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Oral Sessions

Oral Session A1 – Advances & Basic Stuff

A1-1
Animal responses evoked by chronic vestibular implant stimulation

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Loss of accurate vestibular transduction having normal high signal-to-noise ratios occurs for many reasons and results in balance deficits, perceptual deficits, and severe impairment of vestibulo-ocular reflexes in patients. Rehabilitation helps such patients cope with their deficits but does not return normal function. With restoration of normal function as our goal, we have developed a vestibular implant that uses electrical stimulation to replace absent vestibular transduction and have investigated this device in a number of chronic animal studies.

As background, electrical stimulation of the vestibular periphery has been successfully used for many years as a scientific tool to investigate the vestibular system and vestibular-evoked responses. In earlier basic science research, each of the five vestibular end organs have been stimulated individually and in combination using short-term (circa 1 hour or less) continuous electrical stimulation. But to our knowledge, our device was the first to provide chronic (hours to months) electrical stimulation of the vestibular system. This has allowed us to focus on investigations that study vestibular acclimation, adaptation, and habituation by measuring vestibular responses evoked by chronic electrical stimulation.

For these studies, guinea pigs and squirrel monkeys were instrumented with headbolts, eye coils, and electrodes. Animals wore the prosthesis circuitry in a small cap attached to their head bolt. Eye movements were recorded using standard search coil techniques. The electrodes were inserted into the lateral semicircular canals and biphasic current pulses were provided to the vestibular system via these electrodes. Rate of stimulation was constant when the animals were at rest to mimic normal "tonic" activity. For our studies, the tonic stimulation rate was 200 to 250 pulses per second. This is somewhat higher than the average resting rate of around 100 Hz in primates and allowed us to modulate neural activity both upward and downward. In some studies, as the animal's head rotated, the rate of stimulation was modulated up and down to mimic the normal vestibular coding. In this talk, we will present several recent results alongside the following completed studies.

Study A: Since pulsatile electrical stimulation elicits neural responses that are phase-locked to the current pulses, we investigated in guinea pigs whether our prosthesis evokes eye movements at the frequency of the prosthesis pulse rate. Such high-frequency responses, if present, might cause visual blurring. We found that such eye movements were measured and had a velocity magnitude of 8.1 deg/s initially but reduced by more than 80% within 20–30 minutes. The responses remained about the same magnitude for the following week. While the initial response may yield perceptible blurring, the habituated responses are small enough that visual blurring will likely be imperceptible after habituation occurs.

Study B: In this study, we investigated how the squirrel monkey VOR adapted when chronic motion-modulated electrical stimulation was applied to the horizontal semicircular canals. Prosthetic stimulation was cycled between off, low-sensitivity, and high-sensitivity stimulation states. The VOR response initially demonstrated a low gain, abnormal rotational axis, and substantial asymmetry. During chronic stimulation, the gain increased, the rotational axis improved, and the VOR became more symmetric. Gain changes were augmented by cycling the stimulation between the off and both low- and high-sensitivity states every few weeks. The VOR time constant remained low throughout the period of chronic stimulation. These results demonstrate that the brain can adaptively modify the gain, axis,

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and symmetry of the VOR when provided with chronic motion-modulated electrical stimulation by a canal prosthesis.

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A1-2

Discharge frequency versus recruitment coding for a unilateral vestibular implant

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Introduction: We have developed a minimally invasive unilateral vestibular implant that allows for chronic natural and electrical activation of individual ampulae. We have used electrical stimulation, natural rotation, and neural recording at the end organ and in the vestibular nucleus to evaluate the mechanisms that underlie these processes.

Methods: Our device is a modified cochlear implant, with tripolar leads for insertion adjacent to the ampulae of individual canals. It produces modulation based on recorded head velocity or preprogrammed stimuli. The device can also record compound action potentials resulting from stimulation. To evaluate the device we implanted multiple canals in rhesus monkeys unilaterally. We recorded eye and head position with scleral coils. We rotated the animals en-bloc. We recorded single neurons and field potentials in the vestibular nucleus with tungsten microelectrodes.

Results: Electrical stimulation and rotation in the plane of the implanted canal both produced eye movements largely in the plane of the implanted canal. Increasing current and frequency of electrical stimulation produced increasing eye velocity, with a fixed current threshold, an initial rapid rise in velocity with stimulus frequency, and a saturation of velocity at higher frequencies. Combination of electrical and rotational stimulation produced a summation of eye velocity. Very little eye velocity adaptation was seen with repeated or prolonged electrical stimulation in the rotationally responsive canal. Evoked potential and single unit recording suggested that increasing current at fixed frequency recruited increasing numbers of vestibular afferents and vestibular nucleus neurons due to a distribution of thresholds to electrical stimulation. Vestibular neurons followed the frequency of the electrical stimulation at lower frequencies, but began dropping spikes in response to higher frequency stimuli. Higher stimulus currents produced more reliable frequency following. Single neurons often responded to both rotational stimulation and electrical stimulation. The majority of neurons responded only to electrical stimulation from a single canal. Rotationally responsive neurons were typically activated only by electrical stimulation of the canal aligned with the plane of rotation to which they were maximally responsive. During combined electrical and rotational stimulation, single neurons showed summation of rotationally and electrically elicited spikes only at low frequencies of electrical stimulation.

Conclusions: Surprisingly, either amplitude modulation or frequency modulation can be used to drive smooth eye velocity profiles with electrical stimulation of the vestibular end organ. These responses can be summed with rotational responses in real time to produce a reliable behavioral response. The mechanism for amplitude modulation is recruitment, while frequency following underlies frequency modulation. The interaction between electrical stimulus following and both frequency and current explains the saturation in eye velocity at high frequencies, and the absolute eye velocity at which saturation occurs with increasing current. The shape of the relationship between current and velocity for a given frequency of electrical stimulation is determined by the distribution of thresholds of neurons. Summation of natural and electrical stimulation occurs in individual neurons only at low stimulus frequency, and therefore does not underlie the summation of behavioral responses that have been observed.

A1-3

Evidence that spatial memory deficits in rats following bilateral vestibular loss may be permanent

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Previous studies have shown that bilateral vestibular deafferentation (BVD) can result in substantial spatial memory deficits in rats and that these are probably related to the loss of vestibular information in the hippocampus. However, none of these studies was conducted beyond approximately 6 months post-op. In this study we investigated whether such deficits persisted at 14 months post-op. and also whether they could be exacerbated by administration of the cannabinoid receptor agonist, WIN55, 212-2 ('WIN'). Twenty eight adults rats were divided into 4 groups: 1) sham surgery + vehicle ($n = 8$); 2) sham surgery + WIN ($n = 7$);

3) BVD + vehicle ($n = 6$); and 4) BVD + WIN ($n = 7$). WIN, at a dose of 1.0 or 2.0 mg/kg/day or vehicle, was administered (s.c) on days 1–10 and 11–20 (respectively), 30 min before the rats performed in a foraging task in darkness, 14 months following BVD or sham surgery. On day 21, the cannabinoid receptor inverse agonist, AM251 (3.0 mg/kg s.c) or vehicle, was administered. The animals' movements were tracked using a digital infrared camera and tracking software. In the dark trials in which the animals could not rely on visual cues, BVD rats searched with a significantly higher velocity and travelled a longer distance in searching for food (both $P = 0.000$), exhibited a longer homing time, a higher homing velocity and travelled a greater distance to reach the home with food, compared to sham rats (all $P = 0.000$). In general, WIN treatment did not significantly affect their performance. Whereas sham animals had a significant preference for the correct home location, BVD animals did not ($P = 0.000$). Analysis of the animals' heading angles using circular statistics indicated that while sham animals had a clear direction toward the correct home, the BVD animals' heading angles were uniformly distributed around 360 degrees ($P = 0.000$), suggesting that they had no memory for the correct home location. The BVD animals also made significantly more errors before reaching the correct home ($P = 0.000$). Following AM251 treatment, the BVD animals still had significantly higher searching and homing velocities compared to the sham animals ($P = 0.001$ and 0.04, respectively) and they still made significantly more errors in the foraging task ($P = 0.05$). These results suggest that, if anything, at 14 months post-op. rats with BVD have more severe spatial memory deficits than at earlier time points and that these memory deficits may be permanent. On the other hand, the administration of cannabinoid drugs had little effect. Regression analysis suggested that the memory deficits could not be predicted from the animals' movement velocity, suggesting that the memory impairment was independent of locomotor hyperactivity.

A1-4

Vestibular function in human subjects and animal models with profound deafness related to GJB2 mutation

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GJB2 gene mutations are known to be the most common cause of nonsyndromic deafness. However, the vestibular function related to GJB2 gene mutation remains to be elucidated. The purpose of this study was to analyze the relationship between GJB2 gene mutation and vestibular dysfunction in vestibular function in human subjects and animal models with profound deafness related to GJB2 mutation.

A total of 31 subjects, including 10 healthy volunteers and 21 patients with CD, were enrolled in the study. The hearing level of all CD patients demonstrated a severe to profound impairment. In 7 CD patients, their hearing impairment was related to GJB2 mutation. Five out of the 7 patients with CD related to GJB2 mutation demonstrated abnormalities in either/both of the two tests. The percentage of vestibular dysfunction of the patients with CD related to GJB2 mutation was statistically higher than both patients with CD unrelated to GJB2 mutation and the healthy controls. On the other hand, A dominant-negative Gjb2 R75W transgenic mouse model shows incomplete development of the cochlear supporting cells, resulting in profound deafness from birth (Inoshita et al., 2008). No morphological differences were observed in utricle and saccule by HE staining at 0–140 days after birth. Balance disorders such as head tilt and swimming abnormality were not observed in R75W+ mice as well as non-Tg mice. GJB2 mutations are responsible for not only deafness but also for the occurrence of vestibular dysfunction in the human. However, no evidence was obtained in the vestibular dysfunction in the genetically engineered animal model.

A1-5

Molecular physiology of signaling and plasticity in functionally distinct central vestibular neurons

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The vestibular system provides excellent opportunities for bridging cellular and molecular mechanisms with behavioral plasticity and clinical dysfunction. Accordingly, we have assembled and developed a number of resources and techniques for identifying and analyzing functionally distinct cell types in central vestibular nuclei, focusing primarily on neurons that subserve the horizontal vestibulo-ocular reflex (VOR). To fully exploit the power of molecular genetic techniques we have focused efforts on mice, which have excellent VOR performance and plasticity. Electrophysiological recordings in brainstem slices targetted to neurons labelled in different lines of transgenic mice can separate central vestibular neurons into two broad classes:

neurons that project axons out of the vestibular nuclei and use glutamate or glycine as neurotransmitters are labelled in the YFP-16 line, while neurons with axons that remain in the bilateral vestibular complex and are either GABAergic or glycinergic are labelled in the GIN line. Several key properties of intrinsic excitability differ between the two neuronal classes, including firing range, temporal precision, filtering, and synaptic integration. Voltage clamp, pharmacological, and immunohistochemical analyses indicate associated differences in underlying potassium and calcium currents. Differences in postinhibitory rebound and spike timing precision are also observed in subsets of neurons in the YFP-16 line which project to the cerebellar flocculus and are densely or sparsely targeted by floccular Purkinje cell axons. Vestibular nerve synapses onto all cell types exhibit remarkable rate-invariance, but activity-dependent plasticity differs across cell types. While high frequency vestibular nerve stimuli induce long term synaptic depression (LTD), pairing nerve activity with postsynaptic hyperpolarization induces long term potentiation (LTP), but only in the subset of YFP-16 neurons that express strong postinhibitory rebound currents. Interestlingly LTD is induced by calcium influx through NMDA receptors, while LTP requires calcium influx through AMPA receptors. To more comprehensively assess key molecular differences across neurons, we have generated single-cell RNA libraries from many identified cells. This rich dataset enables identification of genes that can be used to mark and manipulate specific cell types and provides a platform for linking pharmacological treatments of vestibular disorders with the cellular biology of identifed central vestibular neurons.

Oral Session A2 – VEMP

A2-1

An overview of the ocular vestibular evoked myogenic potential (oVEMP) to bone conducted vibration as a simple clinical test of dynamic utricular function

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Background: The stimulus: Physical measures show that 500 Hz bone conducted vibration (BCV) when delivered to the midline forehead at the hairline (a location called Fz) causes equal amplitude linear acceleration of both mastoids. The physiology: Physiological evidence from guinea pigs shows that of all vestibular neurons it is otolith irregular neurons which are selectively activated by 500 Hz BCV at low intensities (in some cases at or below ABR threshold). The behavioural response: Stimulation of the utricular nerve in the cat generates characteristic eye movements [1] and we have shown that 500 Hz BCV of the mastoid in human subjects generates a similar pattern of eye movements. The myogenic potential: Just before the eye moves there are small myogenic potentials which can be recorded by surface electrodes on the skin beneath the eyes as the subject or patient looks up and so brings the inferior oblique and inferior rectus close to the recording electrodes (Rosengren et al., 2005). The waveform of these potentials is referred to as the oVEMP. In our studies we have focussed on the first negative (excitatory) potential at a latency of 10ms which is called n10.

Objective: Is the first (n10) component of the ocular vestibular-evoked myogenic potential (oVEMP) to brief bursts of 500 Hz bone conducted vibration (BCV) a clinical test of dynamic utricular function? What is the sensory region of origin of the n10 (utricular macula or saccular macula or both)? Can n10 probe dynamic otolith responses in vestibular disease conditions?

Methods: Small myogenic potentials are recorded by surface electrodes beneath the eyes as the patient looks up in response to a total of 50, 7ms bursts of 500 Hz BCV (at the rate of 3/s) delivered to the midline forehead at the hairline. Using a minishaker (B&K 4810) as a stimulator, stimulates both ears about equally and generates oVEMPs with the first negative potential at a latency of about 10ms beneath both eyes in healthy subjects. Mastoid BCV stimulation is not as good as Fz stimulation at detecting asymmetrical function because with mastoid stimulation the n10 amplitude depends heavily on exact B-71 location.

Results: The oVEMP n10 to 500 Hz Fz BCV is symmetrical beneath both eyes in healthy subjects whereas n10 is reduced or absent beneath the contralesional eye after unilateral vestibular loss and n10 is reduced or absent beneath the contralesional eye in superior vestibular neuritis (SVN). Since in SVN most afferents from the utricular macula are dysfunctional, whereas the saccular afferents are still functional, this result implies that the n10 measures dynamic utricular function. In patients tested during acute attacks of Ménières disease (MD), the n10 beneath the eye opposite the affected ear is enhanced, implying increased sensitivity of utricular receptors/afferents in the affected ear during the MD attack. In patients with CT-verified semicircular canal dehiscence (SCD) the n10 opposite the affected ear is enhanced. Large n10 to 500 Hz Fz BCV is a very simple indicator of SCD.

Conclusion: The n10 to 500 Hz Fz BCV is a simple, safe, quick, clinical test of utricular function; it is very easy even for senior patients who only have to lie supine and look up. The actual stimulus presentation time is only 20 seconds or less – by increasing the repetition rate to 21/second, testing time can be as short as 3 seconds which is ideal for testing utricular function of difficult patients or very young children.

Reference

[1] I.S. Curthoys, A critical review of the neurophysiological evidence underlying clinical vestibular testing using sound, vibration and galvanic stimuli, *Clin Neurophysiol* **121** (2010), 132–144.

A2-2
oVEMPs: which stimulus?

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In recent years ocular vestibular evoked myogenic potentials (oVEMPs) have gained interest in the field of vestibular neurophysiology. oVEMPs are electromyographic responses recorded from the extraocular muscles prior to a compensatory eye movement, and are typically evoked by sound or vibration. There have been increasing reports of clinical applications of the oVEMP, but relatively little investigation of its basic properties or relationship to the cVEMP. Evidence from studies using both sound and vibration suggest that the properties of the stimulus delivered are critical determinants of oVEMP characteristics. For vibration, the head acceleration evoked by the stimulus is the most important factor, as this is what the vestibular receptors respond to. We therefore compared oVEMPs and cVEMPs to a range of stimuli in normal subjects.

We recorded oVEMPs and cVEMPs in 61 normal volunteers between 18 and 80 yrs of age using standard recording techniques. We delivered two types of air-conducted (AC) sound (0.2 ms clicks and 500 Hz, 2 ms tone bursts) at 105 dB LAeq. We used three types of vibration (500 Hz, 4 ms bone-conducted (BC) tone bursts, forehead taps, and acceleration pulses delivered to the mastoids). In 10 subjects, triaxial accelerometry was performed to compare responses to different frequencies of vibration (100–500 Hz) delivered at the mastoids and forehead.

Stimulation at the forehead produced acceleration mainly in the sagittal axis. With increasing frequency from 100–500 Hz, this directional specificity decreased markedly. Stimulation at the mastoid produced acceleration mainly in the interaural axis over the entire frequency range. There were only small differences in the prevalence and amplitude of the cVEMP when evoked by the five different stimuli, and prevalence ranged from 91 to 100%. However, there were marked differences in the prevalence and amplitude of oVEMPs evoked by the same stimuli (range 59 to 95%). The AC tone bursts were more effective than the clicks, despite having intensities matched for energy content (59 vs 81%). The AC oVEMP had a systematically higher threshold than the cVEMP (6.1 ± 4.7 dB). BC 500 Hz tone bursts were also relatively ineffective stimuli for the oVEMP (62%), despite producing clear cVEMPs in most subjects (93%). In contrast, forehead taps and lateral pulses produced large oVEMPs in most subjects (96 and 95%). Significant decline in amplitude with age was seen for the cVEMP for both AC stimuli and BC tone bursts ($r = -0.56$ to -0.62), but not taps or pulses. Similarly, for the oVEMPs, an age effect was present for AC clicks and BC tone bursts only ($r = -0.37$ to -0.42).

Overall, the responses evoked by AC stimuli and 500 Hz BC tone bursts had similar characteristics (a higher threshold for the oVEMP and effects of age), while the tap and pulse stimuli clustered together. For AC sound, tone bursts were more effective than clicks, despite the stimuli being matched for total energy. Forehead taps produced the largest reflexes, but were the most variable, while lateral pulses produced clear oVEMP and cVEMPs. While many studies use a forehead 500 Hz BC stimulus, its directional specificity is poor and it produces comparatively less head acceleration than other frequencies and locations. Both AC and BC 500 Hz stimuli have lower thresholds for cVEMPs than oVEMPs. If these stimuli are optimized for the oVEMP they are likely to be supramaximal for the cVEMP, making it difficult to detect cVEMP asymmetry. Conversely, if they are optimized for the cVEMP, oVEMPs may not be reliable. It is therefore important to understand the stimulus-response relationship for any VEMP stimulus, and to compare oVEMPs in patients to normal controls as well as to the cVEMP.

A2-3
Does an SCD just 'amplify' normal oVEMP responses?

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Background: In normal subjects, a gentle tendon hammer tap delivered at the midline forehead at the hairline (Fz) will produce a robust n10 component of the ocular vestibular-evoked myogenic potential (oVEMP) measured by surface EMG electrodes beneath each eye. Mastoid located accelerometer measures show that the tap stimulates both ears about equally and this generates crossed otolith-ocular responses. However, an equivalent tap on the top of the skull at the midline (Cz) also stimulates both ears about equally but elicits either small or non-existent oVEMP n10 component in normal subjects, probably because the direction of the shock waves are different when delivered at Cz compared to Fz.
Objectives: To stimulate with taps at different skull locations in patients with CT-verified SCD and to measure the n10 component of the oVEMP beneath the contra-SCD eye in order to determine if the SCD causes an "amplified" oVEMP n10 response or if the n10 response displays different characteristics. These responses are compared to those from normal subjects. In all cases we studied the oVEMP beneath the contra-SCD eye since the oVEMP is predominantly a crossed response.
Methods: An accelerometer fitted tendon hammer was used to trigger the collection of oVEMP responses using a Medelec Sapphire 2ME two channel EMG system. The averaged responses from surface electrodes positioned under the eyes in response to a minimum of 20 taps at Fz and Cz were collected while the subject gazed upwards in the midline.
Results: Normal subjects show either a small or non-existent oVEMP n10 response to taps delivered on the top of the skull at the midline (Cz). In contrast, in patients with a CT-verified superior canal dehiscence (SCD) the same tap stimuli at both Cz and Fz produced a large oVEMP n10 component of the eye contralateral to the SCD. Unlike normal subjects the magnitude and latency of the contralateral response to Cz taps was equivalent to the response produced by the tap applied at Fz.
Discussion: In normal subjects varying the site of tap stimulation from Fz to Cz significantly reduced the normal n10 oVEMP response, however in SCD patients there was no such significant reduction. On the eye contralateral to the SCD, Cz taps produced an oVEMP n10 response which was similar to the amplitude of the oVEMP n10 to Fz taps in these patients. In other words, changing the primary direction of the stimulus from perpendicular to the forehead to vertically downwards, significantly changed the oVEMP response in normal subject but did not significantly change the oVEMP response in SCD patients.
Conclusion: In patients with CT-verified SCD, the oVEMP response produced by the SCD-affected ear is not merely an "amplified" normal response, but a response which has major differences, probably due to the altered anatomy.

A2-4

Test-retest reliability and normative values of ocular vestibular evoked myogenic potentials (oVEMPs) to bone conducted vibration.

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Quite recently the ocular vestibular evoked myogenic potential (oVEMP) test has been introduced to evaluate the utricular-ocular reflex and the superior vestibular nerve function. oVEMPs can be evoked by air conducted sound, but most of the times bone conducted vibration applied to the forehead is being used to evoke the response. For clinical purposes, a study of the reliability of the oVEMP test is crucial and normative values are indispensable. To assess the reliability of the test, a test-retest setup was used. Therefore eighteen subjects (16 females and 2 males; average age = 27.1 years, SD = 6.8 years) were tested twice on different days (test-retest, average time between two measurements = 56 days). Bone conducted vibration (tone bursts, linear envelope, 500 Hz and 6 ms duration, repetition rate 3–31 Hz in different steps) was applied to Fz (Fz corresponds to the junction of the midline and the hairline) using a mini shaker (Brüell and Kjaer, type 4810) to evoke the oVEMPs. The responses to 50 stimuli were averaged and the latencies of the n10 and p13 peak were determined, as well as the asymmetry ratio between the peak-to-peak amplitudes of the responses below both eyes.
Agreement between the parameters on the two different test days was demonstrated by intra class correlation (ICC) tests and paired Student T tests. All parameters showed a good to excellent reliability. The 'minimal difference' (MD) values for the different parameters were calculated using the test-retest measurements as

well. The normative values were based on data of 85 subjects (58 females and 27 males; average age = 28.7 years, SD = 9.2 years). Effects of age and gender were studied as well. The results of the test-retest study and the influence of the gender and the age on the oVEMP parameters will be presented.

A2-5

Ocular and cervical vestibular-evoked myogenic potentials to 500 Hz Fz bone conducted vibration in semicircular canal dehiscence

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Objective: Superior semicircular canal dehiscence (SCD) is a clinical entity recently described by Minor and characterized by the onset of non-specific vestibular and cochlear symptoms induced by hypersensitivity of labyrinthine receptors due to a bone defect, usually located in the external wall of the superior semicircular canal. The objective of the present prospective study, carried out in a cohort of patients referred to our tertiary referral neurotological centre from December 1st 2008 and November 15th 2009 of 26 subjects [13 males and 13 females, aged between 23 and 85 years, mean age 51.8 years (range 23–85)] with CT-verified superior semicircular canal dehiscence (SCD), was to compare the otolithic responses obtained from patients with unilateral SCD to the responses of a group of healthy subjects in order to investigate the effect of inner ear third mobile window on the n10 component of the ocular vestibular-evoked myogenic potential (oVEMP n10) and the p13–n23 component of the cervical vestibular-evoked myogenic potential (cVEMP p13–n23) evoked by 500 Hz bone conducted vibration (BCV) at the midline forehead at the hairline (Fz) and secondly 500 Hz BCV at the top of the skull (Cz). Previous evidence has led to the proposal that the oVEMP n10 is of utricular origin whereas the cVEMP p13–n23 is of saccular origin [1]. Can the oVEMP n10 to 500 Hz BCV be a useful and easily performed test in clarifying symptoms and signs in patients with a suspected diagnosis of SCD?

Methods: A hand-held Bruel and Kjaer 4810 minishaker, was used to provide BCV stimulation using surface EMG electrodes to record oVEMP n10 and cVEMP p13–n23. The stimulus was 7 ms bursts of 500 Hz BCV at either Fz or at the vertex of the skull (Cz). 27 healthy subjects were tested in the same paradigm.

