of patients with vestibular neuritis a typical, benign paroxysmal positioning vertigo develops in the affected ear within a few weeks.[9,53] It is possible that the otoconia loosen during the additional inflammation of the labyrinth; HSV-1 DNA was also found in the human labyrinth,[54] and this eventually results in labyrinthitis and canalolithiasis. Patients should be warned about this possible complication because there are therapeutic liberatory maneuvers that can quickly free the patient of his or her complaints. The second important complication is that vestibular neuritis can develop into a somatoform phobic postural vertigo.[55,56] The traumatic experience of a persisting organic rotatory vertigo leads to fearful introspection resulting in a somatoform, fluctuating, and persistent postural vertigo, which is reinforced in specific situations and culminates in a phobic behavior of avoidance.

DIFFERENTIAL DIAGNOSIS AND OTHER CLINICAL PROBLEMS

When based on careful history taking and clinical evaluation, the differential diagnosis is determined by two elementary questions: (1) Is the clinical syndrome compatible with peripheral vestibular loss only or are there any central neurologic deficits incompatible with vestibular neuritis? (2) Are there any signs, symptoms, or clinical indications for a specific etiology of an acute unilateral, partial, or complete vestibular loss? Topographically, dysfunctions or lesions in the brainstem and/or cerebellum (so-called vestibular pseudoneuritis) as well as other peripheral vestibular disorders may mimic vestibular neuritis. In other words, there is no pathognomonic test or sign for vestibular neuritis as a clinical entity.[1,12,19,29] In a strict sense, only an acute unilateral peripheral vestibular hypofunction with horizontal semicircular canal paresis can be diagnosed by the proposed procedures, i.e., the head-impulse test and caloric irrigation.

CENTRAL LESIONS MIMICKING VESTIBULAR NEURITIS

There is a small area in the lateral medulla, including the root entry zone of the vestibular nerve and the medial

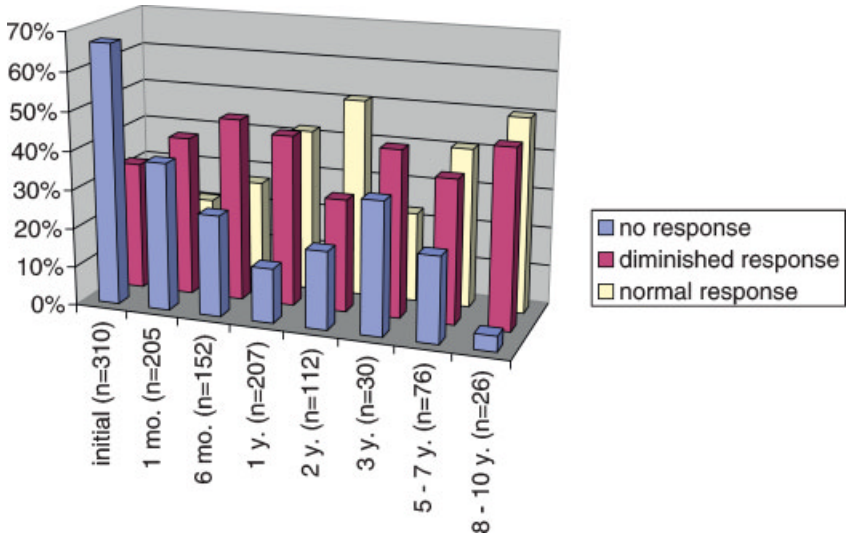

Figure 5 Time course of average recovery of vestibular function after vestibular neuritis as measured by the nystagmus response to caloric irrigation based on 10 retrospective or prospective follow-up studies (see Brandt et al[51]). There is a tendency for recovery to increase over time, with most of the function being regained within the first month after onset.