Results: In response to 500 Hz Fz BCV in SCD patients the oVEMP n10 amplitude beneath the contraSCD eye was substantially and significantly larger than the oVEMP n10 beneath the ipsiSCD eye whereas in these same patients the cVEMP p13–n23 amplitude over the ipsilateral SCM to Fz BCV was slightly but significantly larger than the cVEMP p13–n23 amplitude over the contraSCD SCM. In SCD patients there was a significant relationship between the size of the dehiscence measured from HRCT scans and the amplitude of the contralateral oVEMP n10 potential. The oVEMP n10 to Cz stimulation was still present in SCD patients, but small or absent in healthy subjects.

Conclusion: Since eye-movement recording with three-dimensional scleral search coils is rarely performed and the electrophysiological pattern of air conducted sound cVEMPs is often difficult to obtain in terms of threshold, especially in the elderly and very young as well as in subjects with conductive hearing loss, selecting cases for HRCT to obtain a definitive diagnosis is not easy. A diagnostic protocol based on symptoms and HRCT could also be very expensive, considering the relative rarity of SSCD. These considerations show the need for a fast and easily reproducible test that can be used when SCD is suspected. So in response to 500 Hz Fz BCV an asymmetrical oVEMP n10 with a significantly increased amplitude of contralesional oVEMP n10 (compared to population values of healthy subjects) is a simple, robust, quick, accurate and useful clinical indicator of SCD.

Reference

[1] I.S. Curthoys, L. Manzari, Y.E. Smulders and A.M. Burgess, A review of the scientific basis and practical application of a new test of utricular function – ocular vestibular-evoked myogenic potentials to bone conducted vibration, *Acta Otorhinolaryngol Ital* **29** (2009), 179–186.

Oral Session A3 – VEMP

A3-1

Ocular vestibular evoked potentials (oVEMPs) compared to the subjective visual vertical (SVV) during tilt and eccentric rotation – easier, cheaper and almost better

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Objective: We compared vibration-evoked oVEMPs with the SVV during whole-body roll tilt and eccentric rotation in healthy subjects and patients with unilateral vestibular loss, to determine which test was most sensitive in discriminating impaired utricle function.

Methods: We measured oVEMPs and the visual vertical in 11 patients and 11 healthy subjects. Visual vertical was measured during roll tilts between -9.6 and $9.6°$, and during rotation at $400°$/s with the head upright and the rotation axis located between $\pm$ 3.5 cm from the center of the head.

Results: OVEMPs in patients were strikingly asymmetric, whereas they were approximately symmetric in healthy subjects. Patients showed reduced gain of the SVV during eccentric rotation, and increased errors for both tilt and eccentric rotation tests. OVEMPs were superior at discriminating between patients and healthy subjects, though eccentric rotation could perform nearly as well.

Conclusions: Vibration induced oVEMPs provide a more powerful test for discriminating between healthy subjects and patients with chronic unilateral vestibular loss than visual vertical tests during either whole-body roll tilt or eccentric rotation. They are easier to administer, less demanding on patients, and most importantly, in general more effective at identifying chronic unilateral vestibular loss than visual vertical measurements.

A3-2

Direction dependent excitatory and inhibitory ocular vestibular evoked myogenic potentials (oVEMPs) produced by oppositely directed accelerations along the antero-posterior mid-sagittal axis of the head

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Passive displacements of the head need compensatory eye movements, to preserve clear vision.

Objectives: Ocular vestibular evoked myogenic potentials, oVEMPs) recorded beneath the eyes by looking up represent mainly EMG responses of the inferior oblique muscle. Oppositely directed displacements of the head need oppositely directed vestibulo-ocular reflex (VOR) i.e. compensatory responses. We aimed to study the properties of these responses as they were produced by head taps to the forehead at Fz site and to the back of the head at the inion. We wished also to investigate the relationships between these responses and the 3-D linear head accelerations which might reflect the true stimulus that is acting on the vestibular hair cells.

Methods: We have produced backward and forward directed acceleration stimuli in four conditions i.e. by applying plus and minus head taps to the hairline and to the inion in 16 normal subjects. oVEMPs and 3-D linear accelerations of the heads were recorded at the surface of the mastoids

Results: oVEMPs which were produced by backward and forward directed accelerations of the head showed consistent differences i.e. they were opposite in the phase. The responses produced by backward accelerations of the head had begun with an initial negativity N10, conversely those produced by accelerations directed forward showed with few exceptions an initially a positive response P10. There was high correlation of head accelerations along the antero-posterior axis and with few exceptions also along the head transversal axis but almost no correlation of the accelerations along the vertical axis of the head.

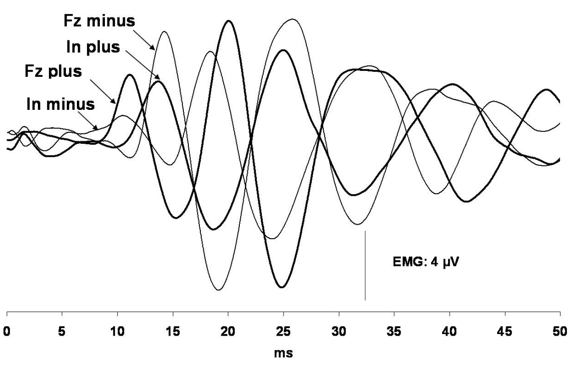

Figure 1: Average EMG responses of 16 subjects produced in the each of the four stimulation conditions. The bold traces show the responses produced by +Taps, the responses produced by -Taps are displayed as thin traces. The responses which were produced concor-

dant acceleration directionb were in phase conversely those which were produced by oppositely directed accelerations were out of phase.

Conclusions: Backward directed head accelerations have produced an initial excitatory oVEMP responses in contrary to the forward directed acceleration of the head was accompanied by an initial inhibitory responses. These responses shoved dependence on acceleration direction in the horizontal plane of the head. This could be consistent with activation of the utricle. Thus, these excitatory and the inhibitory oVEMP responses might represent the utriculo-ocular reflex mediated by utricular afferents with oppositely oriented spatial polarization vectors.

A3-3

Ocular VEMP via bone-conducted vibration stimuli in guinea pigs

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Objective: This study applied the ocular vestibular evoked myogenic potential (oVEMP) test to guinea pigs coupled with morphological examination to establish the animal model for oVEMP.

Method: Ten healthy and 10 gentamicin-treated guinea pigs were enrolled. During each test, a hand-held bone-conducted vibrator was placed on the animal's forehead. An amount of 0.05 mL of gentamicin (40 mg/mL) was dropped directly on the round window membrane of the left ear. After one week, all animals underwent auditory brainstem response (ABR), caloric and oVEMP tests, and were sacrificed for morphological study. A hand-held vibrator was used to deliver bone-conducted vibration stimuli on the frontal bone of a guinea pig for eliciting oVEMPs.

Results: All 10 healthy guinea pigs exhibited bilateral oVEMPs at the stimulus intensity of 139 dB force level (FL), with a mean threshold and latencies of peak nI and pI of 130 $\pm$ 4 dBFL, 3.17 $\pm$ 0.37ms and 4.72 $\pm$ 0.38 ms, respectively. Similar to response rate, the nI-pI amplitude decreased markedly in magnitude as stimulus intensity decreased. Another 10 animals administered with gentamicin (2 mg) on the left round window membrane 1 week after surgery had oVEMPs present beneath the left eye (ipsilateral to the lesion side), whereas oVEMPs were absent and reduced beneath the right eye (opposite to the lesion side) in 7 and 3 animals, respectively. Morphological study of animals with absent oVEMPs identified substantial damage to the utricular macula, providing evidence which strongly confirms the interpretation of a recent clinical test of human vestibular function – that oVEMPs by bone-conducted vibration primarily reflect the operation of the utricular receptors.

Conclusions: This animal model of oVEMP in guinea pigs sets the stage for studying the pathophysiology of utricular disorders.

A3-4

Ocular vestibular evoked myogenic potentials (oVEMPs) after unilateral vestibular deafferentiation due to vestibular schwannoma

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Ocular vestibular evoked myogenic potentials (oVEMPs) evoked by bone conducted vibration (BCV) have attracted much interest as a new clinical test for the otolith-ocular function. It is hypothesized that oVEMPs are mediated by crossed vestibulo-ocular pathways. Since it is known that patients with a unilateral vestibular deafferentiation (uVD) due to a vestibular schwannoma have only one functional vestibular system, they are the ideal test subjects to verify that hypothesis. If the 'crossed pathway'-hypothesis holds, it can be expected that the uVD-patients will only have a response below the eye of the affected side. Therefore nine patients (6 males and 3 females) with a uVD due to a vestibular schwannoma (5 with a right uVD and 4 with a left uVD) were investigated post surgery. The average time after surgery was 22 months (SD = 13 months). All patients underwent the oVEMP test using BCV (tone bursts, 500 Hz and 6 ms duration, linear envelope, repetition rate 3–31 Hz in different steps) at the forehead. The responses to 50 stimuli were averaged.

To assess the saccular function a collic VEMP (cVEMP) test was performed and a unilateral centrifugation test was used to investigate the utricular function. The cVEMP response was evoked using air conducted sound (tone bursts, 500 Hz and 6 ms duration, linear envelope, repetition rate 5.26 Hz). The unilateral centrifugation test was performed using a sinusoidal translation profile (0.013 Hz, amplitude = 4 cm, max. rotation speed = 400°/s). Both the cVEMP and unilateral centrifugation test are known to adequately indicate a unilateral loss.

Results indicated that oVEMPs were absent below both eyes in all nine patients, even below the eye of the affected side where a response could be expected. In a separate study with 92 healthy subjects we obtained bilateral oVEMP response in 85 of those subjects and absent oVEMPs in only 7 subjects (7.6%). However, in this study we obtained absent oVEMPs in 100% of the patients, which indicated that the absence is not due to methodological issues. cVEMPs were absent only on the affected side. Since the cVEMP-response is an ipsilateral response, these results were expected. The unilateral centrifugation test gave an asymmetry of 100% towards the affected side as could be expected as well. These results refute the posed hypothesis and suggest that the concept of the oVEMP being mediated by a crossed response should be revised.

A3-5

Influence of the repetition rate of the stimulation on the ocular vestibular evoked myogenic potentials (oVEMPs) to bone conducted vibration.

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The ocular vestibular evoked myogenic potential (oVEMP) test evoked by bone conducted vibration (BCV) has been hypothesized to assess the otolith-ocular function and evaluate the superior vestibular nerve. Since different labs use different repetition rates of the BCV to evoke the oVEMP response, we performed a comparative study to investigate the effect of that repetition rate of the stimulation on the test outcome. Therefore 85 healthy subjects (58 females and 27 males; average age = 33 years, SD = 14 years) were studied using different stimulation rates of the BCV. The repetition rate of the stimulation was gradually varied from 3 stimuli to 31 stimuli per second (3-5-7-9-11-13-21-31 stimuli per second). The sequence was repeated in the opposite direction immediately after the first sequence and all other settings were kept constant. Bone conducted vibration (tone bursts, linear envelope, 500 Hz and 6 ms duration) was applied to Fz (Fz corresponds to the junction of the midline and the hairline) using a mini shaker (Brüell and Kjaer, type 4810) to evoke the oVEMPs. The responses to 50 stimuli were averaged and the latencies of the n10 and p13 peak were determined, as well as the asymmetry ratio between the peak-to-peak amplitudes of the responses below both eyes. Repeated measures-ANOVA tests indicated that there were no significant effects ($p > 0.05$) of the BCV repetition rate on the oVEMP parameters. The reproducibility of the test outcome was investigated using intra class correlation (ICC) and the highest ICC coefficients were obtained with 11 and 13 stimuli per second. At 5 stimuli per second the lowest reproducibility was observed and when a stimulation rate of 21 or 31 stimuli per second was used, the n10-p13 complex was less clearly discernable due to additional peaks prior to the n10-peak. Those additional peaks complicated the analysis. We therefore conclude that a stimulation rate of 11 or 13 stimuli per second is most optimal since a) it has the highest reproducibility and b) it decreases the test time, which is certainly to be preferred for use in clinical settings.

A3-6

Does VEMP testing detect vestibular damage related to head trauma and whiplash injury?

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Objective: Otolithic injury presenting as benign paroxysmal positional vertigo has a number of causes but is very common after mild head trauma. Many of these patients also report additional complaints of imbalance and newly developed visual vestibular mismatch, which have been attributed to being indicative of otolithic pathology.

Work done in our lab some years ago suggested that the rate of posturography abnormalities was not related to the presence or absence of head trauma in whiplash patients, and the suggestion was that the abnormalities seen were related to damage to the balance system of the ear. We see many patients with similar stories who have not suffered head trauma. They often have normal caloric assessments, normal neurologic assessments, but abnormal posturography, and the suggestion has been that they have suffered non-traumatic otolithic damage.

Vestibular evoked myogenic potential (VEMP) testing is thought to be able to detect saccular dysfunction, which is an integral part of the vestibular complex. Subjective visual vertical (SVV) testing is thought to be a measure of utricular pathology. Caloric testing in head injured patients and whiplash patients is often unhelpful and these patients often deny any complaints of true vertigo. It has been suggested in the past that they have suffered otolithic damage.

In a recent study, results suggested that the incidence of VEMP abnormalities is similar in

- Patients who have vestibular complaints after head injury
- Patients who have vestibular complaints after whiplash injury
- Patients who have vestibular complaints but no trauma.

We wondered if we might be able to pinpoint more accurately the site of lesion in our whiplash and head trauma patients, by comparing the incidence of VEMP abnormalities, and incidence of SVV abnormalities in patients with "otolithic sounding" complaints and then compare them to our vestibular patients who had not suffered trauma.

Method: 100 patients were referred to our tertiary/quaternary care centre for complaints that were thought to be of balance system origin. Referrals included medical legal patients referred to us through the legal system and also regularly referred medical patients. Patients were divided up into three groups:

- No head injury related to onset of complaints
- Whiplash type of injury (but no head strike) associated with onset of complaints
- Traumatic head injury of some type associated with onset of complaints

All patients underwent Computerized Dynamic posturography, VEMP, SVV, and caloric testing after extensive history taking.

Results were reviewed retrospectively. Patients were also assigned blindly in a retrospective manner based on their histories to one of two groups, based on their principal complaint:

- an "otolithic complaint" group
- a "semicircular canal complaint" group.

Results: SVV and VEMP abnormalities were very helpful in delineating vestibular damage, as these tests were frequently often the only abnormalities found in patients with mild head injury. This confirms suspicions raised in an earlier smaller study. Abnormalities in these two assessments were also helpful in delineating the nature of patients' complaints. Although patients have differing sets of complaints, their complaints are suggestive of damage to the vestibular structures of the inner ear, as the rate of occurrence is similar across all of our patient groups. In many of our patients these two tests of otolithic function are the only abnormalities seen, which is helpful in the medical legal patient.

Conclusion: SVV and VEMP testing assess two different otolithic structures, and this present study has now shown how these two site-specific assessment techniques can be combined with posturography in assessing patients who have complaints suggesting balance system pathology after whiplash and mild head injury.

A3-7

Vestibular-evoked myogenic potential (VEMP) in the evaluation of schistosomal myeloradiculopathy

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Background: Vestibular Evoked Myogenic Potential (VEMP) is a test that assesses the vestibulospinal pathway, studying the integrity of the brainstem vestibular nuclei and then to the sternocleidomastoid (SCM) muscle through the upper cervical segments and the accessory nerve. Schistosomal Myeloradiculopathy (SMR) is the most severe and disabling ectopic form of Schistosoma mansoni infection. Although schistosomiasis is likely to be responsible for a significant number of cases of myelopathy of unidentified etiology in endemic areas, the prevalence of SMR is unknown. Cervical spinal cord abnormalities, although not as frequent, have been reported in SMR. This study aims to evaluate subclinical cervical abnormalities in the vestibulospinal pathway in subjects with SMR. Methods: Fifty-nine subjects, of whom 30 had no S. mansoni infection (control group) and 29 had SMR, were selected for this study. Controls were referred to our outpatient clinic for evaluation and treatment of different infectious diseases such as intestinal nematodes and bacterial or viral infections. All 29 patients with SMR were consecutively admitted to the hospital from 2005 to 2007. VEMP was performed in all patients with SMR 6 months after completion of treatment. Outcome was defined as 1) full recovery when the patient presented complete improvement of his neurologic status; 2) partial recovery when the patient remained with deficits that did not interfere with daily activities; and 3) no recovery when no change in the clinical picture was observed after treatment. The analysis of the VEMP results was conducted in a masked fashion; the examiner was unaware of the treatment outcome. During each recording session, in seated position, the subject was instructed to rotate the head toward the contralateral side of the tested ear to keep the SCM muscle under tension. The acoustic stimuli were short tone bursts (1 kHz, 118 dBHL, rise-fall 1 ms, and plateau 2 ms). The stimulation rate was 5 Hz; 200 responses were averaged for each run. The EMG signals were amplified and band-pass filtered between 10 and 1.500 Hz (Bio-logic Program). Results: Normal VEMP response was recorded in 19 subjects of the study group. The mean values were latency of the P13 = 13.8 ± 0.6 ms, and the latency of the N23 = 23.7 ± 0.38 ms; the asymmetry rating regarding amplitude = 30.17%. Abnormal VEMP was recorded in 10/29 patients with myeloradiculopathy (34%), with no response in 4 of 10 (40%). Among the six responsive, there was prolongation of P13–N23. The mean values were latency of the P13 = 14.60 ± 0.09 ms, and latency of the N23 = 25.3 ± 0.51 ms; the asymmetry rating regarding amplitude = 29.41%. There was higher prolongation of both latencies P13/N23, when the means of the six responsive patients were compared with normal controls (N = 30) and patients with myeloradiculopathy without VEMP alterations (N = 19; $P < 0.05$, ANOVA/Scheffé). VEMP response was correlated to neurologic abnormalities after treatment, and abnormal VEMP was found in 80% of those with neurologic abnormality (P < 0.05). Trend analysis showed a statistically significant linear tendency. The relative odds for VEMP abnormalities were 3 and 18 times higher for "partial recovery" and "no recovery," respectively, compared with "full recovery" (x2trend = 7.48; $P < 0.006$). Conclusion: VEMP may be used to screen for silent lesions and help in early diagnosis of even subtle spinal cord involvement. For SMR, this test was shown to be useful in diagnosing upper medullary involvement and should be tried in forthcoming studies to evaluate treatment response. in forthcoming studies to evaluate treatment response.

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Oral Session A4 – Postural Control

A4-1

The impact of external noise perception on sway in normal individuals

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A4-2

First trial postural reactions to unexpected balance disturbances: a comparison with the acoustic startle reaction

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Aim: This study compared acoustic startle responses to first trial reactions following a perturbation of stance induced by support-surface tilt.

Background: Unexpected support-surface movements delivered to standing subjects elicit first trial postural reactions, which are of larger magnitude and cause greater instability compared to those of subsequent identical perturbations. The nature of this first trial reaction (FTR) remains largely unknown. We hypothesized this reaction consists of a generalized startle reaction, with a similar muscle response synergy to that of an acoustic startle reaction, combined with an automatic reaction.

Methods: Eight healthy subjects stood on a support-surface platform and unexpectedly received a series of 10 consecutive backward-directed platform rotations followed by 10 startling acoustic stimuli or vice versa. Outcome measures included full body kinematics, head accelerations (measured with accelerometers) and surface EMG recordings from several muscles including those known to be involved in startle reactions (masseter) and in responses to perturbations as well (sterncleidomastoid-SCM) or in responses to perturbations alone (soleus). We examined the habituation of responses by comparing the amplitude of trial 1 to trial 2 and to the average of trials 6–10.

Results: Both perturbation and acoustic (ac) startle responses showed FTRs, as shown in larger kinematic and EMG responses, also in startle-responsive masseter muscles. The habituation rate of EMG responses to repeated exposure to identical stimuli was comparable for both conditions. EMG response latencies for perturbations were, with the exception of a stretch reflex response in soleus, around 100ms. These latencies were significantly delayed in SCM and masseter muscles for first trial perturbations compared to ac-startle responses, but earlier in trunk muscles. Supra-threshold head vertical linear acceleration and ankle dorsiflexion preceeded muscle response onsets in the perturbation condition. However supra-threshold head pitch acceleration occurred with SCM onset for the ac-startle condition.

Conclusions: Our results confirm those of previous studies showing that unexpected postural perturbations induce reactions with larger amplitude muscle synergies than habituated responses. Onsets were at the same latency across body segments. Different synergies are present for ac-startle responses. These act at two different latencies with earlier responses in the SCM and masseter muscles but longer latencies in the trunk and legs. The delayed response in the lower body for ac-startle, is probably the result of preceding head movement induced by SCM contractions. Common to FTRs for both stimulus conditions is the startle-like response in masseter, and all muscle response habituation rates. For the postural FTR, the marked cocontraction is the probable cause of instability. Postural FTRs may be triggered by the arrival of unexpected afferent volleys formed by lower-leg somatosensory inputs. Vestibular inputs are unlikely as the triggering source because of the long delay between supra-threshold head accelerations for the vestibular system and the onset of perturbation responses. For this reason (and synergy differences), FTRs for perturbations are not completely startle-like as the response does not immediately follow the arrival of the first sensory volleys. However both perturbations and ac-startle responses may be modulated by vestibular signals once triggered. Experiments with vestibular loss patients and lower-leg proprioceptive loss patients are needed to resolve the issue of which sensory signals or combinations thereof trigger and modulate first trial reactions to perturbations.

A4-3

Foam surfaces and standing balance testing: The balance perturbing effects, the perturbing mechanisms and considerations for clinical and experimental practice

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Objective: Standing on a foam surface is a common technique in balance testing to distinguish patients with balance problems from those without, particularly in the case of suspected vestibular disorder. Standing on foam is believed to exaggerate balance deficits by decreasing the reliability of information from cutaneous mechanoreceptors of the plantar soles (base of the feet), though foam surfaces also alter the effectiveness of ankle torque. To fully grasp the usefulness of foam in the assessment of balance disorders, a detailed understanding of how foam perturbs standing balance is necessary. In a series of three studies we present the balance perturbing effects and begin demonstrating the balance perturbing mechanisms on foam. Finally, we suggest considerations for clinical or experimental practice.

Methods: Study I: The relative anterior-posterior movement at the knee, hip, shoulder and head and torque between the feet and surface were measured on foam and a solid surface with eyes open and closed in 12 healthy adults (mean age 26 years). This study demonstrated the balance perturbing effects of foam.

Study II: Anterior-posterior and lateral torque between the feet and surface and whole-body postural coordination (angular ankle, knee, hip, shoulder and head movement) were measured on three foam surfaces differing in their properties (i.e. density and elasticity modulus) and a solid surface with eyes open and closed in 30 healthy adults (mean age 22.5 years). The foam were categorised firm, medium and soft by their elasticity modulus. This study evaluated the contribution of surface properties towards the balance perturbation on foam.

Study III: Anterior-posterior and lateral torque between the feet and the surface were measured in 16 healthy adults (mean age 20.8 years), with and without decreased mechanoreceptive sensation on the plantar soles from plantar cutaneous hypothermic anaesthesia (ice-cooling), and with eyes open and closed. Tests were conducted on foam and a solid surface. Slowly and rapidly adapting plantar mechanoreceptive sensation were assessed and determined with tactile sensitivity and vibration perception respectively after balance testing. This study evaluated the contribution of decreased plantar mechanoreceptive sensation towards the balance perturbation on foam.

Results: Standing on foam increased postural sway, specifically, knee and hip movements were increased relatively more than shoulder and head movements, and changed postural coordination compared with a solid surface. Vision decreased movement above 0.1 Hz, stabilised shoulder and head movements more relative to hip and knee movements on foam.

Postural sway amplitude and relative knee movements were significantly larger when the foam surface was

denser and more elastic. The stabilising effect of vision was also larger when subjects' standing balance was challenged more by the support surface.
Rapidly adapting sensation was decreased significantly by hypothermic anaesthesia, but not slowly adapting sensation. Hypothermic anaesthesia produced a stability change on a solid surface that was different in spectral composition, amplitude, direction and that responded differently to vision compared with standing on foam.
Conclusions: Standing on foam exerted a significant balance perturbation which changed the contribution from the sensory systems. This perturbation was more closely related to the foam properties than to a decrease in the reliability of rapidly adapting mechanoreceptive sensation on the plantar soles. Further research is now required to elucidate the exact reasons foam surfaces perturb standing as they do.
Considerations: The foam properties affect body movements and these should be taken into account either by employing a universally standard surface or by factoring the surface properties into the movement measurement.
When evaluating balance deficits with foam, the contribution of vision is different depending on the surface properties.
The effect of foam on cutaneous mechanoreceptors of the plantar soles remains to be determined.