and superior vestibular nuclei, in which a lesion may be confused with peripheral vestibular nerve or labyrinthine lesions. We have seen several patients with multiple sclerosis who have pontomedullary plaques or small lacunar strokes (Fig. 6)[57] at the root entry zone of cranial nerve (CN) VIII. This leads to a fascicular nerve lesion, which mimics vestibular neuritis known as vestibular pseudoneuritis. The differential diagnosis between central and peripheral causes of unilateral vestibular loss is simple, if the patient has obvious additional brainstem signs. If this is not the case, differential diagnosis is indeed difficult. Therefore, the clinical signs to differentiate vestibular neuritis (40 patients) from central vestibular pseudoneuritis (43 patients) in the acute situation were correlated, and the final diagnosis was assessed by neuroimaging.[19] Skew deviation was the only specific, but nonsensitive (40%) sign for vestibular pseudoneuritis. None of the other isolated signs (head-thrust test, saccadic pursuit, gaze-evoked nystagmus, subjective visual vertical) were reliable; however, multivariate logistic regression increased their sensitivity and specificity to 92%.[19]

Cerebellar infarction may also mimic vestibular neuritis, namely in the territory of the posterior inferior cerebellar artery (PICA),[58–61] especially isolated nodular infarction.[62] It may also cause incomplete ocular tilt reaction,[63] in particular if the dentate nucleus is involved,[64] which may make the differential diagnosis even more difficult. Infarction in the territory of the anterior inferior cerebellar artery (AICA) may also mimic vestibular neuritis, but it is most often associated with unilateral hearing loss (due to cochlear ischemia) and additional brainstem signs.[65,66] All in all, cerebellar infarction may cause isolated vertigo and a pathological Romberg sign, but clinical examination and testing of hearing will allow its differentiation from vestibular neuritis and vestibular pseudoneuritis in most cases. However, further studies are necessary on this important issue to correlate clinical vestibular and ocular motor signs with magnetic resonance imaging (MRI) of lesions in the cerebellum.

Acute attacks of vestibular migraine may also mimic vestibular neuritis because they may be associated with a rotatory vertigo and horizontal-torsional nystagmus. Accompanying symptoms and the course of the disease help to differentiate between the two entities.

PERIPHERAL VESTIBULAR LESIONS

The differential diagnosis of peripheral labyrinthine and vestibular nerve disorders mimicking vestibular neuritis includes numerous rare conditions. Nevertheless, extensive laboratory examinations, lumbar puncture, computed tomography, and MRI are not part of the routine diagnostics of vestibular neuritis for two reasons: (1) the disorders are rare, and (2) typical additional signs and symptoms will be indicative of other disorders. An initial monosymptomatic vertigo attack in Ménière's disease or a short attack in vestibular paroxysmia[67] can be confused with vestibular neuritis in a patient admitted to the hospital in an acute stage. The shortness of the attack and the patient's rapid recovery, however, allow differentiation. During the course of the disease, almost all patients with Ménière's disease develop hypoacusis, tinnitus, or aural fullness in the affected ear, which also allows differentiation. An initially burning pain and blisters as well as hearing disorders and facial paresis are typical for herpes zoster oticus (Ramsay–Hunt syndrome). In such cases, acyclovir or valacyclovir is indicated. It has to be pointed out that there may be a skew deviation in herpes zoster oticus due to the complete unilateral peripheral vestibular deficit; i.e., of the pars superior and inferior of the vestibular nerve[20] and—contrary to vestibular neuritis—a contrast enhancement of CN VIII. Cogan syndrome (often overlooked) is a severe autoimmune disease accompanied by interstitial keratitis and audiovestibular symptoms (hearing disorders are very prominent). It occurs most often in young adults and responds, in part only temporarily, to the very early administration of high doses of corticosteroids (1000 mg per day for 5 days, then slowly tapered off), or like other autoimmune diseases of the inner ear, to a combination of steroids and cyclophosphamide.