A4-4

Perceptual and locomotor responses to galvanic vestibular stimulation with and without sensory conflict

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Prolonged vestibular stimulation undergoes time-varying signal changes via peripheral and central processing pathways. When there is no conflicting sensory input the vestibular signal will adapt over time, but in the presence of a conflicting visual signal it somehow must align or be recalibrated quickly to create a unified perception. Galvanic vestibular stimulation (GVS) can be used to evoke a pure vestibular signal and after-effects in darkness could reveal how the signal is recalibrated. Experiment 1 recorded the perception of self-rotation evoked in darkness, during and following bilateral GVS (1.5 mA) over 2 minutes via verbal report in 12 healthy subjects aged 21–54 years. To evoke maximum yaw and minimal roll perception from GVS, standing subjects had their head's pitched downward with Reid's plane at 72 degrees to the horizontal [1]. In Experiment 2, GVS was applied for 1–6 minutes during exposure to a stationary visual scene. Locomotor trajectories afterward were recorded over 5 minutes in darkness: the response period. During the response period the GVS either remained on, was turned off, or the polarity was reversed.
The results of Experiment 1 showed that GVS evoked an illusion of rotation toward the cathode and this declined over 100 seconds. When the GVS was turned off there was an equivalent perception of rotation in the opposite direction. The decay profile was equivalent (adj-R2 $= 0.87$) to previously published data of perceptual rotation during continually increasing and decreasing rotational velocity [2]. This indicates that GVS activation bypasses the signal transformation process of the canal-cupular system and reveals the long-term adaptation process with time constant of 76 seconds. In Experiment 2 after GVS conditioning to exposure with a stationary visual field, after-rotation was in the direction of the prior cathode and the profile reflected adaptation of central vestibular processes with the peak velocity increasing with conditioning time. When the GVS remained on during the response period, a small rotation toward the anode remained. This could be the result of down-regulation of the vestibular signal in the presence of the stationary field. However, when the polarity of the GVS stimulus reversed in the response period, the velocity toward the prior anode increased significantly ($P < 0.01$) indicating that the vestibular signal had been recalibrated rather than down regulated. We conclude that GVS signals are interpreted within the CNS as angular acceleration of the head. A systems model suggests that modulation of vestibular gain occurs via the brainstem velocity storage process. When there is a visual-vestibular conflict, there is an initial down-regulation of the vestibular input to accord with the visual scene, but the gain increases as the signal is recalibrated over time.

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A4-5

What advantages do two vestibular labyrinths offer the human balance system?

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When an animal is at rest, vestibular primary afferent neurons discharge spontaneously with firing rates that vary across species. The firing rate is particularly high in primates, for example 65–90 s-1 in squirrel monkey [3] and 90–115 s-1 in macaque monkey [2]. A higher resting rate allows each afferent to signal bidirectionally and symmetrically over a greater physical range. This means that for a natural head movement within that range, the left and right semicircular canals would transmit essentially the same information to the balance system. Here we ask whether the human balance system receives duplicate information from the two labyrinths, and if so, what advantage it offers.

To investigate this we used monaural galvanic vestibular stimulation to modulate the firing of vestibular afferents from each labyrinth independently and measured the resulting balance responses. Two stimulators were used so that each side could be stimulated either on its own (monaural) or together (binaural). The polarity of stimulation was varied with the active electrode over the mastoid being an anode or a cathode with respect to an indifferent electrode placed 2 cm lateral to the T1 spinous process. Balance responses were measured from 1) electromyographic activity of left and right gastrocnemius, 2) the ground-reaction shear force vector, and 3) the body sway vector at the level of C7. The medium-latency response was measured as it most likely represents the response to semicircular canal inputs [1].

With monaural stimuli, body sway vector magnitudes for anodal stimulation (5.04 $\pm$ 0.35 mm) and cathodal stimulation (4.93 $\pm$ 0.48 mm) were not significantly different (t19 $=$ 0.29, P $=$ 0.77). This indicates that semicircular canal afferents are symmetrically bidirectional for stimuli of this size. EMG responses showed that individual leg muscles receive equal inputs from the two labyrinths even though a single labyrinth appeared capable of signaling 3-D head motion. To deduce principles of left-right integration, balance responses to binaural stimulation were compared with responses to monaural stimuli. The binaural response direction was compatible with vector summation of the two responses from left and right monaural stimulation. The binaural response magnitude, however, was only 64–74% that predicted by the monaural sum. This probably reflects a central non-linearity between vestibular input and motor output because stimulation of just one labyrinth revealed a power law relationship between stimulus current and response size with exponents 0.56 (force) and 0.51 (displacement). Thus, doubling total signal magnitude either by doubling monaural current or by binaural stimulation produced equivalent responses.

We conclude that both labyrinths provide independent estimates of head motion that are summed vectorially and transformed non-linearly into motor output. The former process improves signal-to-noise and reduces artifactual common-mode changes. The latter process enhances responses to small signals without saturation of large signals. Both processes offer advantages for detecting the small head movements needed to control human balance.

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A4-6

Otolith and canal involvement in the balance response to galvanic vestibular stimulation

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Objective: Passing a direct current through mastoid electrodes (galvanic vestibular stimulation; GVS) evokes a stereotyped response in standing humans. The

response contains two independent, oppositely directed balance reflexes, traditionally referred to as short- and medium-latency responses. Though widely considered vestibular in origin, the reason for their different sign and latency is unclear. One appealing hypothesis is that the short- and medium- latency responses are evoked through stimulation of otolith and canal afferents respectively [1]. Here we examine this hypothesis.

Methods: Based on the anatomy and morphology of the vestibular organs, binaural bipolar vestibular stimulation is predicted to evoke a net head rotation signal about a naso-occipital axis and a net linear acceleration signal along the inter-aural line [4], whilst with monaural stimulation, the net linear head-motion signal is expected to deviate substantially from the inter-aural line. Healthy young adult participants (binaural experiment $n = 8$; monaural experiment $n = 20$) held various strategic head on body postures meant to alter the significance of these vestibular evoked head motion signals to the balance system. This enabled us to deduce involvement of net linear and rotational signals in the balance response. Cross-covariance between motor output (gastrocnemius EMG and ground reaction forces) and 172s of a random waveform stimulus (stochastic VS), which gives equivalent responses to GVS [2], were used to assess the direction of the short-latency response (cf. [5]).

Results: During binaural bipolar stimulation when the head is in a nose-down pitch posture, the evoked rotation signal indicates yaw about an earth vertical axis [3], which we assume does not require a balance response. However, the predicted inter-aural linear acceleration still requires a balance response. In agreement with the otolith-canal hypothesis, we found that with the head pitched down the medium-latency muscle reflex was almost entirely abolished whilst the short-latency muscle reflex was maintained and directed along the inter-aural line in both head upright and head down postures. In contrast, when we measured the directions of the short-latency response to monaural stimulation, we found large discrepancies between the predicted non inter-aural response direction and the measured response direction, which continued to act along the inter-aural line both with the head upright and head down.

Conclusions: Our findings indicate that 1) the net canal signal is paramount in the GVS evoked medium-latency response (in agreement with Cathers et al. [1]) and 2) the net otolith signal does not make significant contribution to either the GVS-evoked short- or medium-latency responses. These findings may suggest a non-vestibular source for the short-latency response.

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A4-7

Cortical transcranial direct current stimulation increases the duration of the ‘broken escalator’ locomotor aftereffect.

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Abstract: The ‘broken escalator phenomenon’ describes the unusual sensation and transient imbalance experienced when walking onto a stationary escalator. Experimentally, stepping onto a stationary platform that was previously moving elicits a locomotor aftereffect characterised by inappropriately fast gait velocity and a forward displacement of the trunk, and increased EMG activity in the legs (Reynolds and Bronstein 2003). Non-invasive brain stimulation, such as transcortical magnetic stimulation (TMS) and cortical transcranial direct current stimulation (tDCS) has been used in the study of motor performance to modulate excitability in defined cortical areas (Nitsche MA et al., 2002). Studies of cortical plasticity using brain stimulation have focussed on hand and arm areas of the motor cortex. In this paper we examine the effect of bihemispheric tDCS on the size and duration of the ‘broken escalator’ locomotor aftereffect in 30 healthy volunteers.

Subjects completed five baseline trials walking onto a stationary sled (BEFORE condition). Subjects then received either sham stimulation or tDCS stimulation (2 m A) for 15 minutes at rest. For bilateral stimulation of primary motor cortex leg areas and prefrontal cortex, the stimulating (anodal) electrode was placed across the scalp to cover a region 10–20% in front of Cz (international 10–20 EEG system). Subjects then walked onto a moving platform (MOVING condition,

or adaptation trials), and then again onto a stationary sled (AFTER condition). We measured gait velocity, forward trunk displacement, foot contact timing, and EMG of the ankle flexor-extensor muscles.

Both tDCS and sham groups showed a locomotor aftereffect in the AFTER trial with inappropriately high gait velocity, forward trunk displacement and increased EMG activity in the legs. In addition, the tDCS group showed a significantly larger trunk displacement in the 1st AFTER trial compared to sham, and a persistence of the locomotor aftereffect into the second AFTER trial.

Our results suggest that tDCS applied to motor cortex leg areas may enhance motor learning of a gait task. Application of DC stimulation prior to the motor learning task may prime the motor cortex and thus facilitate the acquisition and consolidation of new muscle synergies. These findings raise the possibility of using non-invasive brain stimulation in patients with gait disturbances as a therapeutic tool.

Oral Session A5 – Vestibular-Eye Interaction

A5-1
Effect of vestibular activation on human visual cortical area V5/MT excitability

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Objectives: The visual and vestibular systems, either independently or in combination, are important for our ability to detect self-motion. The vestibular system is sensitive to head acceleration whilst the visual system can indicate self-motion during constant velocity self-motion. Although complimentary, the two systems may conflict, e.g. when we see a train move past, we may sense self-motion rather than object motion. The brain may resolve this visuo-vestibular conflict via a reciprocal inhibition between visual and vestibular cerebral cortical regions. The evidence supporting this concept derives from functional neuroimaging [1], a correlational technique. We investigated visuo-vestibular interaction directly by measuring visual cortical excitability in area V5/MT using Transcranial Magnetic Stimulation (TMS) during vestibular activation in 12 volunteers.

Methods: The intensity of a single TMS pulse required to elicit a Phosphene (a flash of perceived light produced by stimulating visual cortex) is a measure of visual cortical excitability. Area V5/MT was localised by surface markings and confirmed in some subjects using a neuronavigation system (BrainVoyager). We titrated the TMS intensity to a fixed level whereby 20 TMS pulses (inter-pulse duration of 6s) elicited 10 phosphenes (out of 20 pulses) i.e. a baseline phosphene probability of 0.5 (in reality we obtained a phosphene probability of 0.52; $n = 960$). We then applied 3 further trains of 20 TMS pulses at the same intensity and inter-stimulus interval (6s) as baseline; i.e. during (i) caloric-induced vertigo commencing 20s after the end of the 40s period of irrigation (ii) first recovery period (iii) a final recovery period. Each TMS run lasted 2 minutes and each run was separated by 1 minute from the end of the previous run.

Results: We compared the probability of obtaining a phosphene during vertigo and the 2 recovery phases as compared to baseline. We found that during vertigo the phosphene probability fell to 0.44 and this was significantly different compared to baseline ($P < 0.002$; 2-tailed chi square). This vertigo effect recovered back to baseline (phosphene probabilities in recovery phases of 0.49 and 0.51 respectively). Furthermore the effect of vertigo on phsophene perception was only significant ($P < 0.002$) for the ipsilateral condition (i.e. irrigation and TMS on same side) but not for the contralateral condition ($P = 0.15$).

Conclusion: Our data suggest that vestibular activation results in visual cortical inhibition in area V5/MT, at least for supramaximal vestibular stimulaton. Additionally we found a lateralisation effect excluding a non-specific vertigo effect on phosphene perception. We did not find a significant effect of the side of hemisphere stimulated or ear irrigated implying a relatively symmetrical effect on brain structures in effecting visuo-vestibular inhibition. Recent primate data show that visually sensitive neurones in area V5/MT are not modulated by vestibular stimulation [2]. This does not neccessarily contradict our data however, since one possibility is that vestibular modulation of visually sensitive V5/MT neurones requires concurrent visual and vestibular activation. Indeed our finding supporting the concept of a visuo-vestibular inhibtion may be overly simplistic since recent data suggest that the relative strengths of two incident sensory inputs of different modalities may determine how these signals are combined, i.e. antagonistically or synergistically [3]. Thus one implication is that there may be visual-vestibular synergy at threshold vestibular activation versus visual-vestibular inhibition during vertigo (a supra-maximal vestibular activation). Further work will be required to answer this question.

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A5-2

Does the human electrically-evoked vestibulo-ocular reflex rely on vestibular hair cell transduction?

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Vestibular reflexes, evoked by human electrical (galvanic) vestibular stimulation (EVS), are utilized to assess vestibular function and investigate its pathways. The premise that the electrically evoked vestibulo-ocular reflex (eVOR) was induced by direct electrical activation of the vestibular nerve has been challenged by the eVOR loss following hair cell death in gentamicin vestibulotoxicity.

Objectives: We investigated if the eVOR was mediated by vestibular hair cell transduction rather than by direct vestibular nerve activation.

Methods: eVORs recorded as binocular three dimensional eye movements evoked by bilateral, bipolar, 100ms direct current at [0.9, 2.5, 5.0, 7.5, 10.0]mA with dual-search coils from 11 subjects with one functioning vestibular labyrinth, five subjects without any functioning vestibular labyrinth and 11 normal subjects.

Results: EVS of one functioning vestibular labyrinth elicited biphasic (excitatory-inhibitory), maintained, graded eVORs. We showed an excitatory eVOR to cathodal EVS with 9ms latency, and an inhibitory eVOR to anodal EVS, opposite in direction, half the amplitude with 12ms latency. Both excitatory and inhibitory eVORs were maintained with constant direct currents and graded with current intensities, exhibiting excitatory inhibitory asymmetries. These characteristics were consistent with hair cell electrophysiological properties but inconsistent with vestibular nerve properties. We showed that current will spread from a stimulating electrode on the head to any functioning labyrinth. It is not possible in normal subjects with two functioning vestibular labyrinths to stimulate one labyrinth in isolation. Hence the notion of unilateral EVS is only valid in subjects with one functioning labyrinth.

Conclusions: Our finding suggests that the eVOR relies on vestibular hair cell transduction. Therefore clinical interpretation of the EVS test should equate electrically-evoked vestibular reflex loss from a diseased labyrinth to vestibular hair cell or nerve pathology and this test may be utilized to investigate vestibular receptor dysfunction.

A5-3

The mechanism underlying human electrical vestibular stimulation

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It is well known that surface electrical currents applied to the skull induce vestibular reflexes, thought to be generated by stimulation of the vestibular nerve. Recent findings (Aw et al., 2008) have questioned whether these responses may in fact be generated by the vestibular hair cells.

Objectives: To examine the underlying mechanism of electrically evoked vestibulo-ocular reflex (eVOR) production in the light of new data, which suggests that the vestibular hair cells may be involved in genesis of the response, and to develop a simple model of the response.

Methods: eVORs were recorded as binocular three dimensional eye movements evoked by bilateral, bipolar, brief direct current pulses (1–200 ms) at 5.0 mA stimulation on the mastoid bone with binocular dual-search coils in human uni-labyrinthine subjects.

Results: Electrical stimulation of one functioning vestibular labyrinth elicits biphasic, maintained, graded eVORs with the same 9 ms latency as that found for acoustic stimulation through the entire mechanotransduction pathway. Direct stimulation of the myelinated afferent nerve or its spike trigger zone would be expected to produce a shorter latency because it bypasses the hair-cell mechanotransduction delay of about 2 ms. We found that the eVOR can be approximated by a second-order system over a range of currents and pulse durations. Similarly, injection of current pulses into hair cells also generates second-order modulation of their receptor potentials with similar dynamics. The eVOR pulses showed summation patterns that can be reliably predicted by our simple model.

Conclusions: Our results and model suggests that modulation of the hair cell currents by externally applied electrical current could be the source of the eVOR, rather than stimulation of the afferent nerve. This has implications for the study of vestibular reflex pathways and interpretation of clinical results.

A5-4

Maintaining binocular fixation while moving: A model of smooth pursuit in three dimesions

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The eyes track targets that move relative to the head based on visual input, but they must also interact with angular and linear vestibular ocular reflexes to maintain binocular fixation on targets during head and body movement. The temporal dynamics of pursuit eye movements and the corresponding neural control mechanisms for accomplishing the movements in one dimension have been described and modeled. Much less is known about how pursuit is controlled in three dimensions, especially how it interacts with the linear vestibulo ocular reflex when the head moves along a fore-aft direction. To study pursuit in three dimensions, it is necessary to have a 3-D kinematic model of pursuit and to establish the role of binocularity. Here we show that the kinematics of 3D pursuit can be modeled considering that: 1) the control tends to align the visual axis of each eye with the target axis, and 2) that pursuit in 3D satisfies Listing's law. Listing's law for saccades is maintained because of the fundamental 2D positional control of a 3D oculomotor plant that is constrained by pulleys (Schnabolk and Raphan, 1994; Raphan, 1997; Raphan, 1998). Pursuit control was similarly modeled as a 2D velocity control of the 3D oculomotor plant with pulleys. The model extracted 2D velocity information from the projections of target motion on a 2D retinal map. Combining this pursuit model with the angular vestibulo ocular reflex (aVOR) explained many of the non-commutative properties attributed to the aVOR. An extension of the model to binocular control also predicted data obtained in rhesus monkeys on 3D pursuit and convergence (Yakushin et al., 2009). Thus, the model shows that the control of pursuit in 3D follows similar a 2D organizational principle as for saccadic control. It also shows how the 2D vector signals would interact with the angular and linear vestibulo ocular reflexes (aVOR and lVOR) to maintain binocular fixation during movement.

A5-5

Neural correlates of motor learning in the vestibulo-ocular reflex: dynamic regulation of multimodal integration

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Motor learning is required for the reacquisition of skills that have been compromised as a result of brain lesion or disease, as well as for the acquisition of new skills. Behaviors with well-characterized anatomy and physiology are required to yield significant insight into changes that occur in the brain during motor learning. The vestibulo-ocular-reflex (VOR) is well suited to establish connections between neurons, neural circuits, and motor performance during learning. Here we examined the linkage between neuronal and behavioural VOR responses in alert behaving monkeys (macaca mulata) during the impressive recovery that occurs after unilateral vestibular loss. We show, for the first time, that motor learning is characterized by the dynamic reweighting of inputs from different modalities (i.e., vestibular versus extra-vestibular) at the level of the single neurons which constitute the first central stage of vestibular processing. Specifically, two types of information, which did not influence neuronal responses prior to the lesion, had an important role during compensation. First, unmasked neck proprioceptive inputs played a critical role in the early stages of this process demonstrated by faster and more substantial recovery of vestibular responses in proprioceptive sensitive neurons. Second, neuronal and VOR responses were significantly enhanced during active relative to passive head motion later in the compensation process ($>$ 3 weeks). Taken together, our findings provide evidence linking the dynamic regulation of multimodal integration at the level of single neurons and behavioural recovery, suggesting a role for homeostatic mechanisms in VOR motor learning.

A5-6

Virtually dizzy – modelling the human vestibulo-ocular response.

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A patient VOR response simulator has been developed that is capable of modelling human eye movements when rotated on a vestibular chair. The system consists of three main sections, a detector corresponding to a lateral semi-circular canal, simulation of the brainstem processing including neural integration, saccade generation, higher level cortical inputs, and a response mechanism simulating the ocular motor plant causing analogous eye movements.

The peripheral vestibular organ functions are well understood, the lateral semi-circular canal in the inner ear responds to horizontal angular acceleration and project to the vestibular nucleus via the VIIIth cranial nerve. Here excitatory and inhibitory nerve impulses are integrated and passed via a 3 neuron reflex arc to the ocular motor plant that innervates the lateral and medial rectus muscles of the eyes causing movement to the left and right. When the eye deflection reaches a certain orbital offset a corrective saccade is triggered. If the head continues to rotate the process repeats causing a rhythmic eye motion called nystagmus. How the triggering of the eye position resetting is achieved, and its duration is still a subject for considerable debate. The model has been implemented using the current favoured hypothesis. Control of this process is possible from the cortex via structures such as the Superior Colliculus located in the brainstem. Visual input is also able to suppress the VOR response.

A fluid filled tube representing the lateral semi-circular canal was fitted with a pressure sensor to detect fluid inertia in response to angular acceleration in the horizontal plain. Signals from the pressure transducer were collect by a notebook computer via a data acquisition card with USB interface. The complete system was mounted onto a vestibular chair. The computer was programmed with a model of the VOR system using Labview graphical programming language. This processed the input signal and caused a simulated model of a pupil to deflect on the screen producing convincing nystagmus in response to sinusoidal vestibular chair motion.

The simulated pupilar movement was detected using the vestibular testing chair infra-red camera and processed and analysed as if it were a human response. Initial test results have been compared with ten sets of normal adult data resulting from sinusoidal rotation, collected for the project. A good correlation was found. Model parameters can be adjusted to simulate a range of human VOR dysfunction. Currently the model will only simulate the response to sinusoidal stimuli. Further development is required to model the response to the impulsive stimuli and to improve the signal to noise ratio of the canal input signal at low acceleration velocities.

Oral Session A6 – Inner Ear Morphology

A6-1

A new study on the fluid dynamics in the SCC and the utricle

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Study's objectives: We propose a numerical model for the simulation of the endolymph flow in the vestibular system. This allows a detailed analysis of the flow patterns developing in the utricle and the ampulla. This work is not limited to the macro-mechanics of the SCC as a sensor of angular acceleration, but is aimed also at extending our knowledge of the physiological role of fluid mechanics at the micro scale.

Methods: The flow field inside the SCC and the utricle is modeled as a creeping flow and the resulting governing equations are solved numerically. The wall of the membraneous labyrinth is assumed to be rigid. Its anatomy is extrapolated from CT images of the bony labyrinth and from literature data [1]. BPPV is modeled by introducing free-floating particles into the SCC.

Results: Our results on the macro-mechanics of the SCC are consistent with the models found in the literature [2–4]. An angular acceleration orthogonal to the SCC planes induces a proportional endolymph flow field which deflects the cupula. This deflection turns out to be proportional to the angular velocity of the SCC and the flow in the narrow ducts is well approximated by a Poiseuille flow.

The lumen in the utricle and the ampulla is usually considered much larger than in the narrow ducts and by assuming a Poiseuille flow a priori, many authors consider the flow in the utricle to be negligible compared to the flow in the SCC. However, our results show that angular acceleration can induce a vortex in the utricle and in the ampulla with velocities that can be even higher than the velocities in the narrow duct of the SCC. We found that such a vortex can only be observed when the ratio between the size of the utricular cavity and the diameter of the narrow ducts of the SCC is sufficiently large. Accordingly, we do not observe a vortex if we chose the bony labyrinth as computational domain instead of the membraneous labyrinth.

There exist, however, scenarios where we do not observe the vortex. The most relevant one is found during post-maneuver simulations of BPPV symptoms. There, we observe a particle settling in the SCC inducing a Poiseuille flow which can deflect the cupula leading to vertigo.

The observed vortex may play an important role both in the utricle and in the ampulla. Because of the high velocities of the vortex in the utricle, e.g., the shear stresses acting between endolymph and otolith sensors may have physiological significance.

Conclusions: The basic results of our numerical model are consistent with models previously presented in the literature, both for physiological and BPPV conditions. However, under certain assumptions for the ratio between the size of the utricle and the SCC, we observe a vortex in the utricle and the ampulla which allows velocities even higher than in the narrow duct of the SCC. We expect this vortex to play a physiological role both in the utricle and in the ampulla.

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A6-2

Precise measurement of the human semicircular canals in CT and micro-CT

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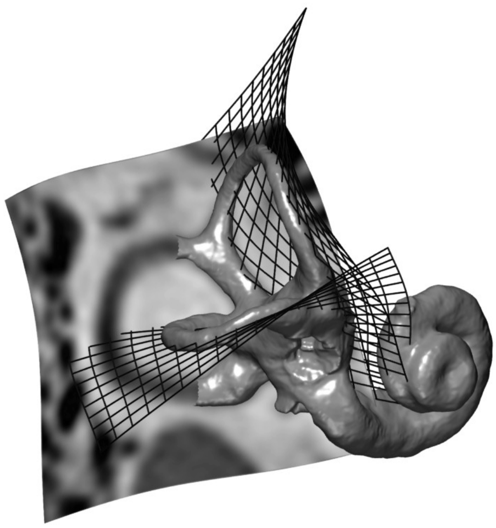
Background: Knowledge of semicircular canal (SCC) geometry forms the basis for understanding and interpreting much vestibular patho-physiology. Historically these interpretations have been based upon average canal planes, however these canals are not planar and their orientation and morphology varies greatly between individuals. The SCCs can be imaged using clinical computed tomography (CT) and magnetic resonance imaging (MRI), however it is difficult to make precise measurements using these modalities due to limiting factors such as partial volumeing and noise; factors which also preclude visualization of the membranous duct. Micro-CT offers a new approach to visualizing the small structures of the inner ear but is limited to cadaveric specimens. Precise measurement of canal geometry is also of interest for fluid dynamic modelling of the canals which has the potential to calculate canal stimulation patterns during an individuals given head movement.