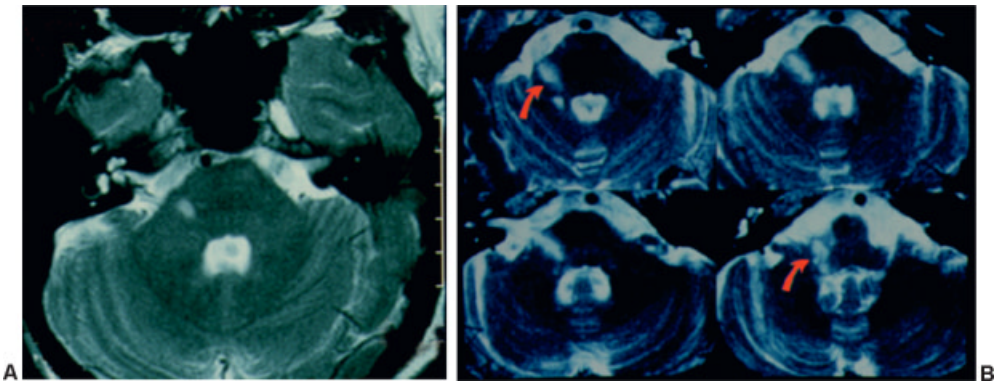

Figure 6 Fascicular and nuclear lesion of the vestibular nerve due to a multiple sclerosis (MS) plaque (A) and vascular lesion (B), mimicking vestibular neuritis (T2-weighted magnetic resonance images).

Rare variants of vestibular neuritis have been described; for example, inferior vestibular neuritis (here there is a selective deficit of the posterior canal combined with sparing of the lateral and anterior canals),[68] and a form in which a dysfunction of the posterior canal is combined with one of the cochlea. The latter probably does not have a viral, but rather a vascular etiology because both structures have a common area of vascular supply.

Vestibular schwannomas, which arise in the myelin sheaths of the vestibular part of the CN VIII nerve, only cause vertigo, a tendency to fall, and nystagmus when the pontomedullary brainstem and the flocculus are compressed, and the increasing peripheral tone difference can no longer be neutralized by central compensation. The main symptom is a slowly progressive unilateral reduction of hearing without any identifiable otologic cause, which is combined with a caloric hypoexcitability or nonexcitability. In rare cases, there is also a loss of hearing, as well as acute vertigo, in cases of a purely intracanalicular dilatation, which can be confirmed by MRI and treated early by microsurgery or gamma knife.

MANAGEMENT

The management of vestibular neuritis involves (1) symptomatic treatment with antivertiginous drugs (e.g., dimenhydrinate, scopolamine) to attenuate vertigo, dizziness, and nausea/vomiting; (2) causal treatment with corticosteroids to improve recovery of peripheral vestibular function; and (3) physical therapy (vestibular exercises and balance training) to improve central vestibular compensation.[69]

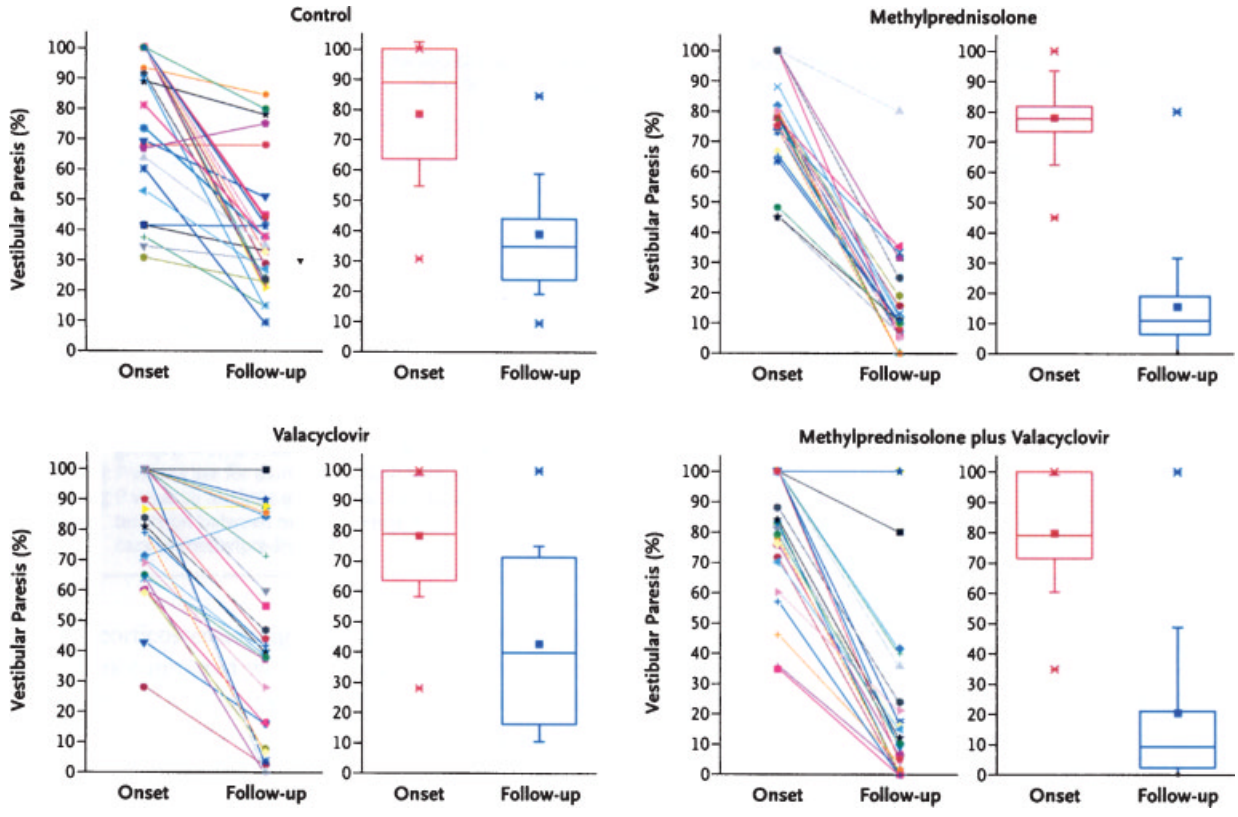

Figure 7 Unilateral vestibular failure within 3 days after symptom onset and after 12 months. Vestibular function was determined by caloric irrigation, using the vestibular paresis formula (which allows a direct comparison of the function of both labyrinths) for each patient in the placebo (upper left), methylprednisolone (upper right), valacyclovir (lower right), and methylprednisolone plus valacyclovir (lower left) group. Also shown are box plot charts for each group with the mean (▪) ± standard deviation, and 25% and 75% percentile (box plot) as well as the 1% and 99% range (x). A clinically relevant vestibular paresis was defined as >25% asymmetry between the right-sided and the left-sided responses.[22] Follow-up examination showed that vestibular function improved in all four groups: in the placebo group from 78.9 ± 24.0 (mean ± SD) to 39.0 ± 19.9, in the methylprednisolone group from 78.7 ± 15.8 to 15.4 ± 16.2, in the valacyclovir group from 78.4 ± 20.0 to 42.7 ± 32.3, and in the methylprednisolone plus valacyclovir group from 78.6 ± 21.1 to 20.4 ± 28.4. Analysis of variance revealed that methylprednisolone and methylprednisolone plus valacyclovir caused significantly more improvement than placebo or valacyclovir alone. The combination of both was not superior to steroid monotherapy. (From Strupp et al.[72])

Symptomatic Treatment

During the first 1 to 3 days, when nausea is pronounced, vestibular sedatives such as antihistamine dimenhydrinate 50 to 100 mg every 6 hours or the anticholinergic scopolamine can be administered. Their major side effect is general sedation. Transdermal application of scopolamine hydrobromide avoids some of the side effects of the conventional means of administration. The most probable sites of primary action are the synapses of the vestibular nuclei, which exhibit a reduced discharge and diminished neural reaction to body rotation. These drugs should not be given for longer than 3 days because they prolong the time required to achieve central compensation.[70,71]