Objective: We sought to accurately and objectively reconstruct a mathematical description of the SCC geometry from CT in living humans, in order to make precise anatomical measurements of both individual and average SCC geometry.

Methods: In order to reconstruct the SCCs accurately in this setting an active contour approach was employed. Active contours are curves that minimise a cost function, generally design to balance contour smoothness against its alignment to features within the image domain. Our framework models the canals by processing cross-sectional slices in an iterative manner to produce 3D centre-line paths of the bony SCCs; it also allows a direct comparison and analysis of ears within and between subjects. The accuracy of our methods was directly validated using micro-CT as a ground truth comparison. The CT scans were acquired using a General Electric (GE) Lightspeed VCT and the uCT scans were acquired using a Skyscan 1172. All software used in this project was written in LabVIEW 9.0 (National Instruments) and the anatomical illustrations were rendered using Houdini 10.0 (Side-FX).

Results: The 3D SCC geometry was calculated from CT imaging of 34 anatomically normal human ears, within which the normal range of geometrical attributes (non-planarity, radius of curvature and inter-SCC angle) are examined. We also calculated the average SCC geometry from this data, which are also described using simple mathematical equations. A slightly modified protocol was applied to an ear exhibiting SCD to demonstrate the use of optimal multi-planar reformatting as a diagnostic aid. The bony SCCs and the membranous structures were also reconstructed from micro-CT to reveal the finer details and evaluate their orientation in relation to the macro geometry that we measure in clinical imaging.

Conclusion: The techniques developed in this study permit the SCC morphology to be precisely measured in living humans. These measurements have numerous applications in research, diagnosis and treatment. For the first time it is possible to interpretation individual physiology and patho-physiology based upon real individual 3D geometry.



Labyrinth with optimal least squares curved planes

A6-3
Whale inner ear morphology: Use of 3D modelling and rapid prototyping technology

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Introduction: A non-invasive method was developed to reconstruct the 3D appearance of whale inner ear and to compare its morphology to human.

This work uses method based on computed tomography (CT), segmentation techniques and rapid prototyping technologies to isolate and visualize the inner ear structure. Moreover this work establishes methods and protocols to determine volume and voxel based density.

Material and Method: Spiral computed tomography images and special computational tools are used to image and isolate whale inner ear. Both the cochlea and the vestibular part of the inner ear with it's semicircular canals are made visual through imaging and 3D reconstruction and modelling.

The CT scan data are imported into a special image processing and editing computer program called MIMICS. In this software environment, bone, muscles and other tissues can be isolated using the Hounsfield (HU) scale which allows discrimination amongst different tissues based on their linear attenuation coefficient. To select and visualise only the region of interest a threshold based on HU values is defined. A maximum and minimum value is established and individual pixels are selected if their value falls in between the threshold values. The inner ear are harvested from fin whales, hunted during the summer 2009, and conserved in formalin.

The segmentation process is based on the visual reorganisation of a region of interest which is very small; indeed the total volume including the whale inner hears is approximately 2000 mm3. A special spiral CT protocol is developed for this propose having tube voltage 140 KV, slice increment 0.29 mm and slice thickness 0.58 mm. The elements present within the inner hear volume and target of the segmentation process are bone tissues with different densities, cartilages and fluid filled cavity these elements appear as areas with low density on HU scale. The image processing starts by selecting an initial cross-section within the region of interest and defining a threshold which display it. Using special editing tools available on MIMICS the contours are adjusted manually around cochlear and vestibular organs. The shape created is projected to the next cross-section and adjusted to fit the new cross-sectional area. The process continues until all cross-sections which build up the cochlear and vestibules, with semicircular canals are added afterwards using editing tools are covered.

Result: Medical modelling techniques and rapid prototyping technologies were employed to display inner ear morphology in whale and human. The cochlea is larger in whales; with volumes between 1400–1600 mm^3 compared to 200–400 mm^3 in human. Maximum diameter between 20–25 mm in whale and between 8–9 mm in human. The length of the cochlea is around 70 mm in whales (2 complete turns) and 30 mm in human (2.5 turns). Remarkable differences are also measured on the semicircular canals but in a different direction. Semicircular canals are thinner in whales: between 0.3–0.5 mm in whales and between 1.2–1.5 mm in human. Beside the semicircular canal radius is also smaller in whales: from 4.4 to 5.6 mm in whales and from 4.6 to 6.5 mm in human.

A6-4

Acoustic resonance and reduced semicircular canal size in cetaceans

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The small size of the semicircular canals of cetaceans makes them unique exceptions to the allometric relationship between body mass and canal size found in all other animals. It has been suggested that cetaceans may have uniquely high-amplitude head movements that require small, low-sensitivity canals to avoid oversaturation. Recent data, however, contradict this possibility. An alternative hypothesis is that high-frequency, high-amplitude sounds produced by cetaceans might interact unfavorably with larger canals but that smaller canals would not be similarly affected. The vestibular labyrinths of 25 extant odontocetes (toothed whales) and 4 extinct protocetids were visualized using microCT scans. The resonant frequencies of their semicircular canals, calculated using an open-pipe approximation, were found to range from 75–265 kHz depending on animal size. The estimated resonant frequencies of the canals, had they been of an allometrically appropriate match to animal mass, ranged from 25–132 kHz. These resonant frequencies overlap almost completely with the vocalization frequency of the species examined and could have caused undesired vestibular sensations during vocalizations. Acoustic resonances of the canals of cetaceans may explain their reduced semicircular canal size.

A6-5

Vestibular evoked myogenic potentials divers

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Introduction: Otolith function, which is dependent on linear velocity and acceleration, may be expected to change in underwater divers, who are submerged in a medium that is denser than air. The purpose of the present study was to examine possible changes in the sacculocollic reflex of professional divers, and to investigate whether there might be diving-induced adaptation of the saccular response.

Methods: We used the vestibular evoked myogenic potential (VEMP) response to evaluate saccular function in 12 professional divers shortly after a dive and after an interval of at least 24 hours. The control group consisted of 12 matched non-divers. Wave latencies and amplitudes, asymmetry ratio and the response threshold were compared between the groups.

Results: Statistically significant shortening of N23-wave latency was found in the divers compared with the control group. The Mean $+$ standard error were $22+0.1$ and $22.1+0.7$ milliseconds early and late after a dive in the divers group vs. $24.5+0.5$ milliseconds in the control group. No significant differences were found in any of the VEMP parameters between the early and late post-dive recordings.

Conclusions: We suggest that the reduction in N23 latency reflects long-term adaptation of the sacculocollic reflex to underwater conditions. Increased sensitivity of the reflex is required to compensate for the decrease in linear velocity and acceleration resulting in reduced stimulation of the otolith organ.

A6-6

Whale vestibular morphology and sea sickness

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The inner ear is the part of the ear where forces of the environment are transduced into electrical signals, used by the central nervous system for computation that base body orientation, posture and movement.

The vestibular part of the inner ear is of special interest regarding sea sickness, as observation has shown that if you do not have functional inner ear, you won't become sea sick. In a motion rich environment as at sea, both inner ears are equally stimulated, giving the brain the sensation of this extensive movement. At the same time the eyes and proprioception are signalling almost motionless environment. This conflict of sensory information conveyed to the central nervous system for computation, generates efferent autonomic link that is responsible for most of the disturbing symptoms a person feels during motion sickness.

As a healthy inner ear is required, one can say that motion sickness and seasickness are symptoms of a healthy individual finding himself in an unhealthy environment. The most frequent report of those swimming across The Canal is that the most difficult thing about it is not the actual enduring of the swim itself, but more the burden of seasickness.

In the same sense one can argue that aquatic mammals must also suffer from seasickness. Therefore it has been interesting to look into the inner ear of whales

and try to find out how they have compensated through evolution against sea sickness.
We looked at fin whales inner ears and found out, that the vestibular part of the inner ear, i.e. the semicircular canals as well as utriculus and sacculus which are the main gravity detecting receptors of the inner ear have diminished. This corresponds with the fact that people that find themselves in water, do not detect gravity, even though gravity exists in water, it is more the pressure against the skin that gives information about the depth. These receptors have certainly caused the ancient aquatic mammals to be seasick and therefore the central nervous system has reduced the liability of this information and kept it aside and that is probably the cause of the fact that they have atrophied.

Oral Session A7 – Classification

A7-1

Validation of a clinical syndrome of persistent dizziness and unsteadiness

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Background: A clinical syndrome of chronic, non-vertiginous dizziness has been described in the neurotologic literature for a quarter century. First defined as phobic postural vertigo (PPV) in 1985, refinements including somatoform dizziness and chronic subjective dizziness (CSD) have since been published. The key feature of these syndromes is persistent or fluctuating dizziness or unsteadiness in the absence of active vestibular deficits. Associated features, which vary among definitions, include hypersensitivity to motion of (a) self or (b) surrounding objects, (c) increased symptoms in visually complex environments, (d) difficulty tolerating precision visual tasks, (e) mild anxiety or depression, and (f) obsessive compulsive personality traits. Despite reports that this syndrome, in its various guises, is the second most common problem in tertiary balance centers, it has not been validated and is infrequently considered in general neurotologic practice.

Objectives: 1) To validate the existence of a distinct clinical syndrome of persistent dizziness and unsteadiness, and 2) to identify its key components by testing sensitivities and specificities of diagnostic criteria described by various authors.

Methods: We chose CSD as a marker for this syndrome. CSD is defined by persistent dizziness, no active vestibular deficits, and two of (a)-(d) above. We retrospectively reviewed medical records of 600 consecutive patients referred to our tertiary medical center with vertigo, unsteadiness, or dizziness from April 2008 through July 2009 to identify patients with CSD and three comparison illnesses, Ménière's disease, benign paroxysmal positional vertigo (BPPV), and migrainous vertigo (MV). All patients underwent comprehensive neurotologic examinations, vestibular testing, audiometric assessments, neuroimaging, and screening for anxiety and depression using the Hospital Anxiety and Depression Scale (HADS). We extracted predetermined demographic, historical, examination, and vestibular laboratory variables from the record and verified diagnoses by consensus conference. Patients whose records clearly reflected one of the study diagnoses formed the final cohort. Data analysis proceeded in three steps: (1) univariate differences between the CSD group and others identified potentially discriminating variables, (2) sensitivities and specificities of these variables suggested promising diagnostic criteria, and (3) a receiver operating curve (ROC) revealed the best combination of diagnostic criteria to define a distinct syndrome. The ROC was constructed first using subjects with just one diagnosis to avoid co-morbidity confounds, then again with all subjects to test diagnostic robustness.

Results: The final study cohort contained 93 subjects with CSD, 53 with Ménière's disease, 112 with BPPV, and 65 with MV. Approximately 30% of patients in each group had more than one diagnosis. Demographic variables were poor discriminators. Sensitivities and specificities of symptoms significant in the univariate analysis were chronic dizziness (73%, 73%), chronic unsteadiness (90%, 70%), absence of active vertigo (89%, 76%), hypersensitivity to environmental motion (100%, 66%), and difficulties with visual complexity (100%, 86%). The ROC showed that chronic unsteadiness or dizziness, absent vertigo, and difficulty with visual complexity formed the best set of diagnostic criteria in subjects with one diagnosis (100%, 89%) and in the full cohort (94%, 89%). Subjects with CSD had higher mean HADS scores, but positive HADS rates exceeded 30% in all groups, consistent with known psychiatric co-morbidity in neurotologic illnesses; thus, sensitivities and specificities of anxiety and depression were modest. The presence of active vestibular deficits did not necessarily exclude subjects from the ROC-defined syndrome, but identified

co-existing conditions. Rates of minor abnormalities on exam or testing did not differ across groups.

Conclusions: These results validate the existence of a clinical syndrome of persistent dizziness, unsteadiness, and difficulty with visually complex environments, distinct from episodic vertigo. Several features of previously published definitions were not essential, including the presence of psychiatric morbidity or absence of active vestibular deficits, which instead identified co-existing illnesses.

A7-2

Proposed multi-layer structure for the international classification of vestibular disorders

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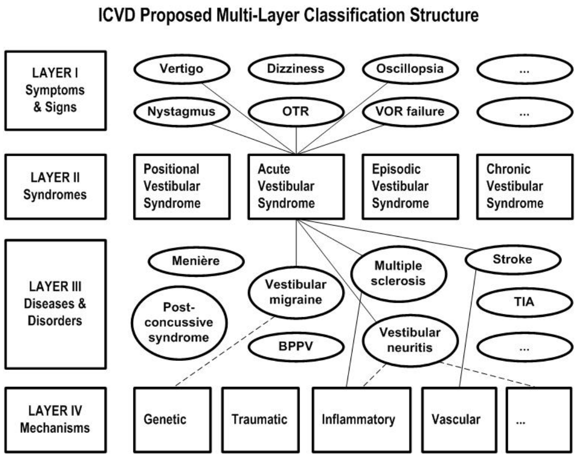
Objectives: Progress in vestibular research has been hampered by a lack of standardization in clinical terminology and inadequate or inconsistent definitions for most vestibular disorders. As part of a broad-based effort to develop a comprehensive classification document, the International Classification of Vestibular Disorders (ICVD), we sought to develop a conceptual structure for the classification system.

Methods: The Committee for the Classification of Vestibular Disorders of the Bárány Society was formed in 2006 to begin developing formalized classification criteria for vestibular disorders to help support standardization for research and clinical purposes. A small working group began by first developing expert consensus definitions for vestibular symptoms, published in 2009. As the committee's efforts have expanded, specific, multi-disciplinary, internationally-representative working groups have been tasked with developing criteria for particular disorders or diseases. One of these working groups was tasked with developing an overall conceptual structure for the ICVD. The group began by reviewing available, analogous classification systems, such as those related to psychiatric and headache disorders. These were discussed and a draft document for ICVD structure circulated among working group members regarding a proposed structure. The results are presented here in abstract form to facilitate discussion in a more open forum at the Bárány Society meeting.

Results: In order to address the need to classify and define vestibular conditions which currently exist at different levels of scientific understanding, the group proposes a multi-layered structure for the ICVD. This includes the following layers: (I) Symptoms and Signs; (II) Syndromes; (III) Diseases and Disorders; (IV) Mechanisms. Layer I, Symptoms and Signs, will seek to develop and publish consensus definitions for vestibular symptoms (e.g., vertigo, dizziness) and signs (e.g., benign paroxysmal positional nystagmus, ocular tilt reaction) pertinent to the assessment of patients with vestibular disorders and forming the foundation for subsequent syndromic or disease definitions. Layer II, Syndromes, offers an intermediate layer of syndromic classification that links constellations of symptoms and signs (e.g., vertigo, nausea, vomiting, head motion intolerance, gait unsteadiness, and nystagmus in the "acute vestibular syndrome") with underlying causes (e.g., vestibular neuritis or acute cerebellar infarction). We propose to begin with four specific syndromes that comprise the bulk of all vestibular presentations: (1) Positional Vestibular Syndrome (e.g., due to benign paroxysmal positional vertigo [BPPV], central positional syndromes); (2) Acute Vestibular Syndrome (e.g., due to vestibular neuritis or acute stroke); (3) Episodic Vestibular Syndrome (e.g., due to Meni ère disease, vestibular migraine, or transient ischemic attack); (4) Chronic Vestibular Syndrome (e.g., due to bilateral vestibular failure or cerebellar degeneration). This layer will allow for standardized inclusion criteria for research studies focused on accurate diagnosis. Layer III, Diseases and Disorders will include diagnostic criteria for important vestibular disorders, as well as links to syndromic and mechanistic layers of the classification. This layer will allow for standardized diagnostic criteria for research studies focused on prognosis or treatment. Layer IV, Mechanisms, will initially be populated with well-defined etiologies that link to multiple vestibular disorders. For example, "trauma" will link back to a mix of disorders including unilateral or bilateral acute vestibulopathy (e.g., associated with skull fracture or iatrogenic surgical neurectomy), post-traumatic BPPV, and dizziness associated with the post-concussive syndrome. This layer will eventually grow to encompass genetic and other mechanisms discovered in the future, and will help support the development of prevention strategies or mechanistically-oriented treatments.

Conclusions: The ICVD will require a conceptual structure that supports ongoing scientific inquiry into diagnosis, prognosis, treatment, and etiologic/mechanistic understanding of vestibular disorders, now and into the future. A multi-layer system for classification could provide such a platform.



Shown are convergent and divergent links for AVS

A7-3

Acute vestibular syndrome – systematic review of bedside diagnostic predictors of stroke

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Objectives: To offer an evidence-based approach to diagnosis of patients presenting with the acute vestibular syndrome (AVS), defined as new and persistent ($>$ 24 hours) dizziness/vertigo, nausea/vomiting, head-motion intolerance, gait instability, and nystagmus. An estimated 250,000–500,000 patients present with AVS to US emergency departments annually. Most such patients suffer from vestibular neuritis (VN), but a subset ($\sim$ 25 $\pm$ 15%) harbor posterior fossa ischemic strokes. We hypothesized that bedside oculomotor exam findings would be the strongest predictors of final diagnosis and that they could distinguish between benign peripheral causes of AVS (P-AVS) and dangerous central causes of AVS (C-AVS) with high accuracy.

Methods: Systematic review of observational studies. We searched MEDLINE for English-language studies (through 12/2009) reporting clinical features, diagnostic evaluation, and differential diagnosis of AVS. Two independent reviewers determined inclusion. Research methods and diagnostic data were abstracted. Studies were rated on methodological quality. Differences were resolved by consensus.

Results: We identified 779 unique citations, of which 15 articles reported details from 10 prospective or retrospective observational studies meeting our inclusion criteria and whose diagnostic reference standard for ruling in or ruling out stroke was rated adequate or superior. We identified no prior systematic reviews or meta-analyses. Included studies reported on both C-AVS and P-AVS ($n = 3$) or on C-AVS only ($n = 7$), and the total number of subjects studied was 392 (P-AVS n = 82; C-AVS n = 310). Studies were of modest quality, and most reported incomplete data on diagnostic accuracy. Obvious general neurologic symptoms and signs in AVS were found to be specific (100%) but insensitive (42%) predictors of stroke in the most unbiased study identified by the review. Three bedside oculomotor exam techniques (horizontal head impulse test [h-HIT], direction-changing horizontal nystagmus, and skew deviation) were found to be strong predictors of C-AVS. While the overall diagnostic sensitivity (85%) and specificity (95%) of a normal h-HIT in AVS patients for predicting stroke was high, its sensitivity varied widely across two prospectively defined subgroups"' those with posterior inferior cerebellar artery (PICA) stroke and those with anterior inferior cerebellar artery (AICA) stroke (sensitivity 99% vs. 62%, $p < 0.001$). Direction-changing nystagmus (sensitivity 38%; specificity 92%) and skew deviation (sensitivity 30%, specificity 98%), when present, were insensitive but specific predictors of C-AVS that complemented the h-HIT in predicting stroke. Finding any one of the three signs (normal h-HIT, direction-changing nystagmus, or skew deviation) in an AVS patient predicted C-AVS with a pooled sensitivity of 98% and specificity of 85%. The estimated negative likelihood ratio (NLR) was 0.02 (95% CI 0.01–0.09), indicating greater "stroke rule out power" for the bedside eye signs than acute brain MRI with diffusion-weighted imaging (DWI) (NLR 0.21, 95% CI 0.16–0.26). MRI with DWI was found to be falsely negative in 12% in the first 48 hours in the one study that used repeat MRI with DWI as the reference standard for a stroke diagnosis.

Conclusions: Most AVS patients have VN (P-AVS) or ischemic stroke (C-AVS). Best evidence suggests that more than half of AVS stroke patients present without obvious general neurological signs. Relying on the h-HIT as a sole predictor of VN (abnormal h-HIT) versus stroke (normal h-HIT) identifies PICA infarcts but misses many AICA infarcts. In the absence of focal neurological signs, a 3-component bedside oculomotor examination, comprising the horizontal Head-Impulse test, evaluation for Nystagmus, and the Test of Skew (H.I.N.T.S.) can rule out stroke with high accuracy that appears to exceed that of urgent MRI. Negative MRI with diffusion-weighted imaging (DWI) obtained in the first 48 hours after symptom onset should not be considered definitive in the presence of any dangerous "H.I.N.T.S." or a high baseline risk for a vascular cause of AVS.

Oral Session A8 – Vestibular Physiology

A8-1

Electrophysiological and immunohistochemical changes in the vestibular nuclear activity following acute hypotension in rats

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Decreased blood flow to the vestibular system causes nausea, dizziness, and other autonomic symptoms. We investigated the pathophysiological mechanism of hypotension-induced dizziness in this study. Vestibular nuclear activities were measured by electrolphysiological and immunohistochemical methods following acute hypotension induced by either hemorrhage or injection of sodium nitroprusside in rats.

Acute hypotension produced excitation of electrical activity in 2/3 of type I neurons and inhibition in 2/3 of type II neurons recorded in the medial vestibular nuclei (MVN). In unilateral labyrinthectomy (UL), 2/3 of type I neurons ipsilateral to the lesion showed an inhibitiory response, and 2/3 of contralateral type I neurons showed an excitatory response following acute hypotension. The response patterns of type II neurons were opposite to those of type I neurons.

c-Fos proteins were expressed selectively in the central area of MVN following a 10% reduction in blood pressure. Blood pressure had fallen by 30%, bilateral expression of c-Fos protein was observed in the superior vestibular nuclei (SVN), MVN, and inferior vestibular nuclei (IVN), but not in the lateral vestibular nuclei (LVN). The expression of c-Fos protein increased proportionately with reductions in blood pressure. In UL, acute hypotension induced the expression of c-Fos protein in the contralateral vestibular nuclei to the lesion, but not in the ipsilateral vestibular nuclei. c-Fos proteins were not expressed in the bilateral vestibular nuclei following acute hypotension in bilateral labyrinthectomy (BL). Expression of phosphorylated form of extracellular signal-regulated kinase 1/2 (pERK1/2), which is one of the major regulatory factors for transcription of the c-fos oncogene in neurons, significantly increased bilaterally in the caudal aspect of MVN and IVN. No labeling of pERK1/2 was observed in LVN. The peak expression of pERK1/2 in these nuclei occurred within 5 min after acute hypotension. In BL, the expression disappeared in the vestibular nuclei. Acute hypotension increased expression of pGluR1 of glutamate AMPA receptor and pNR2B of glutamate NMDA receptor in the MVN. Expression of pGluR1 Ser831 and Ser845 peaked at 5 and 30 min after acute hypotension and expression of pNR2B peaked at 60 min after acute hypotension, respectively. In BL, expression of pGluR1 Ser831, pGluR1 Ser845, and pNR2B was decreased significantly compared to intact labyrinthine animals following acute hypotension.

In microdialysis, glutamate release increased, though gamma aminobutyric acid (GABA) and taurine release decreased in the MVN following acute hypotension. In UL, the levels of glutamate, GABA, and taurine were unchanged in the ipsilateral MVN to the lesion, but glutamate release increased and GABA and taurine release decreased in the contralateral MVN following acute hypotension.

These results suggest that acute hypotension can influence the activity of neurons in the vestibular nuclei through the afferent signals from the peripheral vestibular receptors, and that glutamate, GABA, and taurine in the MVN are involved in this process. (Supported by the Converging Research Center Program through the National Research Foundation of Korea (2009–0082289).