Causal Treatment

Based on the assumption that vestibular neuritis is caused by the reactivation of a latent HSV-1 infection, a prospective randomized double-blind trial was conducted to determine whether steroids, antiviral agents, or a combination of the two might improve outcome in vestibular neuritis.[72] This study with a placebo, methylprednisolone, valacyclovir, and methylprednisolone plus valacyclovir group in 114 patients showed that monotherapy with steroids suffices to significantly improve the peripheral vestibular function of patients with vestibular neuritis. There was no evidence for synergy between methylprednisolone and valacyclovir (Fig. 7).[72] Glucocorticoids (methylprednisolone) should be given within 3 days after symptom onset and for 3 weeks (initially 100 mg/day and then tapered off by 20 mg every 3 days). As in Bell's palsy, the benefit of steroids might be due to their antiinflammatory effects, which reduce the swelling that causes a mechanical compression of the vestibular nerve within the temporal bone. Thus, steroids but not antiviral agents can be recommended as a treatment for acute vestibular neuritis, as they cause a significant functional improvement. These findings are also supported by an ongoing trial in Sweden (Michael Karlberg, personal communication). Steroids have been demonstrated to be efficacious in two prospective, randomized, double-blind, placebo-controlled studies on Bell's palsy, which is also considered an HSV-1 disorder.[73,74] A recent prospective study in only a small number of patients, however, reported that prednisone therapy might enhance earlier recovery, but it does not improve the long-term prognosis of vestibular neuritis.[75]

Physical Therapy

A gradual program of physical exercise under the supervision of a physiotherapist improves the central vestibular compensation of a peripheral deficit. First, static stabilization is concentrated on, then dynamic exercises are done for balance control and gaze stabilization during eye–head–body movements. It is important that the degree of difficulty of exercises for equilibrium and balance be successively increased above normal levels, both with and without visual stabilization. The efficacy of physiotherapy in improving central vestibulospinal compensation in patients with vestibular neuritis has been proven in a prospective, randomized, and controlled clinical study[76] and confirmed in a meta-analysis.[77]

REFERENCES

1. Mandalà M, Nuti D, Broman AT, Zee DS. Effectiveness of careful bedside examination in assessment, diagnosis, and prognosis of vestibular neuritis. Arch Otolaryngol Head Neck Surg 2008;134(2):164–169
2. Lee H, Kim BK, Park HJ, Koo JW, Kim JS. Prodromal dizziness in vestibular neuritis: frequency and clinical implication. J Neurol Neurosurg Psychiatry 2009;80(3): 355–356
3. Halmagyi GM, Curthoys IS. A clinical sign of canal paresis. Arch Neurol 1988;45(7):737–739
4. Brandt T, Dieterich M, Strupp M. Vertigo and Dizziness: Common Complaints. London: Springer; 2005
5. Strupp M, Brandt T. Vestibular neuritis. In: Eggers SD, Zee D, eds. Vertigo and Imbalance: Clinical Neurophysiology of the Vestibular System. Handbook of Clinical Neurophysiology. Vol. 9. 2010. In press
6. Goldberg JM, Fernandez C. Physiology of peripheral neurons innervating semicircular canals of the squirrel monkey. I. Resting discharge and response to constant angular accelerations. J Neurophysiol 1971;34(4):635–660
7. Bergström B. Morphology of the vestibular nerve. I. Anatomical studies of the vestibular nerve in man. Acta Otolaryngol 1973;76(2):162–172
8. Fetter M, Dichgans J. Vestibular neuritis spares the inferior division of the vestibular nerve. Brain 1996;119(Pt 3):755–763
9. Büchele W, Brandt T. Vestibular neuritis—a horizontal semicircular canal paresis? Adv Otorhinolaryngol 1988;42: 157–161
10. Lorente de Nó R. Vestibulo-ocular reflex arc. Arch Neurol Psychiatry 1933;30:245–291
11. Sando I, Black FO, Hemenway WG. Spatial distribution of vestibular nerve in internal auditory canal. Ann Otol Rhinol Laryngol 1972;81(3):305–314
12. Newman-Toker DE, Kattah JC, Alvernia JE, Wang DZ. Normal head impulse test differentiates acute cerebellar strokes from vestibular neuritis. Neurology 2008;70(24 Pt 2): 2378–2385
13. Ewald R. Physiologische Untersuchungen über das Endorgan des Nervus octavus. Wiesbaden: Bergmann; 1892
14. Baloh RW, Honrubia V, Konrad HR. Ewald's second law re-evaluated. Acta Otolaryngol 1977;83(5-6):475–479
15. Böhmer A, Rickenmann J. The subjective visual vertical as a clinical parameter of vestibular function in peripheral vestibular diseases. J Vestib Res 1995;5(1):35–45
16. Zwergal A, Rettinger N, Frenzel C, Dieterich M, Brandt T, Strupp M. A bucket of static vestibular function. Neurology 2009;72(19):1689–1692
17. Safran AB, Vibert D, Issoua D, Häusler R. Skew deviation after vestibular neuritis. Am J Ophthalmol 1994;118(2): 238–245