A8-2

Effects of tinnitus induced by acoustic trauma on performance in a spatial forced alternating T maze task

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Acoustic trauma has recently been reported to affect place cell activity in the hippocampus (Goble, Moller and Thompson, Hear. Res., 253 (2009) 52–59), which is thought to be involved in the encoding of spatial memories. We therefore hypothesized that acoustic trauma that induces tinnitus might affect performance in a spatial memory task. Eight male Wistar rats were exposed to unilateral acoustic trauma (105 dB, 16 kHz for 1 h under anaesthesia) and 8 rats underwent the same anesthesia without acoustic trauma. ABRs confirmed a clear elevation in the hearing thresholds in the noise-exposed ears. The animals were then tested for the presence of tinnitus using a frequency discrimination paradigm in a computer-controlled conditioned lick suppression task at 2 weeks after the noise exposure. The rats were trained to suppress licking using silence (0 dB) as the conditioned stimulus (CS) while challenged with acoustic stimuli that were broad band noise (BBN), or pure tones at 10 kHz and 20 kHz. For each frequency, 4 different stimulus amplitudes were used: i.e., 30, 40, 50 and 70 dB for BBN; 60, 70, 80 and 90 dB for 10 kHz and 70, 80, 90 and 100 dB for 20 kHz. The lick suppression ratio (SR) was used as an outcome measurement. All of the animals established a conditioned lick suppression to the silence (0 dB) and when challenged with the acoustic stimuli, the stimulus resembling the acoustic features of the tinnitus was predicted to produce greater lick suppression, hence, indicate the presence of tinnitus. The SR to stimulus amplitude curve was similar for the sham and noise exposed groups for BBN and 10 kHz. However, at 20 kHz, there was a significant downward shift for the noise exposed group when compared with the sham group, indicating that the noise exposed rats exhibited greater lick suppression when the stimulus was at 20 kHz rather than for BBN or 10 kHz. The greater lick suppression at 20 kHz could only be explained by the assumption that during the presence of the CS (0 dB), a 20 kHz tone must have also been present and served as a CS. Since the acoustic stimulus (BBN, 10 kHz or 20 kHz) was never delivered during the silence (0 dB), the 20 kHz tone that the rat heard must have been an illusory sensation, i.e., tinnitus. Once it was confirmed that tinnitus had been induced, the rats were tested in a spatial forced alternating T maze task. There was no significant difference between groups in the number of days to reach the criterion of 3 consecutive days with at least 7/8 correct responses. The animals were then tested with different inter-trial intervals (ITIs) of 10, 20, 40, 60, 120, 180 s and 10 and 30 min. There was a significant decrease in the percentage of correct responses in the tinnitus group only at the 10 min ITI. These results suggest that tinnitus may induce a mild spatial memory impairment that depends on the time until recall.

A8-3

Responses of rostral vestibular nucleus neurons to low velocity yaw rotation

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Vestibular responses, notably the vestibular-ocular reflex, demonstrate a large linear range in terms of both the frequency content and the amplitude of the stimulus, appropriate for a scaled motor output compensatory to sensory input. For other functions of vestibular sensory information, such as perception and extensor reflexes in response to fall, response linearity is not as important. Thus, central processing of vestibular signals could provide both linear output for the VOR and non-linear signal processing for other vestibular functions. The dynamic range of neuronal responses is limited by saturation and silencing of firing at higher stimulus amplitudes and by overcoming signal to noise issues at low levels of stimulation. We have previously shown that in the low and middle frequency range (0.1 to 2 Hz) of yaw rotation, non-eye movement sensitive vestibular neurons do not respond linearly to increasing stimulus amplitudes ranging between 30 and 210 degrees/sec (Newlands et al., J. Neurophysiology 102: 1388–97, 2009). Open questions remain about whether there is a lower range of amplitudes where linearity of the response to yaw stimulation is seen, what the threshold for central detection of vestibular input is, and whether neurons with eye movement sensitivity (Eye-Head velocity (EHV) cells and Position-Vestibular-Pause (PVP) cells) are different from the non-eye movement neuron cells.

To answer these questions, we examined the responses of neurons in the rostral vestibular nuclei to sinusoidal yaw stimulation at frequencies between 0.2 and 1 Hz and peak velocities of 2.5 and 80 degrees/sec. The neurons were classified as to their eye movement sensitivity during saccadic eye movements to targets and smooth pursuit of a moving target. Data was analyzed off line. The spike train was converted to a continuous instantaneous firing rate by passing the train through an appropriate Kaiser window filter. Sensitivity to yaw rotation was calculated after collecting and averaging multiple cycles of data and fitting the averaged stimulus and response with sine waves while either suppressing the VOR by having the animal foveate a target moving with the animal (VOR suppression) or by mathematically removing the effect of eye position and eye velocity for eye movement sensitive cells. The effect of amplitude and frequency of stimulation on the sensitivity of neurons was investigated across the population of recorded neurons.

All neurons studied were sensitive to yaw stimulation down to 2.5 degrees/sec peak amplitude at frequencies of 0.2, 0.5 and 1 Hz. This was true for both eye movement and non-eye movement sensitive neurons. The sensitivity of the neurons decreased with increasing peak amplitude of stimulation. Eye movement sensitive cells (both EHV and PVP cells) showed similar results to non-eye movement neurons.

Central vestibular neurons are more sensitive at low stimulation amplitudes than at higher stimulation amplitudes. It is likely that the difference in sensitivity based on stimulation amplitude extends the dynamic range of the neurons by overcoming signal to noise issues at near threshold stimulation while allowing higher signal amplitudes to be encoded with reduced saturation and rectification effects. Processes that require linear outputs (the VOR for example) may rely on neural processing mechanisms to restore linearity from nonlinear elements.

A8-4

Pulsed infrared radiation rapidly modulates hair cell neurotransmitter release

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Introduction: Pulsed infrared radiation (IR) has recently been shown to evoke action potentials in peripheral nerve axons and to excite 8th nerve spiral ganglion cells. The objective of the present study was to evaluate the efficacy of pulsed IR to evoke neurotransmitter release from vestibular hair cells, and thereby modulate the discharge rate of primary afferent neurons.

Methods: Optical stimulation of semicircular canal hair cells was achieved in vivo using a fiber-optic coupled pulsed IR laser (1862 nm, Capella, Lockheed-Martin Aculight). The oyster toadfish, Opsanus tau, was used as the experimental model to facilitate the approach. A small craniotomy was made lateral to the dorsal course of the anterior semicircular canal, into the perilymphatic space, to expose the lateral canal ampulla and nerve branch. Trains of IR pulses, 250 and 750 μs each, were delivered to the sensory epithelium at repetition rates between 1 and 200 pulses per second (pps). Laser output was delivered using a 400 μm diameter low-OH optical fiber (Ocean Optics), polished and positioned in contact with the apex of the membranous ampulla. This placed the IR source approximately 300 μm above the apical surface of the sensory epithelium. Single unit afferent nerve action potentials were recorded in response to pulsed IR stimulation of presynaptic hair cells and to simulated angular velocity stimuli.

Results: Pulsed IR irradiation of hair cells evoked dramatic changes in the discharge rate and phase locking of semicircular canal primary afferent neurons. For tonic pulse trains, some afferent units increased their discharge rate while other unit decreased discharge rate. Regularity of discharge increased during IR stimulation. In a subset of afferents, a single action potential was evoked for each IR pulse for stimulus frequencies up to nearly 100 Hz. The time latency from the onset of the IR pulse to the afferent phase-locked action potential was $\sim$ 7.6 ms. Results show that pulsed IR radiation of hair cells modulates hair cell neurotransmitter release and that this leads to modulation of afferent discharge rates. Preliminary calcium imaging experiments indicate that pulsed IR evokes rapid increases in intracellular calcium and that this signaling underlies changes in synaptic transmission reported here.

Conclusion: Our results show that modest doses of long wavelength ($\sim$ 1860 nm) pulsed infrared radiation (IR) causes inner-ear hair cells to rapidly change their rate of neurotransmitter release, which dramatically alters the discharge rate of afferent neurons. Many afferents phase lock to the stimulus and fire an action potential for each IR pulse. This allows IR stimuli to be used to control the timing and rate of action potentials transmitted by the 8th nerve to the brain. The response is robust and involves a yet unidentified mechanism of IR triggered transient increases in intracellular calcium. IR calcium photorelease might be particularly relevant to the future development of neural prostheses or other therapeutic interventions.

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A8-5

Membrane proteins define microdomains in the vestibular afferent calyx

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The vestibular calyx ending performs at least two very different functions, receiving input on its inner surface from ribbon synapses, and generating an action potential at the heminode that is transmitted to the brain. Until recently, this afferent terminal was considered to be rather homogenous in membrane composition. With confocal and EM immunogold studies, we have found that the calyx ending consists of different membrane domains, each marked by a set of cell adhesion proteins, scaffolding proteins, and voltage-gated ion channels. The domains consist of: 1) a synaptic zone, 2) an apical zone adjacent to the striated organelle, and 3) an initial segment zone leading up to, 4) a heminode. Furthermore, calyx endings in dimorphic and calyx afferents can be distinguished immunohistochemically by subsets of voltage-gated channels, by differences in the distribution of these channels within the calyx and within the sensory epithelium, and by the locations and sizes of their heminodes. This talk will present further evidence for membrane ionic channel composition in the calyx ending contributing to these diverse functions in vestibular afferents.

A8-6

Asymmetry in vestibular responses to cross-coupled stimulus

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Objectives: The cross-coupled stimulus (CCS) to the vestibular system is created any time a head rotation is performed while rotating about another axis. Asymmetric CCS responses to different rotational directions have been previously noted and are widely acknowledged, yet remain poorly understood. In previous studies we have shown that head turns performed while supine on a rotating centrifuge are more intense going from a right-ear-down to nose-up position than in the reciprocal direction. The objective of this study was twofold: 1) to correctly describe the asymmetries in responses to different configurations of CCS stimulation, and 2) to test two previously proposed hypotheses for explaining the asymmetries, dominant direction and dominant end position. Methods: The CCS was developed by having subjects perform four types of 60-degree yaw head turns while lying either supine or prone on a horizontally rotating centrifuge turning either clockwise or counter-clockwise. Three experimental conditions were tested: clockwise supine ($n = 33$); counterclockwise supine ($n = 10$); and clockwise prone ($n = 10$). In all three conditions subjects performed six repetitions of all 4 head turn types. Subjective tumbling intensity, tumbling duration, and motion sickness scores were recorded for each head turn. Results: Based on the tumbling intensity, head turns to the left are dominant during clockwise supine centrifugation ($p < 0.0001$) and head turns to the right are dominant during counterclockwise supine centrifugation ($p = 0.0020$), conforming to what is expected from previous studies. For prone centrifugation, however, head turns to the left are more intense than head turns to the right ($p = 0.0078$), which does not fit with the previously proposed dominant direction hypothesis. Similar trends are observed in the subjective tumbling duration data, although the comparisons were not significant at the 0.05 level. Conclusion: The dominant direction hypothesis is refuted based on the results from prone centrifugation. There seems to be a dominant end position effect, although this is small in magnitude and cannot by itself explain the CCS asymmetries. An alternative internal model hypothesis is proposed that matches the data from all three experiments.
This work was supported by the National Space Biomedical Research Institute NASA NCC 9-58.

A8-7

Achiasmatic zebrafish as a behavioral model for infantile nystagmus syndrome (INS)

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Infantile nystagmus syndrome (INS) is a human ocular motor disorder that is characterized by involuntary con-

jugate, mostly horizontal uniplanar oscillations of both eyes, present at birth or shortly after. INS is associated with substantial visual impairments that often lead to reduced occupational and social functioning. Thus far, the etiology of INS is poorly understood. The study of INS has been largely confined to humans and few other higher vertebrates, making it very difficult to track down the origin and the underlying neuronal processing of INS. Recently, we discovered that achiasmatic zebrafish belladonna (bel) mutants display spontaneous oscillations of the eyes that closely resemble INS in humans. In sum, bel mutants show an array of behaviors that closely mimic INS in humans: ocular motor instabilities (reserved optokinetic response, OKR, and spontaneous eye oscillations) and postural instabilities (unstable swimming behavior, described as looping). All these unstable behaviors have been linked to the underlying optic nerve projection defect, are vision-dependent, and are not due to a vestibular deficiency The waveform characteristics of the spontaneous oscillations in zebrafish bel mutants possess variability comparable to those in human INS. We found instances of all waveform classes pertaining to human INS. Despite their qualitative similarity, spontaneous oscillation and human INS waveforms differ in quantitative aspects: Whereas mean frequency and peak slow phase velocity were much higher in humans, the amplitude of spontaneous oscillations in zebrafish substantially exceeded that of human INS. Our detailed analysis revealed that the spontaneous oscillations in zebrafish bel mutants are, albeit quantitatively different, essentially identical to human INS with respect to their waveforms. Thus, the achiasmatic zebrafish bel mutant is a very promising model for human INS due to not only the behavioral similarity, but also the inexpensiveness and accessibility. And, as such, it may help advance our understanding of human INS and potentially lead to new treatment algorithms.

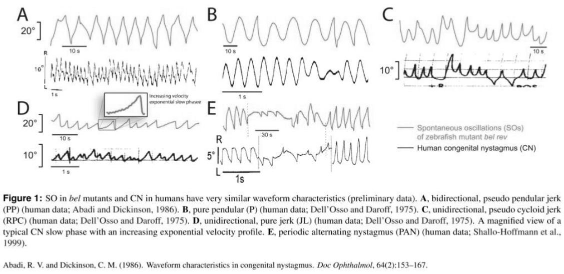

Figure 1: SO in *bel* mutants and CN in humans have very similar waveform characteristics (preliminary data). **A**, bidirectional, pseudo pendular jerk (PP) (human data; Abadi and Dickinson, 1986). **B**, pure pendular (P) (human data; Dell'Osso and Daroff, 1975). **C**, unidirectional, pseudo cycloid jerk (RPC) (human data; Dell'Osso and Daroff, 1975). **D**, unidirectional, pure jerk (JL) (human data; Dell'Osso and Daroff, 1975). A magnified view of a typical CN slow phase with an increasing exponential velocity profile. **E**, periodic alternating nystagmus (PAN) (human data; Shallo-Hoffmann et al., 1999).

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A8-8

The use of ocular counterroll and horizontal nystagmus patterns in trapezoidal eccentric rotation as indicators of canal and utricular function.

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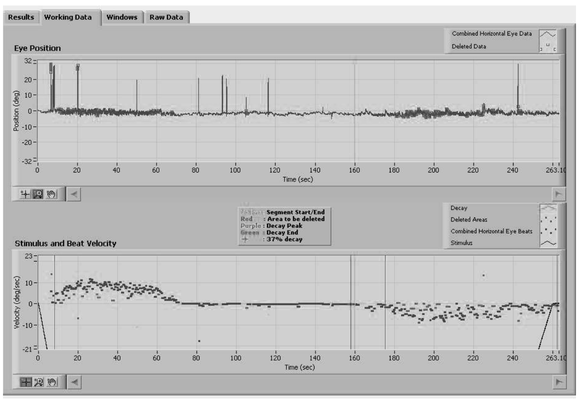
Historically, the examination of utricular function has proven to be challenging. Modern equipment and techniques have improved the clinical ability to assess this vestibular organ. Among the most useful clinical tools is eccentric rotation. By rotating an individual at a small distance off of the central axis of rotation, the examination of individual utricles is possible (Clarke et al., 1996). The stimulus parameters used for eccentric rotation typically include lateral translations during high frequency rotations or eccentric placement of a patient prior to delivering sinusoidal stimuli. The primary measurement tool is often the estimation of subjective visual vertical (Böhmer and Mast, 1999; Gresty and Bronstein, 1986) or assessments of vestibulo-ocular or otolith-ocular reflexes.
The purpose of this presentation is to describe the ocular movements that were exhibited by individuals with normal vestibular function during sustained trapezoidal eccentric rotation. Ten adults (5 female, 5 male) between the ages of 23 and 44 years (mean = 25.7, SD = 6.61) with no history of vestibular or neurologic disorders underwent eccentric trapezoidal rotations. Testing was performed on a Neuro-Kinetics, Inc. (Pittsburgh, PA USA) Neuro-Otologic Test Center (NOTC) rotational chair at the Vestibular Clinic at Bloomsburg University of Pennsylvania (PA, USA). Participants underwent 4 cm eccentric rotations at both the right and left positions. The rotational stimuli involved an acceleration of 5°/s2 over 60 seconds until a maximum velocity of 300°/s was achieved. Rotation at maximum velocity was maintained for 100 seconds followed by a deceleration of 3°/s2 over 100 seconds. The horizontal and torsional components of the participants' eye movements were recorded using infrared oculographic techniques.
Eccentric rotations in a trapezoidal paradigm elicited both horizontal and torsional eye movements for all participants under all stimulus parameters. The torsional measurement of position revealed an increase in ocular counterroll that corresponded to the acceleration of the chair; however, the counterroll reached a maximum rotation of 2–5° at approximately 20 seconds

after onset of rotation. The ocular counterroll position remained approximately the same during eccentric rotation at maximum velocity (100 seconds) and then decreased to the initial ocular position during deceleration. However, ocular counterroll velocity (which increased to its maximum value within 20 seconds) decreased to zero in 6 to 15 seconds after achieving maximum rotational velocity. The rolling motion of the eye would then reverse during the deceleration phase of the stimulus. A similar pattern was shown by the horizontal components of the eye movements.

These findings can be used to develop a novel method of assessing ocular counterroll and horizontal nystagmus in the trapezoidal eccentric rotations. The plateau in ocular counterroll velocity achieved during the acceleration phase of the stimulus demonstrates a possible saturation point in the responsiveness of the utricle. In addition, this timing pattern can lead to the development of time constants for utricular function. Further examination of the pattern exhibited by the horizontal nystagmus is underway. Additional subjects are currently undergoing testing.



Torsion position & velocity plots

A8-9

Dynamic posturography: the clinical value in the diagnosis of patients with acute vertigo

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Objective: To explore the clinical value of dynamic posturography in the diagnosis and differential diagnosis of acute vertigo.

Methods: 200 acute vertigo patients with full clinical documents in vertigo clinic of our hospital from May 2007 to May 2008 were retrospectively analyzed in this study. All the patients firstly underwent the inspection of static and dynamic posturography, and then, were subjected to caloric test. Surface of the statokinesigram (SSKG) was selected as assessment parameter of static posturography. The vestibular, somesthetic, and visual scores of sensory organization test (SOT) were selected as assessment parameters of dynamic posturography. Twenty healthy subjects were selected as a control.

Results: Of the 200 patients with vertigo, 160 cases were diagnosed as peripheral vertigo, whereas, 40 cases were central vertigo. Among the 160 cases with peripheral vertigo, the abnormal rate of dynamic posturography, caloric test and static posturography were 90.0%, 68.8% and 47.5% respectively. There existed a statistically significant difference between dynamic posturography and caloric test or static posturography. Of the 40 cases with central vertigo, 23 cases were abnormal in vestibular score of SOT, accounting for 57.5%, which was much lower than that in the peripheral vertigo. The somesthetic and vestibular scores were both abnormal in 16 cases of central vertigo (40.0%) and was significantly higher than that in peripheral vertigo (15.0). There was no statistically significant difference in the visual scores of dynamic posturography between central vertigo and peripheral vertigo. Among the 20 cases of healthy subjects, results of dynamic posturography were abnormal in only one case, with a specificity of 95%.

Conclusions: There was a higher rate of sensitivity in dynamic posturography than caloric test in diagnosis of acute vertigo. Dynamic posturography helps to confirm the presence of abnormalities in selected patients with peripheral vertigo whose caloric tests are normal. There were some different characteristics of the results of dynamic posturography between peripheral and central vertigo, suggesting that dynamic posturography is a complementary test aiding in the differential diagnosis of peripheral and central vertigo.

A8-10

A new vestibular evoked potential occurring 6 msec after stimulus onset with air-conducted tone auditory stimuli

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Objective: It is now known that sound of the right intensity and frequency can stimulate the vestibular end organs, allowing us an alternative way of obtaining vestibular evoked potentials. Myogenic vestibular evoked responses, with recording mainly from the sternocleidomastoid muscle (SCM) and from the inferior oblique muscle, has been recorded up to now with this stimulus. Neurogenic vestibular evoked potentials that are recorded from the scalp and are electrographic rather than myogenic in origin, have so far been recorded in the form of N3 (click air-conducted), N5 (tone air-conducted), and P10 (bone-conducted stimulus) waveforms. The purpose of this study is to find other neurogenic vestibular waveforms obtained with air-conducted sound.
Methods: The experiments were organized into four parts: (A) Topographical scalp mapping, (B) determining the consistency in appearance of candidate vestibular waveforms, (C) further characteristics such as their (i) relationship to vestibular evoked myogenic potentials (VEMP), (ii) sensitivity to 5 kHz tone, (iii) threshold of activation, and (D) recording of the new vestibular waveforms in a case of hearing loss.
Results: A montage was discovered, O2-P3 and O1-P4 with left and right ear stimulation respectively that yielded a negative wave at 6 msec after stimulus onset and was labeled N6. It is not a VEMP, disappears with 5 kHz tone stimuli, has a high threshold of stimulation and is present in a case of hearing loss.
Conclusion: A new vestibular waveform is discovered that probably originates at or near the midbrain based on its latency. Together with the previously mentioned waves, lesions along the vestibular pathway can now be localized further.

Oral Session B1 – Vestibular Loss

B1-1
Horizontal conjugate gaze (h-CGD) in the acute vestibular syndrome

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Objective: To measure the frequency and diagnostic significance of upright and supine horizontal conjugate gaze deviation (h-CGD) in the acute vestibular syndrome (AVS).

Background: Under normal distance viewing conditions in an awake, healthy patient, the globes rest just nasal to the orbital midposition with the visual axes of the two eyes nearly parallel. With eyes closed, the eyes may drift apart slightly due to lack of visual input facilitating binocular fusion, but, in a healthy individual without strabismus, the globes remain close to the orbital midposition. h-CGD may occur in various pathologic states that create a right-left bias in sensory inputs to the oculomotor system or its motor outputs. Vestibular neuritis (VN) causes an acute, asymmetric loss of vestibular function that often mimicks brainstem or cerebellar stroke, so bedside signs distinguishing the two conditions are clinically useful. Ocular lateropulsion (OL) is h-CGD in the upright position, evident only with visual fixation removed or suppressed. OL is reported as a frequent sign in lateral medullary infarction, but its diagnostic utility for predicting central versus peripheral causes of AVS is unknown. Supine, radiographic h-CGD has been characterized in hemispheric stroke, where it predicts the side of a lesion even when other clinical or radiographic signs are absent. Radiographic h-CGD has not been studied in AVS.
Methods: We assessed neuroimaging evidence of supine h-CGD in 123 patients with AVS defined as acute vertigo/dizziness, nausea/vomiting, head motion intolerance, and gait instability $>$ 24 hours. Radiographic h-CGD was defined as the angle between a line bisecting the lens (zonular/"long axis") in each eye and a line perpendicular to the naso-occipital axis. We compared this to bedside h-CGD assessment with video goggles in seated and supine position in a subset of patients. Final lesion localization was based on MRI plus clinical follow-up for those without radiographic stroke.
Results: Among 123 high-risk AVS presentations, there were 80 ischemic strokes, 30 VN, and 13 other diagnoses. All patients were able to maintain gaze in the primary position with eyes open. Supine, radiographic h-CGD was identified in 38% (n = 47/123)' 57% (n = 17/30) of VN (all ipsilesional) versus 38% of strokes (n = 30/80) (24 ipsilesional, 6 contralesional) (p = 0.08, Fisher's exact). It was found in patients with lateral brainstem, cerebellar, or combined infarction, but absent in those with medial longitudinal fasciculus lesions (n = 11). OL was present in 50% (n = 13/26) of tested stroke patients (7 lateral medullary or lateral medullary/cerebellar, 3 lateral pontine, 3 pure cerebellar) but absent in VN (n = 0/9) (p = 0.006, Fisher's exact).
Discussion: Our study demonstrates that radiographic h-CGD behind closed eyelids in AVS is present in

patients with a peripheral localization (VN) as well as those with a central localization (posterior fossa stroke), in roughly similar proportions. By contrast, clinically-evident OL in the upright position following brief eye closure was found only in those with stroke. This suggests either that only central lesions disrupt the normal modulatory effects of visual fixation on h-CGD; the effects of visual fixation on h-CGD are modified by supine positioning or sustained eye closure; or both. Future studies should seek to distinguish among fixation effects (duration of eye closure), otolithic effects (positioning), or an interaction between the two as a cause for the discrepancy. Radiographic h-CGD in the direction of the nystagmus slow phase offers lateralizing information in the late evaluation of patients with compensated peripheral vestibular lesions. Clinicians routinely include the presence of sustained h-CGD observations in patients as part of the NIH stroke scale evaluation. We propose they consider adding routine assessment of h-CGD after brief or sustained eye closure and by neuroimaging as a means of assessing subclinical right-left asymmetries in gaze position.

B1-2

Dynamic Visual Acuity (DVA) and oscillopsia severity in patients with bilateral vestibular loss

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Introduction: Many patients with bilateral vestibular function loss complain about oscillopsia which might suggest a loss of DVA. The aim of our study was to investigate whether the subjective complaint of oscillopsia can be assesed by quantifying the DVA in patients with bilateral vestibular loss.
Methods: 30 healthy subjects and 30 patients with bilateral caloric areflexia, absent or strongly reduced responses at rotatory tests and pathological 3D head impulse tests were included. Using a chart with CDHKNORSVZ letters, DVA was determined while subjects walked or ran at 2, 4, 6, 8, 10 and 12 km/h on a treadmill. Normative data were obtained by assessing DVA in the healthy population. The Oscillopsia severity in patient's was assessed with a self developed questionnaire and compared with the patients DVA.
Results: All patients could perform the DVA test when treadmill velocity did not exceed 6 km/h. Even at treadmill velocities of 4 and 6 km/h patients with bilateral vestibular loss showed a significantly decreased DVA compared to healthy subjects. DVA and oscillopsia severity were significantly but weakly correlated.
Conclusions: DVA could be quantified using a treadmill in a reproducible way in both healthy subjects and patients with severe vestibular loss and is a discriminative test to expand the assessment of bilateral vestibular function loss. DVA only weakly correlates with the severity of patient's oscillopsia.

B1-3

A clinical test of the vestibulospinal pathways

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Objective: To develop a measure of the vestibulospinal pathways to the trunk and limbs, we recorded the horizontal shear forces, whole-body displacement and velocity evoked by low intensity cathodal galvanic vestibular stimulation (GVS).
Methods: Twelve healthy controls and seven subjects with medium to large vestibular schwannomas were studied as they stood quietly with their eyes closed and feet together. 1mA 2s monaural cathodal galvanic vestibular stimulation pulses were delivered every 30 seconds. Ground-reaction forces were measured on a Kistler Force Platform. The displacement and velocity of markers placed on the occiput, C7, T7 and hips were measured with a CODA mpx 3D motion pick-up system.
Results: In response to a cathodal galvanic pulse, the whole body swayed anterolaterally away from the stimulus. The horizontal force response began at $\sim$ 250 ms after stimulus onset and peaked at $\sim$ 800 ms. Displacement of an infra-red marker placed over C7 began $\sim$ 400 ms and peaked at 2s.
The average magnitude of the ground reaction force (F), measured from 0.2-1s after stimulus onset was 1.11 $\pm$ 0.5 N, 1.06 $\pm$ 0.42 N and 0.40 $\pm$ 0.14 N for stimulation of controls, unaffected ears and the affected ears of patients. The average velocity of whole body displacement (V) measured from 0.2-1s after stimulus onset was 18.1 $\pm$ 8 mm/s, 22.9 $\pm$ 14.8 mm/s and 8.1 $\pm$ 4.8

mm/s for stimulation of controls, unaffected ears and affected ears. The whole body displacement (D) for these 3 groups was 17.5 ± 7.2 mm (controls), 12.6 ± 4.9 mm (unaffected ears) and 7.0 ± 2.0 mm (affected ears) respectively.

Reflex asymmetry ratios (AR) using the Jongkees Formula were 10.8 ± 6.9% (Force), 10.9 ± 6.9% (Velocity) and 7.8 ± 4.7 (Displacement) for healthy controls. In contrast, significantly higher asymmetry ratios were recorded for the schwannoma patients: 43.9 ± 11.7% (Force), 45.6 ± 14.9% (Velocity) and 27.3 ± 13.6% (Displacement). There was no overlap in the AR recorded from patients and controls for ground reaction force measures. Two subjects with schwannoma had ARs for displacement ($n = 2$) or velocity ($n = 1$) that fell within the normal range.

Conclusion: The Force, Velocity and Displacement magnitudes evoked by GVS provide a quantitative and lateralizing measure of the vestibulospinal pathways. GVS offers a safe and technically simple means of measuring vestibulospinal function in subjects presenting with disequilibrium and gait instability.

B1-4

Improved dynamic visual acuity testing to assess peripheral vestibular function

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Objective: Our aim was to improve dynamic visual acuity (DVA) testing by evaluating novel parameters.

Methods: One hundred neuro-otologically healthy subjects (age range, 19–80 years) and 15 patients with bilateral ($n = 5$) or unilateral ($n = 10$) peripheral vestibular loss (age range, 27–72 years) were included. Visual loss (i.e. static visual acuity (SVA)- DVA) during active and passive head rotations and at different head velocities () were compared with each other and with quantitative horizontal head impulse testing (qHIT) with scleral search coils. Additionally, we used an adaptive algorithm for changing the size of the Landolt rings to minimize the number of head impulses.

Results: Passive head impulses were significantly better than active and optotype presentation at head velocities $> 150°$/s was significantly better than $> 100°$/s. Using the better parameters, the DVA test discriminated highly significantly ($p < 0.0005$) between subjects with bilateral vestibulopathy, with unilateral vestibulopathy, and normal subjects. The number of required head impulses could be reduced to 40. DVA test sensitivity was 100%, specificity 94%, and accuracy 95% with search coil head impulse testing used as a reference. In healthy subjects, VA-loss increased significantly with age ($p < 0.0005$, R2 = 0.04).

Conclusions: DVA testing with Landolt rings that are adaptively changed in size enables detection of peripheral vestibular dysfunction in a fast and simple way and the results are comparable to search coil HIT.

B1-5

Postural control, vestibular neuritis, wavelets and fractal analysis

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What is the postural control a few months after a vestibular neuritis (VN)? Using dynamic posturography and stabilometric signal treatment with wavelets and fractal analysis, we tried to answer this question by isolating the pathological postural parameters of VN.

Material and Method: group of 15 patients (GP) suffering from VN was compared to a group of control subjects (GC). Both groups underwent successively a videonystagmography (VNG), a dynamic posturography (PDY), and an assessment using symptomatic scales (ES).

Results: GP and GC were comparable in terms of age mean, sex-ratio, average height and weight. The differences between GP and GC were the videonystagmography criteria such as spontaneous nystagmus (NS) ($P = 0.005$), head shaking test (HST) ($p = 0.001$), vibratory test (TVO) ($p = 0.009$), and also the symptomatic scales scores for the Vertigo Symptom Scale (VSS) ($p = 0.011$), the Dizziness Handicap Inventory (DHI) ($p = 0.001$), and the Short Form 36 (SF36) ($p = 0.01$). All the 84 new parameters of both GP and GC differ. This difference was significant ($p < 0.05$) in 16 cases (19%), and highly significant ($p < 0.01$) in 11 other cases (13%). The condition "unsteady platform" was the greatest discriminant in both groups, the conditions "closed eyes" and "HST" were a little or non-discriminant.

Conclusion: We are showing that VN is the cause of a disruption of the new stabilometric parameters. These are more adapted than the previous parameters to analyse the non-periodic oscillations of the posture and they probably will become increasingly important in the follow-up and rehabilitation of patients.

Oral Session B2 – Head Impulse

B2-1

Etiologic diversity of positive head impulse test in ENT daily practice

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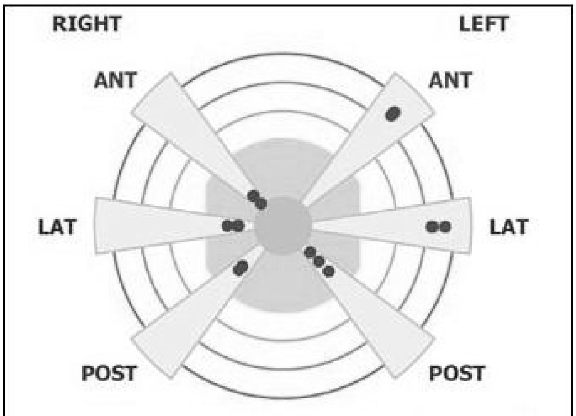
Study objectives: By considering each element of the chain linking the semicircular canal to the eyeball we intend to show, using enough documented clinical cases, the etiological diversity which, for a given canal, can lead to a pathologic Curthoys & Halmagyi's Head Impulse Test (HIT).

Method: To increase the sensitivity of the HIT, instead of considering the Halmagyi's sign i.e. the Catch up saccade we use a device called V-HIT (Video HIT). That device allows measuring the VOR deficit during the fast passive head movement by considering the angular ratio gaze deviation/head rotation. To achieve this goal the V-HIT is composed of a camera recording patient's face, an infrared light source creating a corneal reflection, and a computer monitoring head acceleration in horizontal or vertical direction. Head rotation in a given direction is deduced from grey gradients displacements in patients face images, while gaze deviation is calculated thanks to infrared light reflection coordinates by reference to pupillary centre. Each canal deficit is expressed on line as a percentage in a specific diagram called "canalogram" (see figure). The semicircular canals (SCC) are displayed as a six branch star. Branch orientation is in relation to canal anatomical array. The canalogram represents the patient facing the examiner therefore the patient's right SCC is the left branches of the star. The green zone of the canalogram is the statistical normal zone (35% deficit in horizontal direction, 40% in vertical at 2SD). The dots identify the result of the measurement of the Head Impulse Test. The color of the dot, green or red, indicates the canal deficit to be normal or pathological.

Results: Using the V-HIT in ENT daily practice since 2003, we could observe pathological head Impulse test in a wide variety of etiologies, in spite of the fact that ENT normal recruitment reduces the probability of meeting various central pathologies. Some pathologies belonging to peripheral syndromes may concern the canal itself as well as the VIIIth nerve. But others are purely central, or even may concern the last element of the chain: the eye muscles.

Conclusion: In a standard ENT daily practice pathological head impulse is not synonymous with a peripheral damage, and may also be seen in a wide variety of central syndromes. Clinical data are in fact the most important elements allowing a proper interpretation of the test results.



Canalogram in a left superior neuronitis

B2-2

The video head impulse test: diagnosis of bilateral vestibulopathy after gentamicin vestibulotoxicity

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Background: Systemic antibiotic therapy with gentamicin can occasionally cause bilateral vestibulopathy due to hair cell toxicity. The head impulse test is a safe, quick way to assess vestibular function at the bedside. Until recently quantitative measurement of the test had to be done with the scleral search coil technique which is not practical in seriously ill patients [1].

Methods: We developed a novel non-invasive video head impulse system as a clinical tool for diagnosing peripheral vestibulopathy [2]. The light-weight (60 g) goggles, designed to minimize inertia and slippage, are equipped with a high-speed video camera (250 Hz) and a miniature inertial measurement unit to measure eye and head velocity.

Results: We validated the video measurement of the head impulse test by simultaneous measures with video and search coil recordings in healthy subjects and patients with unilateral vestibular loss and extended that validation in a patient with bilateral vestibulopathy after gentamicin vestibulotoxicity [2]. We then applied that test to additional patients after gentamicin vestibulotoxicity in clinics. The video system was able to quantify the deficit of the vestibulo-ocular reflex and visualize the catch-up saccade pattern which confirms the vestibular deficit. The system proved to be easy to use in clinics and allowed measurements in acute patients at the bedside as well as convenient sequential studies.

Conclusion: The video head impulse test is a safe, accurate and practical clinical tool for diagnosing bilateral vestibulopathy. The test may be useful for early detection of gentamicin vestibulotoxicity at the bedside.

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Support: The Garnett Passe and Rodney Williams Memorial Foundation, the National Health and Medical Research Council Australia, and the Australian Research Council.

Disclosure: GN Otometrics provides funding for further development of the video system. None of the authors received personal compensations from GN Otometrics.

B2-3

The video head impulse test: diagnosis of unilateral vestibulopathy

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Background: Clinical diagnosis of unilateral vestibulopathy with the head impulse test relies on visual detection of the catch-up saccades that compensate for the deficient vestibulo-ocular reflex after head rotation to the affected side. However, these corrective saccades cannot reliably be seen when they occur during head rotation [1]. Until recently quantitative measurements of the head impulse test had to be done with the scleral search coil technique which is not practical in a clinical setting.

Methods: We developed a novel non-invasive video head impulse system as a clinical tool for diagnosing peripheral vestibulopathy [2]. The light-weight (60 g) goggles, designed to minimize inertia and slippage, are equipped with a high-speed video camera (250 Hz) and a miniature inertial measurement unit to measure eye and head velocity. We validated the diagnostic accuracy of the system by simultaneous measures of patients with unilateral vestibulopathy with video and search coil recordings.

Results: Simultaneous video and search coil recordings of eye movements were closely comparable. The video system identified the affected side in unilateral vestibulopathy as accurately as search coil measurements and detected both overt and covert saccades. The system proved to be easy to use in clinics and allowed measurements in acute patients as well as convenient follow-up studies.

Conclusion: The video head impulse test is a safe, accurate and practical clinical tool for diagnosing unilateral vestibulopathy.

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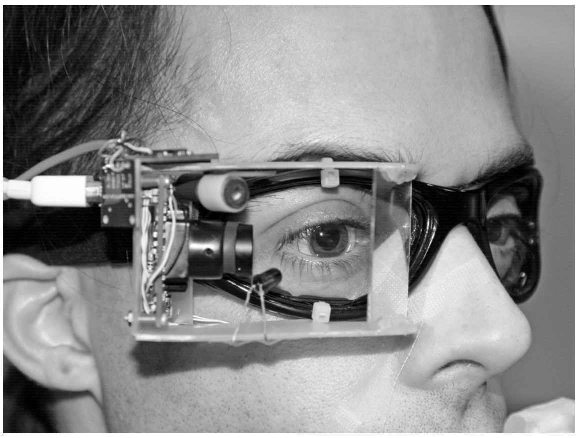

The video head impulse test.

B2-4

Head impulse testing after chronic complete vestibular loss: catch-up saccades

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Background and Objectives: The head impulse test assesses vestibular function using passive high-acceleration head rotations. In healthy subjects such head rotations lead to compensatory eye rotations in the opposite direction, which are mediated by the vestibulo-ocular reflex (VOR) and act to stabilize gaze. If the VOR is deficient, the eyes move with the head and the subject must make catch-up saccades to bring gaze back to the target. Such catch-up saccades are appropriately directed and can have latencies as short as 90 ms [1]. This implies a mechanism which allows sensory information to directly trigger catch-up saccades. The sensory trigger could be visual, proprioceptive or residual vestibular [2,3]. The aim of our study was to identify the relevant trigger-mechanisms.

Methods: Five patients who had undergone surgery for bilateral vestibular Schwannomas several years prior to the study were assessed with the head impulse test as previously described [1,4]. Horizontal head impulses were performed under two conditions:

1. with a permanently visible target in dim light and
2. in darkness with a flashed target which was switched off before impulse start.

Eye and head movements were measured with the search-coil technique as previously described5.

Results: In patients with no residual vestibular function catch-up saccades stabilized gaze when the target was permanently visible; there were no catch-up saccades when the target was flashed in darkness before impulse start. In patients with residual vestibular function, catch-up saccades helped to stabilize gaze in light and in darkness.

Conclusions: Catch-up saccades can be triggered by residual vestibular function or by visual feedback. Proprioceptive feedback alone does not suffice to trigger catch-up saccades. This should be borne in mind when advising and rehabilitating patients with bilateral vestibular deficiency.

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B2-5

Is the caloric stimulation indispensable?

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Introduction: Caloric stimulation of the horizontal canal is considered as the gold standard to test the function of the peripheral vestibular apparatus. But there is no objective method to countercheck the results of the caloric test.

As we know the head impulse test (HIT) gives good information in case of a loss of one vestibular apparatus, on the other hand the occurrence of a vibration induced nystagmus (VIN) corresponds well with the results of the caloric test. So we propose to replace the irrigation of the external ear canal by a combination of head impulse test and vibratory stimulation.

Methods: A comparison was done within three groups: vestibular neuritis ($n = 100$), definite Menière's disease ($n = 100$) and several cases with exactly proven pathology e.g. vestibular schwannoma or gentamicin treated inner ears.

Results: In general a high correlation between caloric stimulation (CS), HIT and VIN was found. The correlation was more important for caloric test and vibration induced nystagmus than for the caloric stimulation and HIT.

These results seem explainable by the fact, that the HIT becomes positive only in a complete loss or a very strong diminution of peripheral vestibular function. Interestingly it could be proven, that in some cases the caloric test showed wrong results, whereas the HIT and the VIN indicated correctly the vestibular lesion.

Conclusion: In conclusion it seems justified to replace the caloric stimulation by the combination of head impulse test and vibratory stimulation.

B2-6

Assessing vestibulo-ocular function without measuring eye movements

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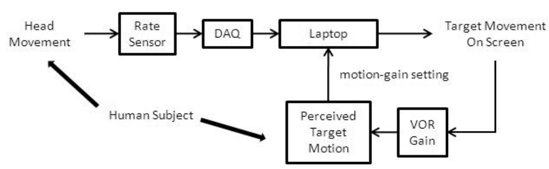
Objectives: The accuracy of the vestibulo-ocular reflex is typically measured by recording eye movements during head motion, but this process can be invasive, time-consuming, and expensive. Therefore we developed a device to assess vestibulo-ocular function without measuring eye movements. A head-mounted rate sensor measures head movement and uses it to control the position of a visual target displayed on a laptop computer screen. As the head turns, if the eyes do not move appropriately to stabilize retinal images, the visual target will undergo illusory motion proportional to the amount by which the eye movement is deficient in compensating for head motion. Thus a subject having miscalibrated VOR gain (eye velocity / head velocity not equal to 1) will perceive a stationary target as moving. By using head movement data to control target position through a variable motion-gain in real time, the subject can adjust the motion-gain so that the target appears fixed in space during head movements. This motion-gain setting reflects the extent with which the target must be moved (either more or less) relative to head movement so that the target appears visually stationary. Therefore, the motion-gain value set by the subject to null perceived target motion provides a surrogate measure of VOR gain (Fig. 1).

Methods: To test this procedure, four healthy subjects wore convex lenses (between 1.5 and 6 diopters) as a means to miscalibrate their VOR gain. The initial motion-gain was set to 1, and subjects adjusted this value such that a visual target appeared stationary during active sinusoidal head movements. Then, the motion-gain value was set to that predicted by the lens optics, and subjects were again asked to null any perceived motion. Testing was performed in darkness, and subjects were readapted to a gain of 1 before switching lenses.

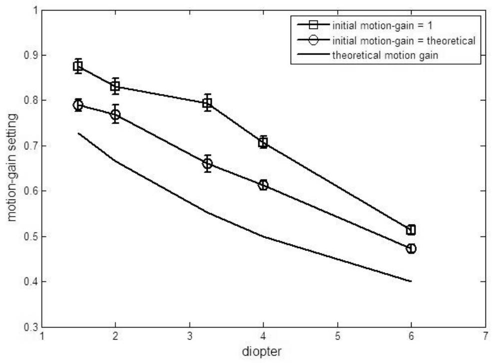
Results: The effect of convex lenses is to magnify the visual scene on the retina, thus increasing the speed with which images appear to move as the head turns. Therefore, assuming no adaptation to the lenses, subjects required VOR gains larger than 1 to perceive stationary images as remaining still during head movements, and thus had to set motion-gain to values less than 1 to null apparent target motion (the exact value depending on the strength of the lens). For example, a 4D convex lens has a 2X magnification power (magnification $= 1 +$ diopters / 4), and therefore requires an optimal VOR gain of 2. Since the subject's VOR gain is nominally 1, the motion-gain setting must be adjusted to approximately $1 / 2 = 0.5$ for the visual stimulus to appear stationary.

As dioptric power increased, subjects required smaller motion-gain settings to null perceived target motion, as expected based on lens optics (Fig. 2). Additionally, a range of motion-gain values were acceptable to the subject such that the visual target appeared stationary (as seen by comparing the squares and circles on Fig. 2). The discrepancies between reported and theoretical motion-gains were likely due to unaccounted-for translation of the eyes at the near viewing distance, visual distortion of the target as viewed through the lenses, rapid adaptation to altered magnification, or sensory tolerance for retinal slip with a miscalibrated VOR.

Conclusions: This device was able to accurately portray the gain of the VOR, within 10%. Future modifications may include the ability to assess VOR phase characteristics. This methodology has important implications for clinical settings and others (such as space-flight) where it is desired to assess vestibular function with minimal time and equipment.



Control of Target Movement Based on Head Motion



Motion-Gain vs. Diopter Power

Oral Session B3 – Mathematical Modelling

B3-1
Identification of and compensation for sensorineural time delays in human postural control

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Maintenance of human upright stance requires the contribution of neurally-mediated control mechanisms whereby orientation cues derived primarily from proprioceptive, vestibular, and visual sensory sources are combined and used to activate muscle contractions to generate corrective torque that opposes the destabilizing torque due to gravity. This stabilization process is organized as a closed-loop feedback control system. Significant time delays are present in the feedback loop due to sensory transduction, neural transmission of sensory and motor signals, central processing of sensory information, and muscle activation. Unlike an open-loop control system where a time delay simply delays the response to a stimulus, a time delay in a closed-loop feedback control system has a major influence on response dynamics and can even lead to instability if the delay is excessive or if the neural control parameters are not properly adjusted to account for the time delay. The neural control parameters refer to the transformation that determines the amplitude of corrective torque generated per unit of sensory-derived body-motion information.

Understanding the influence of time delay on postural control would be facilitated by identification of the time delay, but this is complicated by multiple factors. One factor is that there are multiple time delays. Different components within a sensorimotor system have different delays (e.g. in proprioception, short latency stretch reflex and longer latency mechanisms) and it is likely that there are different time delays in different sensory systems. Simply identifying the shortest time delay gives only limited insight into how postural dynamics are affected by the delays because the component of the response associated with the shortest time delay may not be providing the most important contribution to the overall corrective action. Therefore, an attempt to understand the influence of time delay should account for the relative contributions to corrective torque generation from different components of the system. However, the contributions from different sensory systems have been shown to vary as a function environmental and stimulus conditions (e.g., stimulus amplitude) in a process known as sensory re-weighting. Therefore, the influence of time delay on postural dynamics would be expected to vary as a function of environmental and test conditions. Finally, the contribution of intrinsic/passive mechanisms needs to be considered. Intrinsic mechanisms generate corrective torque with no time delay via biomechanical spring and damping properties of muscles and tendons. The greater the contribution of intrinsic mechanisms, the lesser the influence of time delay of neurally-mediated control mechanisms.

There are several potential strategies that could facilitate stable control in a system with significant time delays and these strategies could be adjusted to compensate for increased delays due to disease processes or aging. One is to use co-contraction of muscles to increase the contribution from intrinsic mechanisms and thus decrease reliance on time-delayed feedback mechanisms. Another is to use a complex control scheme that includes a prediction of body motion rather than relying solely on time-delayed sensory cues. Alternatively, a simpler control scheme, based only on time-delayed sensory feedback, could be used that adjusts neural control parameters in order to maintain stability while minimizing disruption of postural dynamics.

Experimental results will be presented to illustrate methods to estimate time delays using both time-domain and frequency-domain techniques under conditions where anterior-posterior body sway was perturbed by surface rotations, visual surround rotations, or by simultaneous presentations of uncorrelated surface and visual rotations. Preliminary results using a method that artificially lengthened the time delay showed no evidence that subjects make use of a complex predictive control scheme. Rather the added time delay can be compensated by altering sensory weights and neural control parameters.

Work supported by NIH grant R01AG017960.

B3-2
Modelling the vestibular system-fifty years of progress

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Objective: To trace the application of math model to the field of vestibular research. Vestibular function, in health and disease, on the ground and in space, in the young and the elderly, has been a continuing challenge for the application of engineering and physics to biology. In the MIT Man-Vehicle Laboratory we have used successively advanced modeling tools to describe a wide variety of problems. Methods: Beginning with classical control models and frequency response descriptions of the 'torsion pendulum model', we extended out modeling to otolith function and otolith-canal interaction for rotation about an off-vertical axis. Adaptation to sustained stimuli required additional terms in the models. Model predictions lead to experiments of three types – psychophysical measures of perceived oreintation and motion, the 3-dimensional eye movements associated with AVOR, LVOR and OCR, and eventually forays into single unity recording in alert monkeys. Results: Multi-sensory interaction, particularly visual-vestibular interaction, lead to expansion of our early work relating sensor 'noise' and motion thresholds, to Kalman Estimator models using optimal control and 'modern control' systems. Further development lead to the 'Observer Model' Conclusion: Modelling work in numerous labs around the world entailed an iterative approach of data analysis, model refinements, model testing with experiments, further model refinement of correction, and application to real world problems. Among the more interesting applications were: testing of human balance, measurement and analysis of nystagmus, space motion sickness and other effects of weightlessness, algorithms for motion drives in flight simulators, and spatial disorientation in aviation accidents.