18. Vibert D, Häusler R, Safran AB, Koerner F. Diplopia from skew deviation in unilateral peripheral vestibular lesions. Acta Otolaryngol 1996;116(2):170–176
19. Cnyrim CD, Newman-Toker D, Karch C, Brandt T, Strupp M. Bedside differentiation of vestibular neuritis from central "vestibular pseudoneuritis.". J Neurol Neurosurg Psychiatry 2008;79(4):458–460
20. Arbusow V, Dieterich M, Strupp M, Jäger L, Brandt T. Herpes zoster neuritis involving superior and inferior parts of the vestibular nerve causes ocular tilt reaction. Akt Neurol 1997;24:S94
21. Jongkees LB, Maas JP, Philipszoon AJ. Clinical nystagmography. A detailed study of electro-nystagmography in 341 patients with vertigo. Pract Otorhinolaryngol (Basel) 1962; 24:65–93
22. Honrubia V. Quantitative vestibular function tests and the clinical examination. In: Herdman SJ, ed. Vestibular Rehabilitation. 1st ed. Philadelphia: FA Davis; 1994:113–164
23. Murofushi T, Halmagyi GM, Yavor RA, Colebatch JG. Absent vestibular evoked myogenic potentials in vestibular neurolabyrinthitis. An indicator of inferior vestibular nerve involvement? Arch Otolaryngol Head Neck Surg 1996; 122(8):845–848
24. Colebatch JG, Halmagyi GM, Skuse NF. Myogenic potentials generated by a click-evoked vestibulocollic reflex. J Neurol Neurosurg Psychiatry 1994;57(2):190–197
25. Murofushi T, Curthoys IS, Topple AN, Colebatch JG, Halmagyi GM. Responses of guinea pig primary vestibular neurons to clicks. Exp Brain Res 1995;103(1):174–178
26. Colebatch JG. Vestibular evoked potentials. Curr Opin Neurol 2001;14(1):21–26
27. Nadol JB Jr. Vestibular neuritis. Otolaryngol Head Neck Surg 1995;112(1):162–172
28. Brandt T. Vertigo: Its Multisensory Syndromes. 2nd ed. London: Springer; 1999
29. Baloh RW. Clinical practice. Vestibular neuritis. N Engl J Med 2003;348(11):1027–1032
30. Schuknecht HF, Kitamura K. Second Louis H. Clerf Lecture. Vestibular neuritis. Ann Otol Rhinol Laryngol Suppl 1981;90(1 Pt 2, 1 Part 2):1–19
31. Hirata Y, Gyo K, Yanagihara N. Herpetic vestibular neuritis: an experimental study. Acta Otolaryngol Suppl 1995;519:93–96
32. Furuta Y, Takasu T, Fukuda S, Inuyama Y, Sato KC, Nagashima K. Latent herpes simplex virus type 1 in human vestibular ganglia. Acta Otolaryngol Suppl 1993;503:85–89
33. Arbusow V, Schulz P, Strupp M, et al. Distribution of herpes simplex virus type 1 in human geniculate and vestibular ganglia: implications for vestibular neuritis. Ann Neurol 1999;46(3):416–419
34. Theil D, Derfuss T, Strupp M, Gilden DH, Arbusow V, Brandt T. Cranial nerve palsies: herpes simplex virus type 1 and varicella-zoster virus latency. Ann Neurol 2002;51(2): 273–274
35. Theil D, Arbusow V, Derfuss T, et al. Prevalence of HSV-1 LAT in human trigeminal, geniculate, and vestibular ganglia and its implication for cranial nerve syndromes. Brain Pathol 2001;11(4):408–413
36. Nahmias AJ, Roizman B. Infection with herpes-simplex viruses 1 and 2. II. N Engl J Med 1973;289(14):719–725