B3-3
Modeling posture control and vertigo

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Abstraction and modeling of human sensorimotor functions is a worthwhile goal in view of future medical interventions (e.g. deep brain stimulation) and assistive devices (e.g. neural prostheses). Modeling biped stance lends itself to this goal for several reasons. One is that the vestibular sensor, a major constituent of this control, is relatively simple and is rather well understood owing to studies of VOR (vestibulo-ocular reflex), self-motion psychophysics, and analogies to technical gravito-inertial sensors. Furthermore, under certain conditions a simplification of stance biomechanics is possible (single inverted pendulum, SIP). Still, system identification is difficult due to the multisensory, redundant, and adaptive nature of the system. Part of past research focused on controller types and delay times, with some agreement on basic aspects. Other research focused on multisensory integration aspects. It tries to understand, for example, the sensory reweighting mechanisms that allow the system to deal ad hoc with many different and even novel external disturbance situations. A recent model provides this flexibility. It draws on psychophysical findings that suggest online two-steps inter-sensory interactions, which (1) fuse transducer (receptor) inputs into sensors and output physical variable measures, and (2) fuse the sensor signals into estimates of external disturbances. By this, the manifoldness of external impacts on stance becomes decomposed into four basic disturbances (support surface rotations and translational accelerations, field forces such a gravity and contact forces such as push). The estimates (rather than the sensor signals) are used for feedback in a 'disturbance injection' control (disturbance estimation and compensation, DEC, model). The model showed a high describing and predictive power across many human experiments. It is versatile, lending itself to fusion of the reactive with volitional balancing control as well as with voluntary movement (proactive) control. Furthermore, the control principles are applicable to other sensorimotor functions such as targeting head and arm movements. They have been successfully embodied into a posture control robot, fostering interaction with roboticists in the novel interdisciplinary research field of neurorobotics.
The vestibular system contributes furthermore to perceptual stability when one experiences the self in the world. This is achieved through sensory reconstruction of self-kinematics with reference to the world- a demanding information processing. Its failure upon vestibular impairment leads to vertigo, often combined with nausea. Causes are manifold and localized anywhere on the way from the receptors to high integration centers (and may involve other senses such as vision or auxiliary mechanisms such as the VOR). Clinical, electrophysiological, and anatomical knowl-

edge may lead the way to an abstraction and modeling of the mechanisms that underlie a given vertigo syndrome. For example, starting at receptor levels, a canal lesion may lead to an illusion of self- or surround turning. This is a ‘plus’ symptom, whereas lesions of most other receptors lead to ‘minus’ symptoms (information loss). Modeling the canal afferents’ bidirectional rotation coding (through ‘vestibular tone’, i.e. coding is about some elevated firing level) together with the known inhibitory commisures between the corresponding vestibular nuclear neurons on both brainstem sides is able to explain the rotation illusion. Other examples would be to explain an erroneous perception of the gravitational vertical through some impairment of the neural canal-otolith fusion, or a visual vertigo by a mismatch in dynamics between visual and vestibular angular velocity signals. Arguable, even cervical vertigo may re-emerge under a new light if explained by an impaired coordinate transformation of vestibular space coordinates from the head to the trunk (and further down to the body support surface), as it is required for balancing and many other tasks. Such deeper understanding of symptoms and their compensation will improve diagnosis and treatment of our patients.

B3-4

Modeling stance control in neurological patients with Parkinson’s rigidity and hereditary spasticity

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Objectives: Stance and gait abnormalities are core features of many neurological diseases. In clinical practice, these deficits are usually characterized using Romberg’s balance test and by recognizing typical abnormal gait patterns. Typical features of e.g. Parkinson’s disease (PD) gait are small steps, and an abnormally large number of steps when changing walking direction. Other diseases show atactic or broad-based gait patterns. However, how these observations of abnormal stance and gait are related to deficits in the sensorimotor system of these patients is still not known.
Methods: Using simple feedback models, we aim to decompose stance and gait observations into abnormalities of functional subunits. Those are e.g.: sensor or motor latencies, gains of position, damping and force feedback, intersensory interactions, noise properties in different sensory channels etc.
Following this approach, patients were instructed to stand on a moving platform. We apply platform rotations and translations of varying frequencies and amplitudes and different sensory conditions (eyes closed, eyes open) to generate a set of transfer functions for each patient. Then, we fit simple feedback models to these transfer functions to identify and quantify the functional subunits listed above.
Results: We will present data from Parkinson’s disease and hereditary spastic paraplegia (HSP). We demonstrate patients’ profiles of sensorimotor control during stance and the effects of different treatment regimens on these profiles.
Conclusion: We are able to identify and quantify different subunits of sensorimotor control during stance in different neurological diseases, exemplified here by PD and HSP. One of our aims is to find key features of stance and gait deficits in different neurological diseases and e.g. how much deficits overlap. Another aim is use the individual profiles of patients and the effect of treatments on these profiles to tailor therapeutic interventions more precisely.

B3-5

Optimal coordination and control of posture and movements

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This lecture presents a theoretical model of stability and coordination of posture and locomotion, together with algorithms for continuous-time quadratic optimization of motion control. Explicit solutions to the Hamilton-Jacobi equation for optimal control of rigid-body motion are obtained by solving an algebraic matrix equation. The stability is investigated with Lyapunov function theory and it is shown that global asymptotic stability holds. It is also shown how optimal control and adaptive control may act in concert in the case of unknown or uncertain system parameters. The solution describes motion strategies of minimum effort and variance. The proposed optimal control is formulated to be suitable as a posture and movement model for experimental validation and verification. The combination of adaptive and optimal control makes this algorithm a candidate for coordination and control of functional neuromuscular stimulation. Validation examples with experimental data are provided.

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Oral Session B4 – Eye & Head Movements

B4-1

A new clinical test of otolith function

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Background: Despite extensive attempts to develop neuro-otological tests, the integrity of vertical semi circular canal and otolith function remain difficult to assess objectively in the clinical setting. This study aims to quantify static ocular counter-roll from head tilt using a new device – INOG (Imperial Neuro-Otology Goggles) – which we have developed.
Methods: This technique utilises a head-mounted device (INOG) consisting of an LED positioned 42 cm in front of one eye which projects the light through a striated lens. The striated lens can be rotated by hand in the torsional plane and rotation of the lens changes the orientation of the light streak. An angular scale indicates the angle through which the lens is rotated. The light source has two brightness intensities (dim and bright). INOG was used to measure ocular counterroll in 16 healthy volunteers (mean age 30 years). At the beginning of the test, with the subject upright the bright light source was shone into the subject's left eye, to induce a horizontal retinal afterimage. Once a prominent afterimage was obtained, the bright light was switched off and the subject's head was then tilted in roll by 45 degrees. The head tilt produced a torsional movement of the eye (counterroll) and a concomitant tilt of the afterimage. The light source was then turned on to the dim setting. With the head held in the tilted position, the subjects were asked to superimpose the perceived afterimage and the new dim light, by rotating the striated lens. The rotation angle is a true representation of the angular torsion that has occurred at the retinal level. To validate our device, we simultaneously recorded torsional eye movements from the other eye using video-oculography (VOG).
Results: Mann-Whitney U test demonstrated a non significant p value (0.24) between the two different measuring techniques. Mean ocular counterroll using the INOG device was 5.2 degrees (range 4–7, SD = 0.8) for rightward head tilt and 5.4 degrees (range 4–7, SD = 1.1) for leftward head tilt of 45 degrees. Mean ocular counterroll as measured with VOG was 4.95 degrees (range 4.0–6.5°, SD = 0.74°) for rightward head tilt and 5.14 degrees (range 4.0–6.5°, SD = 0.90) for leftward head tilt. We performed a separate study of ocular counterroll in two patients with bilateral vestibular failure, using the INOG device and 45 degree head tilts. Patient 1 had absent counterroll. This patient also showed complete otolith failure on the utricular centrifugation test (UCF). Patient 2 had 2 degrees of counterroll to right head tilt and 1 degree of counterroll to left head tilt. This patient had partial preservation of otolith function on the UCF. These findings imply a correlation between ocular counterroll and utricular function, and lend further support to the utility of the INOG device.
Conclusions We have devised a non-invasive, quick, reliable test of otolith function that can be easily used in the consulting room. In addition we have demonstrated preservation of otolith function in one patient with total loss of semicircular canal function. Therefore, this test could be a valuable screening tool to assess otolith dysfunction in patients with intact canal function, or alternatively assess the integrity of otolith function in patients with absent canal function.

B4-2

Functional imaging of the development of the vestibulo-ocular reflex circuit

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Little is known about how specific synaptic connectivity patterns are established in polysynaptic sensorimotor circuits. Motoneurons that innervate different muscles are molecularly distinct, a feature that central premotor neurons might utilize in making specific synaptic connections onto them. Alternatively, appropriate specificity might be achieved through the action of differential activity patterns. We assessed the specificity of inputs from vestibular projection neurons onto oculomotor, trochlear and abducens motoneurons during development of the vestibulo-ocular reflex circuit in the chicken embryo. Anatomical studies using anterograde axonal tracing show that synaptic connections from vestibular afferents onto vestibular projection neurons and from the latter onto motoneurons develop at specific early stages of embryonic development. Functional imaging of the entire developing circuit shows that different vestibulo-ocular channels establish motoneuron pool-specific synaptic connections

from the initial stages of innervation. These specific patterns of input are not disrupted by chronic NMDA receptor blockade or by spontaneous activity that synchronously coactivates all the neurons in the reflex circuit. Both of these conditions are known to be highly disruptive to the development of specific connections in sensory systems. The lack of dependence on activity-related mechanisms implicates molecular recognition as the principal determinant of synaptic specificity in the vestibulo-ocular reflex circuit.

B4-3

Dynamic visual acuity before, during and after exercise in traumatic brain injury subjects and normal controls

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<**Text Not Available**>

B4-4

A dynamic visual acuity test with a flasing optotype

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Static visual acuity is dominated by visual factors. If, however, motion is at issue, be it from the optotype, the observer, or the eyes, the resulting dynamic visual acuity (DVA) also depends on vestibular, and other neuro-physiological factors. To assess the effects of all factors possibly involved, we developed a new DVA test with a relatively high level of controllability of the position and velocity of the image of the optotype on the retina.

To control for the retinal optotype image position, subjects are required to fixate a small fixation target on a computer screen. We use a CRT display to reduce smear as observed on LCD screens. Then, the fixation target is replaced by an optotype for 200 ms only. The optotype consists of digits with well defined gaps (thus excluding 1s and 7s). By presenting optotypes of different sizes repeatedly, the fraction of correct answers can be estimated accurately using a psychometric function fit. The matching gap size obtained at, e.g., 75% correct then determines the minimum angle of resolution (MAR), or, alternatively the acuity (1/MAR, the MAR in minutes of arc). To reduce the number of trials required to obtain a reliable acuity threshold, we use an optotype consisting of two digits of different sizes. To enhance the discriminating power of the test, these digits are masked by surrounding Hs causing contour interaction. Using different combinations of fixation target, optotype, and head motion, different DVA-subtests can be realised.

Static acuity is measured using a static fixation target as well as a static optotype. The effect of retinal slip can be tested using a static fixation target interrupted by a dynamic optotype moving symmetrically over the position of the (missing) fixation target. Because the optotype is only presented for 200 ms, eye following is largely prevented. To study the effect of eye movements, the fixation target is moved slowly over the computer screen, interrupted by the optotype at the center of the screen, the optotype moving with the same speed as the fixation target and continuing its motion. The slowly moving fixation target allows for optimal smooth pursuit eye movements in healthy subjects, but may be interrupted by saccades due to neurological deficiencies, fatigue, and/or use of drugs and alcohol. The vestibulo-ocular reflex (VOR) could be tested by fixating a static fixation target interrupted again by a static optotype while making yaw head movements. By measuring head position dynamically, the optotype can be presented at the straight ahead position, and when the desired head angular velocity is within certain limits. Lastly, we use a head mounted display with a static fixation target and a static optotype while making head movements again, the imagery thus moving with the head, allowing to study VOR suppression.

Several studies are currently well under way, elaborating the differentiating power of this test with respect to ocular, vestibular and neurological disorders, as well as the effects of alcohol and fatigue (see e.g., Van Rooy et al., this meeting). DVA may thus contribute to the diagnosis of several diseases, the evaluation of their treatment, but it may also be used as a non-clinical fit-to-function tests for operators dealing with high risks, such as pilots and air traffic controllers.

B4-5

Three-dimensional signal analysis of nystagmus with video-oculography

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Objectives: Three-dimensional signal analysis can be applied to nystagmus in order to study otoneurological patients who suffer vertigo and other balance problems. We developed an analysis and modeling algorithm for three-dimensional nystagmus measured with a video-oculography system. We were also interested in verifying an otoneurological hands-on convention called Ewald's first law: the trajectory of nystagmus induced by a semicircular canal in the inner ear should reflect the anatomic orientation of the semicircular canal [1].

Methods: We recorded spontaneous nystagmus from 47 patients (29 females and 18 males) with the mean age of 49 $\pm$ 16 years. Most of them suffered from acute, unilateral loss of vestibular function. Twenty-eight had vestibular neuritis and eight had labyrinthitis (vestibular loss accompanied with hearing loss). The other had various problems like fistula. The underlying pathology was unilateral in 44 patients, bilateral in one patient, and central in two patients.

We used video-oculography to record three-dimensional nystagmus at the frequency sampling of 500 Hz to separately produce horizontal, vertical and torsional signals for each eye. Measurements were performed with covered eyes by applying two videocameras embedded in a mask (3D VOG Video-oculography, Sensomotoric Instruments, Germany) in a quiet laboratory room. After calibration, where a patient changed the gaze between nine fixed dots on a wall, we estimated amplitude resolutions to be well below 1°. The lack of fixation was important during nystagmus recording, since nystagmus is at its fastest without visual fixation and to hinder possible disturbance of environment and light. The duration of every measurement was 30 s.

On the basis of signal analysis techniques and straightforward vector calculus, we were able to recognize slow phases of nystagmus to compute their mean angular velocities used to estimate from which semicircular canal of the inner ear the disorder was originated. Figure 1 shows an example where dots on the unit sphere corresponds to unit vectors as slow phase velocities of nystagmus beats detected and accepted as valid. The normal vectors of the planes formed by the semicircular canals are set on the sphere. Their locations (component values) are based on [2]. The least angle between them and the mean velocity vector (long line in the middle of the dots) indicates which semicircular canal was computed to reveal the principal origin of the disorder. Table 1 contains the average results of 47 patients.

Results: We found out that for all 47 patients the normal vector of one of the two horizontal semicircular canals was the closest. On average, 43 nystagmus beats were accepted. The mean velocities of their nystagmus slow phases were 7.9, 2.8 and 3.7°/s for horizontal, vertical and torsional nystagmus. We quantitatively estimated the influence of the semicircular canals as projections of the mean vector on the normal vectors. Despite the pathology horizontal canals seemed to be predominant in driving the nystagmus.

Conclusion: The signal analysis means developed is effective in studying otoneurological problems and extends three-dimensional nystagmography using video-oculography. Our results support Ewald's first law.

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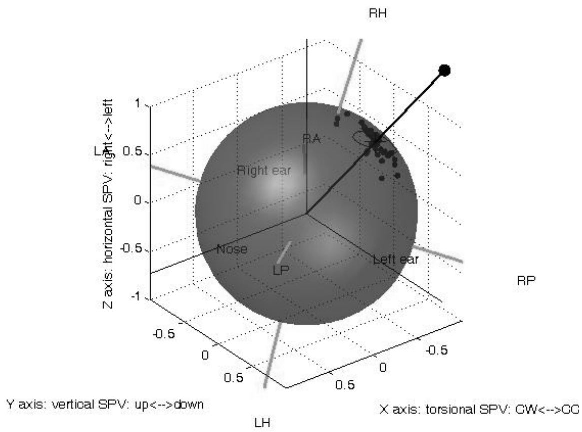

Table 1
Means and standard deviations of angles between the mean velocity vectors and the nearest normal vectors of the planes of the semicircular canals, and estimates e (from [0, 1]) of incluence of either left or right semicircular canals

Normal vector of	Left horizontal	Left anterior	Left posterior	Right horizontal	Right anterior	Right posterior
Number	20	0	0	27	0	0
Angle [°]	19.5±8.2	-	-	18.0±9.3	-	-
Influence estimate e	0.87±0.10	0.05±0.07	0.08±0.08	0.88±0.10	0.07±0.07	0.05±0.05

B4-6

Dynamic visual acuity of patients with vestibular neuritis

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To explore the clinical feasibility of a newly developed Dynamic Visual Acuity test we performed this prospective cohort study. As part of a larger study comparing the effects of different deficiencies, the current study focused on patients with vestibular neuritis with a dynamic unilateral deficiency of the vestibular ocular reflex (VOR). Data were compared with those of healthy control subjects. This test aims to measure different kinds of static and dynamic visual acuity by means of different subtests, and to be quick, cheap and user friendly (see: Bos et al, this meeting.).
Vestibular neuritis is a condition in which the patient complains about an acute onset of rotatory vertigo and nausea lasting several days without any ear symptoms. Most of the patients are symptom free after 1 to 6 weeks due to central compensation mechanisms. However, high frequency head movements may still cause oscillopsia and impaired balance. Due to a residual VOR deficit visual tracking in those patients is poor. We therefore expect that patients will show a marked deficit during the VOR subtest and relatively good performance during VOR suppression.
Dynamic visual acuity (DVA) is the threshold of visual resolution obtained during relative motion of either an optotype, the observer, or the eyes. Already in 1994 it was established that DVA is a quantitative and clinically feasible measure of oscillopsia that reflects functionally significant abnormalities of the VOR in unilateral vestibular pathology due to neurectomy or labyrintectomy. The test contains 9 short subtests in which the optotype, the head, and/or the eyes move, resulting in static, retinal slip, and bidirectional smooth pursuit, VOR and VOR-suppression acuity values.
In total 24 subjects were enrolled of which 9 were patients which had had vestibular neuritis less than a year ago (mean age 54 $\pm$ 11 years, range 40–69 years) and 15 were age and sex matched control subjects. All patients with vestibular neuritis exhibited significantly decreased unilateral excitability measured by caloric testing ($>$ 50% asymmetry between the two sides) at the time they were diagnosed. Data-analysis was performed by determining the minimal angle of resolution (MAR) for each participant and each subtest separately. Statistical analyses were performed to determine threshold differences between patients and healthy control subjects.
Results show no differences between healthy subjects and patients on static visual acuity. Also the subtests for retinal slip and smooth pursuit were not significantly different. However, the VOR subtest shows a statistically significant difference between both groups; the patients show a reduction of the acuity ($p < 0.05$). In addition patients show a better performance on the VOR suppression subtest ($p < 0.05$).
The fact that the static, retinal slip, and smooth pursuit acuity values in these patents were not different from those of control subjects, while only those measurements involving the organs of balance did, may well be understood by the mere deficiency of the vestibular afferents. Patients with vestibular neuritis have impaired visual acuity during VOR as induced by active head movements. Using a new task, we showed that their visual acuity is actually better when the VOR needs to be suppressed. We therefore conclude that dynamic visual acuity may reveal a deficiency in vestibular neuritis patients, who otherwise have recovered from their disorder. A newly developed test has proven to be fast to perform, noninvasive and at a low cost and can therefore be an accurate screening method for vestibular pathology in general.

B4-7

Development of a normative percentage of saccadation during smooth pursuit testing

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The smooth pursuit test is a standard component of the ocular motor test battery. The test provides information regarding the status of the ocular motor system and associated neural structures. The most common form of assessing pursuit testing is through the velocity gain. The velocity gain looks at the average velocity of the eyes compared to the average velocity of the visual stimulus. When an individual is unable to maintain the proper eye velocity to match the moving target, a corrective saccade is required to correct for the eye

position error. Abnormalities in the velocity gain are generally interpreted as indicators of central pathology. The determination of abnormal saccadic intrusions upon the pursuit function has primarily been through subjective estimation. With a few exceptions, saccadic or cogwheel pursuit is a subjective determination made by each investigator. Some studies have found an increased percentage of saccadation during pursuit in patients with neurological disorders versus normal individuals; 44% vs 4%, respectively (Hartje et al., 1978). Saccadic intrusion into pursuit has also been found in individuals with obsessive compulsive disorder (Pallanti et al., 1996), amblyopia (Ciuffreda et al., 1979), and even schizophrenics (Holzman et al., 1973).
The purpose of this presentation is to describe a new method for the quantitative assessment of saccade intrusion in the smooth pursuit eye movements. These techniques; developed by Neuro-Kinetics, Inc., show significant promise as tools in standard clinical practice. Smooth pursuit testing was performed on 31 individuals (17 female, 14 male) between the ages of 18 and 49 years (mean $= 25.2$, SD $= 7.1$) as part of a standard ocular motility battery. Pursuit stimuli consisted of a laser stimulus projected on the walls of a lightproof enclosure. The stimuli were presented as 3 cycles at 0.10, 0.20, 0.50, and 0.75 Hz. Summary statistics were calculated in order to develop ranges of saccadation percentage in normal individuals, along with preliminary normative data (i.e., 2 SD from the mean). The results demonstrate that this method can quantitatively evaluate percentage of saccades more completely than previous observation methods by calculating the percentage of the total tracking movement contributed by the saccadic system. Examples of patients with smooth-pursuit impairment exhibiting a higher percentage of saccadic tracking and lower smooth pursuit gain compared to the normal subjects will also be shown.

Oral Session B5 – Meniere's

B5-1

Spontaneous recurrent attacks of vertigo that do not lead to permanent audio-vestibular deficit

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Objective: To investigate whether clinical features of vertigo attacks can distinguish patients with benign recurrent vertigo from those with Meniere's disease.
Methods: A structured interview was used to analyze features in patients with benign recurrent vertigo, i.e. those who have normal audiograms and caloric test result even though they have had recurrent vertigo ($n = 63$). A group of patients with definite Meniere's disease ($n = 112$) served as controls.
Results: At the time of the interview both groups had had vertigo attacks for a mean period of eight years. Compared to the Meniere's disease group, patients with benign recurrent vertigo had: a female preponderance, increased susceptibility to motion sickness, earlier age of onset, and increased incidence of migraine headaches (IHS criteria). As expected unilateral auditory symptoms were much more common in patients with Meniere's disease but bilateral auditory symptoms were equally common in both groups. With regard to the vertigo attacks, duration tended to be shorter in patients with benign recurrent vertigo but there was a large overlap in the duration of attacks between the two groups. Triggers (stress/emotional upset, fatigue, menstrual periods) and associated symptoms (imbalance, nausea and vomiting, headache, sensitivity to light) were not significantly different in the two groups.
Conclusions: One can not distinguish vertigo attacks in patients with benign recurrent vertigo from those in patients with Meniere's disease based on duration, triggers or associated symptoms. Benign recurrent vertigo is a heterogeneous clinical syndrome with a subset closely associated with migraine.

B5-2

VEMP threshold response curves in Meniere's syndrome: sensitivity / specificity

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Background: In literature between 2004–2006 it was suggested that in patients with Meniere's syndrome there may be a change in the shape (shift upwards in the most sensitive frequency) of the VEMP threshold response curve developed over the frequencies from 250–1k Hz. Literature in 2009 and 2010 has been in agreement with the original studies showing the most sensitivity frequency for the VEMP threshold response curves is at 500 Hz. To date no estimates of sensitivity and specificity of the technique in identification of Meniere's has been reported.
Objectives: The primary objective was to provide estimates of the sensitivity and specificity of the VEMP threshold response curve in the identification of patients with Meniere's syndrome. Secondly, to define

the differences in clinical characteristics of those patients with Meniere's for whom the technique identified and those missed.

Methods: The project was performed in two phases. For both phases a prospective clinical protocol was begun in JAN of 2008 where cervical VEMP threshold response curves for tone burst stimuli at frequencies of 250, 500, 750 and 1k Hz were obtained for any patient with a presentation of spontaneous events dizziness independent of the working diagnosis. Phase 1 was a quality improvement initiative to review the preliminary estimates of sensitivity of all patients between JAN 2008 and DEC 2009 with the working diagnosis of Meniere's syndrome (N = 75). This resulted (see results below) in a high enough association between changes in the VEMP threshold response curves in the Meniere's patients to indicate the need for a formal review. Phase 2 was an IRB approved full retrospective review of all patients seen between JAN 2008 and JUN 2010 for whom the final diagnosis of Meniere's syndrome was made using strict application of the AAO-HNS 1995 criteria. This group (N = approximately 80 by end of JUN 2010) served for development of estimates of the sensitivity of the threshold response curve. For estimates of specificity, all patients between JAN 2008 and JUN 2010 for whom VEMP threshold response curves were performed as part of the clinical protocol but did not have Meniere's syndrome were reviewed (N = approximately 60 by end of JUN 2010). To add to the specificity group consecutive patients for 6 weeks, independent of symptom presentation, had the threshold response curve VEMP protocol (N = 50). For the primary objective ROC curve analysis was used to determine the optimal cut point (how much of a frequency shift in the threshold response curve) for identification of possible Meniere's patient and the sensitivity and specificity for the technique. The secondary objective accomplished with the use of statistical correlation and linear regression analysis for the characteristics of Meniere's patients (age, duration of disorder active Meniere's, magnitude of caloric asymmetry and severity of hearing loss) in relationship to a positive VEMP threshold response curve for Meniere's syndrome.

Results: The results of phase 1 suggested a sensitivity of 44% in the cohort (N = 75) of those with working diagnosis of Meniere's. However, in this preliminary review if those patients suspected of Meniere's without a formal diagnosis were included (total N = 200) the estimate of sensitivity was 65%. Phase 2 with the formal statistical analysis is still in progress and will be reported at the meeting.