37. Theil D, Derfuss T, Paripovic I, et al. Latent herpesvirus infection in human trigeminal ganglia causes chronic immune response. Am J Pathol 2003;163(6):2179–2184
38. Murakami S, Mizobuchi M, Nakashiro Y, Doi T, Hato N, Yanagihara N. Bell palsy and herpes simplex virus: identification of viral DNA in endoneurial fluid and muscle. Ann Intern Med 1996;124(1 Pt 1):27–30
39. Theil D, Derfuss T, Paripovic I, et al. Latent herpesvirus infection in human trigeminal ganglia causes chronic immune response. Am J Pathol 2003;163(6):2179–2184
40. Theil D, Horn AK, Derfuss T, Strupp M, Arbusow V, Brandt T. Prevalence and distribution of HSV-1, VZV, and HHV-6 in human cranial nerve nuclei III, IV, VI, VII, and XII. J Med Virol 2004;74(1):102–106
41. Gianoli G, Goebel J, Mowry S, Poomipannit P. Anatomic differences in the lateral vestibular nerve channels and their implications in vestibular neuritis. Otol Neurotol 2005;26(3): 489–494
42. Arbusow V, Theil D, Schulz P, et al. Distribution of herpes simplex virus type 1 in human geniculate and vestibular ganglia: implications for vestibular neuritis. Ann Neurol 1999;46:416–419
43. Sekitani T, Imate Y, Noguchi T, Inokuma T. Vestibular neuronitis: epidemiological survey by questionnaire in Japan. Acta Otolaryngol Suppl 1993;503:9–12
44. Depondt M. [Vestibular neuronitis. Vestibular paralysis with special characteristics]. Acta Otorhinolaryngol Belg 1973;27(3):323–359
45. Katsarkas A, Galiana HL. Bechterew's phenomenon in humans. A new explanation. Acta Otolaryngol Suppl 1984; 406:95–100
46. Zee DS, Preziosi TJ, Proctor LR. Bechterew's phenomenon in a human patient. [letter]. Ann Neurol 1982;12(5):495–496
47. Brandt T, Strupp M, Arbusow V, Dieringer N. Plasticity of the vestibular system: central compensation and sensory substitution for vestibular deficits. Adv Neurol 1997;73:297–309
48. Okinaka Y, Sekitani T, Okazaki H, Miura M, Tahara T. Progress of caloric response of vestibular neuronitis. Acta Otolaryngol Suppl 1993;503:18–22
49. Meran A, Pfaltz CR. [The acute vestibular paralysis (author's transl)]. Arch Otorhinolaryngol 1975;209(3):229–244
50. Ohbayashi S, Oda M, Yamamoto M, et al. Recovery of the vestibular function after vestibular neuronitis. Acta Otolaryngol Suppl 1993;503:31–34
51. Brandt T, Huppert D, Hufner K, Zingler V, Strupp M. Long-term course and relapses of vestibular and balance disorders. Restor Neurol Neurosci 2009. In press
52. Kim HA, Hong JH, Lee H, et al. Otolith dysfunction in vestibular neuritis: recovery pattern and a predictor of symptom recovery. Neurology 2008;70(6):449–453
53. Huppert D, Strupp M, Theil D, Glaser M, Brandt T. Low recurrence rate of vestibular neuritis: a long-term follow-up. Neurology 2006;67(10):1870–1871
54. Arbusow V, Theil D, Strupp M, Mascolo A, Brandt T. HSV-1 not only in human vestibular ganglia but also in the vestibular labyrinth. Audiol Neurootol 2001;6(5):259–262
55. Brandt T, Dieterich M. Phobischer Attackenschwankwindel, ein neues Syndrom. Munch Med Wochenschr 1986;128: 247–250
56. Brandt T. Phobic postural vertigo. Neurology 1996;46(6): 1515–1519

57. Thömke F, Hopf HC. Pontine lesions mimicking acute peripheral vestibulopathy. J Neurol Neurosurg Psychiatry 1999;66(3):340–349
58. Duncan GW, Parker SW, Fisher CM. Acute cerebellar infarction in the PICA territory. Arch Neurol 1975;32(6): 364–368
59. Huang CY, Yu YL. Small cerebellar strokes may mimic labyrinthine lesions. J Neurol Neurosurg Psychiatry 1985; 48(3):263–265
60. Magnusson M, Norrving B. Cerebellar infarctions as the cause of 'vestibular neuritis'. Acta Otolaryngol Suppl 1991; 481:258–259
61. Magnusson M, Norrving B. Cerebellar infarctions and 'vestibular neuritis'. Acta Otolaryngol Suppl 1993;503:64–66
62. Moon IS, Kim JS, Choi KD, et al. Isolated nodular infarction. Stroke 2009;40(2):487–491
63. Mossman S, Halmagyi GM. Partial ocular tilt reaction due to unilateral cerebellar lesion. Neurology 1997;49(2):491–493
64. Baier B, Bense S, Dieterich M. Are signs of ocular tilt reaction in patients with cerebellar lesions mediated by the dentate nucleus? Brain 2008;131(Pt 6):1445–1454
65. Lee H, Sohn SI, Jung DK, et al. Sudden deafness and anterior inferior cerebellar artery infarction. Stroke 2002; 33(12):2807–2812
66. Lee H, Sohn SI, Cho YW, et al. Cerebellar infarction presenting isolated vertigo: frequency and vascular topographical patterns. Neurology 2006;67(7):1178–1183
67. Hüfner K, Barresi D, Glaser M, et al. Vestibular paroxysmia: diagnostic features and medical treatment. Neurology 2008; 71(13):1006–1014
68. Halmagyi GM, Aw ST, Karlberg M, Curthoys IS, Todd MJ. Inferior vestibular neuritis. Ann N Y Acad Sci 2002;956:306–313
69. Walker MF. Treatment of vestibular neuritis. Curr Treat Options Neurol 2009;11(1):41–45
70. Zee DS. Perspectives on the pharmacotherapy of vertigo. Arch Otolaryngol 1985;111(9):609–612
71. Curthoys IS, Halmagyi GM. Vestibular compensation: A review of the oculomotor, neural, and clinical consequences of unilateral vestibular loss. J Vestib Res 1995;5:67–107
72. Strupp M, Zingler VC, Arbusow V, et al. Methylprednisolone, valacyclovir, or the combination for vestibular neuritis. N Engl J Med 2004;351(4):354–361
73. Sullivan FM, Swan IR, Donnan PT, et al. Early treatment with prednisolone or acyclovir in Bell's palsy. N Engl J Med 2007;357(16):1598–1607
74. Engström M, Berg T, Stjernquist-Desatnik A, et al. Prednisolone and valacyclovir in Bell's palsy: a randomised, double-blind, placebo-controlled, multicentre trial. Lancet Neurol 2008;7(11):993–1000
75. Shupak A, Issa A, Golz A, Margalit Kaminer, Braverman I. Prednisone treatment for vestibular neuritis. Otol Neurotol 2008;29(3):368–374
76. Strupp M, Arbusow V, Maag KP, Gall C, Brandt T. Vestibular exercises improve central vestibulospinal compensation after vestibular neuritis. Neurology 1998;51(3):838–844
77. Hillier SL, Hollohan V. Vestibular rehabilitation for unilateral peripheral vestibular dysfunction. Cochrane Database Syst Rev 2007;(4):CD005397