Conclusions: The preliminary phase 1 estimates of sensitivity are promising enough that if the formal estimates via the ROC analysis are in the 60% range the implication would be that the VEMP threshold response curve technique would be worth the clinical time as a possible unique indicator of Meniere's for a select group of patients.

B5-3

The air-conducted ovemp in Ménière's disease

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Objectives: Evaluation of the general characteristics of the ocular Vestibular Myogenic Potential (oVEMP) evoked by air-conducted (AC) sound in patients with Ménière's disease, and specifically investigation of the stimulus frequency dependency. These patients are already known to have an altered stimulus frequency dependence with regard to their cervical Vestibular Evoked Myogenic Potentials.

Methods: 37 Ménière's patients, consisting of 31 unilaterally affected patients, 5 bilaterally affected patients and 1 unilaterally affected patient with congenital hearing loss at the contralateral side, were tested at stimulus frequencies of 250, 500 and 1000 Hz. Additionally, two groups of healthy subjects were tested: 55 normals at a stimulus frequency of 500 Hz and 22 normals at 250, 500 and 1000 Hz stimulus frequencies. Short tone bursts were presented monaurally through a Beyer DT-48 headphone at a maximum stimulus level of 120 dB Sound Pressure Level (SPL) for stimulus frequencies of 250 and 500 Hz, and 115 dB SPL for 1000 Hz. Recording was performed in upgaze with electrodes underneath both eyes. An AC tone burst evoked oVEMP was characterized by the presence of a negative peak (n1) at around 10 ms followed by a positive peak (p1) at around 15–16 ms with an amplitude (n1-p1) greater than 1.0 μV.

Results: The AC stimulus evoked oVEMP showed a lower response rate at a given stimulus level, a smaller amplitude and higher threshold at 500 Hz stimulus frequency in the affected Ménière's ear. Surprisingly, also the unaffected ears (in the unilateral patients) showed a significant threshold shift at this stimulus frequency, possibly indicating pathological changes in these clinically unaffected ears. Furthermore, the best frequency of 500 Hz that is seen in healthy subjects, with the highest amplitude and lowest threshold at this particular stimulus frequency, is shifted towards the higher frequency of 1000 Hz.

Conclusions: The higher threshold and altered frequency dependence of the AC stimulus evoked oVEMP might help in diagnosing Ménière's disease.

B5-4

Ocular and cervical vestibular-evoked myogenic potentials (oVEMPs and cVEMPs) to bone conducted vibration (BCV) in Ménière's disease during quiescence vs during acute attacks

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Objective: To test whether dynamic otolith function is changed during the acute attack of Ménière's Disease (MD) we measured dynamic otolith function in the same patients during the acute attack and compared these measures to those taken in the same patients during the quiescent phase between MD attacks. The two measures of dynamic otolith function were ocular and cervical vestibular-evoked myogenic potentials (oVEMPs and cVEMPs) produced in response to bone conducted vibration (BCV) of the midline of the forehead at the hairline (a location called Fz). The stimulus was 500 Hz Fz BCV. Other evidence shows that in response to brief 500 Hz Fz BCV the n10 potential of the oVEMP indicates utricular function and the p13 potential of the cVEMP indicates saccular function (reviewed in Curthoys [1]).

Methods: Surface EMG electrodes measured responses to the 500 Hz Fz BCV either from beneath the eyes while the patient looked upwards – the oVEMP – or from over the stretched sternocleidomastoid muscles – the cVEMP. In both cases the stimulus was repeated 7ms bursts of 500 Hz vibration delivered by a hand-held Bruel and Kjaer 4810 minishaker (50 stimuli at a rate of 3/s). The group of MD patients included a total of 53 patients (15 patients tested at both quiescent and attack phases, 35 MD patients who were tested only during quiescence and 3 who were tested only during the attack) diagnosed as having Definite Ménière's Disease, fulfilling the most recent AAO-HNS criteria for Definite MD. These were early MD patients in whom there was no evidence of involvement of the contralateral ear. In addition a total of 16 normal healthy subjects were tested on two occasions with informed consent; 5 male, 11 female; age range (Mean age 38; range 19 to 77). A further 21 healthy subjects provided data on just one occasion (5 male, 16 female; mean age = 44.9; range 19 to 71).

Results: During the MD attack there was a very large increase in the amplitude of the contralesional n10 of the oVEMP compared to quiescence, but there was a significant decrease in the ipsilesional p13 of the cVEMP during the attack compared to quiescence.

Conclusion: In the acute MD attack, dynamic utricular function in the affected ear is enhanced, whereas dynamic saccular function in the affected ear is not similarly affected. That dissociation between oVEMPs and cVEMPs could be due to mechanical factors such as swelling or distortion of the utricular membrane. In fact much of the utricular macula is not attached to bone but rests on the membrana limitans whereas the saccular macula is closely adherent to the bony wall of the temporal bone. Such differential suspension could possibly lead to different responses to the fluid pressure changes exerted by hydrops for predominantly utricular-based dynamic responses (oVEMPs) as opposed to the changes for predominantly saccular-based dynamic responses (cVEMPs). Of course other mechanisms could cause differential changes in receptor sensitivity.

Significance: During an acute attack of MD dynamic utricular function in the affected ear is enhanced, however dynamic saccular function in the affected ear does not appear to be similarly affected: the acute MD attack appears to affect the different otolithic regions of the affected ear differentially.

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B5-5

The Antwerp Meniere Index (AMI): an electrocochleography based method to scale Meniere's disease

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Introduction: For several years, electrochleography (Ecog) has been used to assess the pressure in the

cochlea, in case of suspected endolymphatic hydrops. Transtympanic and extratympanic Ecog was applied, where transtympanic appeared to be more sensitive to detect endolymphatic hydrops.
Click generated summating potential over action potential or the so called SP/AP ratio in combination with tone burst generated SP amplitudes for several frequencies were measured to improve the sensitivity of this test. We here present a method based on backward logistic regression to assess and quantify the degree of Meniere's disease (MD).
Material and Methods: 155 patients underwent transtympanic Ecog, with a Viking IV ABR equipment at the tertiary referral ENT unit at the Antwerp University Hospital, Belgium. These patients were clinically subdivided into the traditional 4 categories, based on the 1995 AAO-HNS criteria: No MD, possible, probable and definite MD. However, one category was added, being 'cochlear MD', since these patients showed all signs of MD, except for the vertigo. Therefore, it appeared that they could not be assigned to the 'no MD' group.
Next, purely based on the 'no MD' and the 'definite MD' group, a binary logistic regression was performed with SPSS V18, to identify the variables that were able to discriminate optimally between these 2 groups.
Results: The logistic regression gave as outcome that a linear combination of the variables AC_125 (pure tone audiometry threshold at 125 Hz), Ecog_SP_500 (Ecog SP amplitude at 500 Hz tone bursts) and Ecog_SP_2000 (Ecog SP amplitude at 2000 Hz tone bursts) could identify with a specificity of 96.6% the 'no MD' group, and with sensitivity of 85.6% the 'definite MD' group. However, this identification is not the real target of this approach, but rather the fact that the equation: AMI=Ecog_SP_500 $+$ 0.5xEcog_SP_2000 $+$ 0,23 AC_125 $-$ 6.5 is able to scale patients with suspected MD on a continuum. The original logistic regression outcome was rescaled such that an AMI of 0 corresponds to the average of the group with no MD and an AMI of 10 corresponds to the average of the group of Definite MD. Since it is a continuous scale, AMI values higher than 10 are possible, as well as lower than 0. They indicate that these subjects exceed the average of the group Definite MD or no MD respectively.
The AMI ($+$ se) of the MD groups yields:
AMI @ No MD group $= -0 + 0.37$ ($n = 58$)
AMI @ Possible MD group $= 1.51 + 0.72$ ($n = 33$)
AMI @ Probable MD group $= 2.74 + 2.3$ ($n = 5$)
AMI @ Definite MD group $= 10.0 + 1.0$ ($n = 35$).
Additionally, the AMI of the Cochlear MD group $= 5.03 + 1.2$ ($n = 24$).
The differences between these groups of patients with the different forms of MD are significant for the comparison No MD versus Definite MD ($p < 0.001$), possible MD versus definite MD ($p < 0.001$) and no MD versus Cochlear MD ($p = 0.036$). When not correcting for multiple comparisons, also Possible versus Cochlear MD and Cochlear versus Definite MD was significant.
Conclusion: The AMI serves as an index to scale the degree of MD, measured with Pure Tone Audiometry as well as Transtympanic Ecog. The higher this Index, the more the hearing is affected, as in the case of the clinically assessed definite MD group. This AMI can be used to evaluate the effect of specific treatment or follow up MD. The AMI is not meant to classify, but to assess the degree of audiometric and Ecog measured dysfunction, with respect to MD.

B5-6

Endolymphatic hydrops in Meniere's disease and sudden deafness detected by MRI in combination with intratympanic gadolinium injection

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Objective: first, to compare the detection rate of endolympatic hydrops between patients with Meniere's disease and sudden deafness by endolympatic image analyses using 3 tesla (T) magnetic resonance imaging (MRI) after intratympanic gadolinium (Gd) injection; second, to clarify the existence of secondary hydrops in living patients following sudden deafness.
Study design: A prospective study.
Setting: Tertiary referral university hospital.
Patients: Ten patients with unilateral Meniere's disease and eight patients with sudden deafness.
Intervention: Gadodiamide hydrate diluted 8-fold with saline was injected into the ipsilateral tympanic cavity 24 hours before MRI.
Main outcome measures: Two doctors independently judged the existence of endolymphatic hydrops in MR images without knowledge of diagnosis.
Results: Endolymphatic space could be detected as a low or no signal intensity area, while perilymphatic space showed high intensity due to enhancement by Gd. Except for one Meniere's patient in whom endolymphatic images could not be evaluated due to faint enhancement by Gd, all other nine patients with Me-

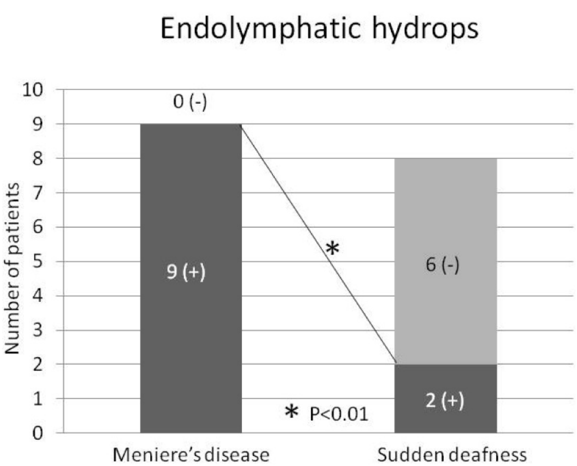
niere's disease and two of eight patients with sudden deafness were diagnosed as having endolymphatic hydrops. This detection rate was statistically different between the diseases. Two hydrops-positive cases with sudden deafness were the secondary hydrops, because images were taken after partial recovery of hearing loss several months after the onset of sudden deafness.

Conclusions: Detection rate of endolymphatic hydrops was significantly higher in patients with Meniere's disease than with sudden deafness, indicating that 3T MRI in combination with intratympanic Gd injection was useful to diagnose an endolymphatic hydrops. Secondary hydrops were also found following sudden deafness and this condition should be strictly separated from Meniere's disease in the diagnosis and treatment of inner ear diseases.

Table 1
Patients profile and location of hydrops

Patient No.	Diagnosis	Sex	Age	CP	EcochG	Hearing lebel	Interval (months)	Hydrops (cochlea)	Hydrops (ant. canal)	Hydrops (lat. canal)	Hydrops (post. canal)	Hydrops (vestibule)
1	Lt. MD	M	28	Lt. 46%	(+)	53.75dB	84M	insufficient	insufficient	insufficient	insufficient	insufficient
4	Lt. MD	M	47	Lt. 26%	(+)	57.5dB	34M	(+)*	(-)	(+)*	(+)	(+)*
5	Lt. MD	F	52	Lt. 66%	(+)	48.75dB	120M	(+)	(-)	(-)	(+)	(-)
6	Lt. SD	F	38	Lt. 58%	(-)	110dB (2K, 4K S.O.)	6M	(-)*	(-)	(-)	(-)	(-)
8	Rt. MD	M	66	Rt. 54%	(+)	58.75dB	48M	(+)*	(-)	(+)	(+)	(+)
14	Rt. MD	M	65	Rt. 30%	(-)	53.75dB	36M	(+)	(-)	(+)	(+)	(+)
15	Lt. SD	M	46	NA	NA	54dB	6M	(-)	(-)	(-)	(-)	(-)
17	Rt. SD	F	34	NA	(-)	58.75dB	11M	(+)	(+)	(-)	(+)	(+)
19	Lt. SD	F	30	NA	NR	98.75dB (2K, 4K S.O.)	1M	(-)	(-)	(-)*	(-)*	(-)*
20	Rt. MD	F	46	Rt. 48%	(+)	51.25dB	48M	(+)	(+)	(+)	(+)*	(+)
21	Lt. SD	F	64	Lt. 60%	NR	58.75dB	2M	(+)	(-)	(-)	(+)	(+)
22	Rt. SD	F	26	NA	NA	92.5dB	7M	(-)	(-)	(-)	(-)	(-)
23	Rt. MD	F	43	Rt. 66%	NR	63.75dB	154M	(+)	(+)	(-)	(+)	(+)
24	Rt. SD	M	34	NA	NA	46.25dB	2M	(-)	(-)	(-)	(-)	(-)
25	Rt. SD	M	52	Rt. 100%	NA	48.75dB	2M	(-)	(-)	(-)	(-)	(-)
26	Rt. MD	F	45	Rt. 24%	(-)	51.25dB	180M	(+)	(+)*	(+)	(+)	(+)
27	Rt. MD	M	43	Rt. 30%	(+)	52.5dB	48M	(+)	(+)	(+)	(+)	(+)
29	Rt. MD	F	32	Rt. 68%	NR	0.5K, 1K, 2K, 4K S. O.	108M	(-)*	(-)*	(+)	(-)	(+)

MD, Meniere's disease; SD, sudden deafness; CP, canal paresis; EcochG, electrocochleogram; EcochG (+), dominant -SP/AP-positive in EcochG; EcochG (-), dominant-SP/AP-negative in EcochG; NR, no response; NA, not applicable; Hydrops (+), hydrops-positive; Hydrops (-), hydrops-negative
Hearing level, average of 500, 1000, 2000, and 4000 Hz; S. O., scale out; Interval, interval between onset of disease and MRI examination
insufficient, insufficient study due to low enhancement; *, Figure is available



Endolymphatic hydrops detected by inner ear MRI

Oral Session B6 – ESCEBD & the Young Ones

B6-1

Presentation of the 'European Society for Clinical Evaluation of Balance Disorders' (ESCEBD)

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The European Society for Clinical Evaluation of Balance Disorders (ESCEBD) meets yearly since 2005 in Nancy, France. Each year, the society focuses on one or two themes related to equilibrium, aiming to obtain the standardization of balance testing and clinical recommendations. An extensive survey of the literature serves as a guideline for the organisation of the meetings to gain insight in the current opinion of clinicians regarding posturography as a clinical tool. Experienced users of posturography and specialists in balance control from about twenty different European countries regularly participate in the meetings with the following clinical background: ENT surgery, neurology, neurosurgery, ophthalmology, physical medicine and rehabilitation, geriatrics, paediatrics, cardiology, sport medicine, physiotherapy, neurophysiology and (clinical) physics. Each meeting begins with the presentation of the conclusions of the topic of the previous meeting. For each session, a coordinator is in charge of an introduction statement (synthesis of the literature) and will collect the questions put by the participants. For every question, experts will successively discuss and propose an answer, the aim to reach a consensus of opinion. Sessions concern for example determination of relevant parameters in posturography; balance control sensory organisation: posturography parameters aiming to determination of sensorial preference; dizziness in elderly; posturography and risk of recurrent falls; posturography and vestibular pathologies: interest for diagnosis, in rehabilitation and for the follow-up of rehabilitation; postural control evaluation in dual-task situations; advances in recognition of posturography as a medical act. The day before the meeting is traditionally assigned to a round table concerning motion sickness susceptibility and the day after to the defences of PhD or Habilitation dissertations.

B6-2

Vestibular-evoked myogenic potential (VEMP) to evaluate cervical myelopathy in human T cell lymphotropic virus type I infection

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Introduction: Vestibular Evoked Myogenic Potential (VEMP) is a middle-latency evoked potential generated by vestibulo-spinal muscle reflex recorded in the ipsilateral muscle, more commonly the sternocleidomastoid (SCM), in response to intense acoustic or galvanic stimulation of the saccule in the internal ear. VEMP explores the sacculocollic pathways which is from the saccular macula through its primary vestibulospinal neurons to the lateral vestibular nucleus, the medial vestibular tract and finally to motor neurons of the ipsilateral SCM. Damage to any of the structures related to the VEMP pathway results in abnormalities of these potential. This test may be of value to investigate sub-clinical cervical mielopathy. HAM/TSP is a progressive inflammatory myelopathy with predominant lesions at the thoracic spinal cord level, although cervical spine can be affected. The purpose of the present study was to define clinical usefulness of VEMP to detect cervical medular involvement related to human T cell limphotropic virus type 1 (HTLV-1) associated myelopathy / tropical spastic paraparesis (HAM/TSP). Methods: Seventy-two individuals were evaluated: 30 HTLV-1 seronegative and 42HTLV-1seropositive (22 asymptomatic, 10 with complaints of walking difficulty without definite HAM/TSP, 10 with definite HAM/TSP). VEMP was recorded using monaural delivered short tone burst (linear rise-fall 1ms, plateau 2 ms, 1 KHz) 118 dB NA, stimulation rate of 5Hz, analysis time of 60 ms, 200 stimuli, band pass filtered between 10 and 1.500 Hz. Results: VEMP had normal values in the seronegative group (30 controls). In the seropositive, abnormal VEMP was seen in 11/22 (50%) of the HTLV-1 asymptomatic carriers, 7/10 (70%) of those with complaints of walking difficulty and 8/10 (80%) of the HAM/TSP patients. In this last group, the pattern of response was different. No VEMP response was more frequent when comparing to the asymptomatic carriers (2-tailed P-value $=$ 0.001). Conclusion: VEMP may possibly be useful to identify patients with subclinical cervical myelopathy and to distinguish variable degrees of functional injury. Minor injury would be related to latency prolongation and major injury to no VEMP response.

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B6-3

Postural control in adolescent extremely low birthweight preterm children

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Introduction: Motorproblems and issues with balance are a known problem amongst extremely low birthweight children ($<$ 1000 g)(ELBW). The postural control system is believed to be a factor in those problems.
Objective: To measure postural control in extremely preterm infants with a birth weight of less than 1000 g in comparison to full-term infants between the age of 14 and 19 years of age.
Patients and Methods: 29 ELBW preterm children and 40 fullterm children at 14–19 years of age took part in this study. In a relaxed upright position, static postural control was measured via a POSTCON^{TM} computerized force plate where balance, body sway and adaptation were evaluated.
Results: From the posturography the ELBW had significantly larger sway to the lateral direction ($p =$ 0.022) when the groups had open eyes. In the high frequency of movement ($>$ 0.1 Hz) the ELBW had a significantly larger sway in almost all acounts with open eyes. There was no significant difference when the groups had their eyes closed.
Conclusions: The adaptation of the postural control system in ELBW is similar to that of the fullterm group. On the other hand the ELBW group are unable to use optic information as well as the fullterm children in their postural control.

B6-4

Blood pressure and heart rate changes induced by sinusoidal galvanic stimulation of the labyrinths in the anesthetized rat

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Introduction: Numerous studies have shown that the vestibular system can produce changes in blood pressure in humans and animals (Reis, Ray, Yates, Macefield, etc.), and we have specifically demonstrated that off vertical axis rotation (OVAR), which sinusoidally activates the otolith organs by changes in head position re gravity, produces sinusoidal changes in blood pressure (BP) at the frequency of rotation (Kaufmann et al., 2002). Here we examined how sinusoidal galvanic vestibular stimulation (GVS) alters autonomic activity in the rat.

Methods: Binaural, sinusoidal GVS was given at 1, 2 and 4 mA at frequencies from 0.01 to 0.5 Hz via electrodes inserted behind the external auditory meati in isoflurane-anesthetized Long-Evans rats. BP was measured intra-arterially at a sampling rate of 250 Hz from the carotid and femoral arteries with a BP transducer and Grass amplifier. Heart rate (HR) was identified from BP peaks, stored as pulses and converted to beats/sec. Changes in BP and HR were fit with sinusoids, using a least mean square algorithm at the frequency of stimulation and at double the frequency. BP and HR modulation amplitudes were normalized to the stimulus current.

Results: There was a clear response of BP and HR at both the frequency of stimulation and at double the frequency as the sinusoidal anodal currents activated each labyrinth. One mA stimuli were ineffective at any frequency. Stimulation at 2 and 4 mA were most effective at low frequencies, and responses were inconsistent or absent at frequencies $\geqslant \neg$ 0.2 Hz. The onset of stimulation was associated with a 20 mm Hg drop in BP and a decrease in HR from 4 to 3 beats/sec ($p < 0.001$). Both parameters recovered within 2–3 min, even with continuous stimulation. Despite this, BP and HR continued to be entrained by the sinusoidal stimulation. The maximal response was produced by the first stimulus, and there was a gradual reduction in the slow decrease in BP when the stimuli were repeated. Thus, the vascular system habituated to the large drop in BP and HR, although Bp and HR continued to be synchronized at the stimulus frequency.

Discussion/Conclusions: Previous studies have suggested that low frequency sinusoidal oscillations of galvanic current primarily activate the otolith organs. Consistent with this, similar sustained drops in BP have been shown in alert and anesthetized rats after linear acceleration (Zhu et al., 2007), and in humans when they tilt their heads during constant velocity rotation (Dai et al., 2003). These results support the hypothesis that the vestibular system has a powerful effect on both blood pressure and heart rate, from activity that arises in the otolith organs.

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B6-5

Physiological effect of cupula shrinkage on the semicircular canal activity.

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Objectives: To examine the effect of half-sized cupula on the semicircular canal (SC) nerve potential.

Method: The posterior SC of the bull frog was isolated in Ringer solution and the entire cupula was removed. The removed cupula was sectioned in half with fine scissors. The half cupula was replaced on the crista. Mechanical endolymphatic flow, slow and fast stimuli were delivered and the evoked action potentials (CAP) of the ampullary nerve were recorded. For slow stimulus, rise-fall time was set to be 5 sec. and for fast stimulus, it was 1 sec. The maximum spike counts and duration of CAP were compared between slow and fast stimuli.

Results: The cupula was successfully sectioned in half and was replaced on the crista. With half-sized cupula, the CAP maximum spike count became smaller (about 79%) under slow stimulus than under fast stimulus. The duration was longer in the slow stimulus.

Conclusion: We have reported that the cupula shrinks under various insults, including drug intoxication and labyrinthitis. Cupula shrinkage creates space between the cupula top and the ampullary roof. This space allows the endolymph to escape when the stimulus is slow, resulting in smaller CAP spikes. Small CAP potentially leads to reduced caloric response. The CAP duration is, however, longer in slow stimulus and shorter in fast stimulus. Short duration in the fast stimulus is possibly due to quick swing back of the half cupula without anchoring effect of its margin with the ampullary wall. These results also suggest that shrunken cupula may cause dizziness because of its hypermobility, particularly when cupulolithiasis is present. Even without cupulolithiasis, hypermobility of the cupula may cause dizziness with slight head movement. This may be a new entity of vestibular pathology. For interpretation of the vestibular tests and the clinical picture of vestibular disorders, we need to be aware of change of cupular morphology in addition to hair cell or neuron lesions.

Oral Session B7 – Differential Diagnosis

B7-1

Dizziness in the emergency department

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Objectives: The aim of this study was to evaluate the extent and quality of work up of dizzy patients in the Landspitali Emergency department (LED).
Patients and Methods: All cases of dizziness as a main complaint among patients in the LED were identified and evaluated in a retospective fashion. Demographics, duration of symptoms, investigation results, diagnosis and other factors were recorded from medical records.
Results: From 1st November 2008 to 28th February 2009 a total of 163 cases were identified. Majority of patients were female, 102 cases (63%). Mean female age was 54 years (± 20 years) and mean male age was 50 years (± 21 years). Blood tests were acquired in 126 cases (77%) and results that could explain dizziness were seen in 26% of the 126 cases. In 69 cases (55%) an electrocardiogram was acquired and 17% of those had some abnormality. In 65 cases (40%) patients underwent a CT scan of the brain. In only 2 cases (2/65; 3%), results from the CT scan indicated a possible cause of dizziness. In 27 cases (17%) patients underwent a MRI of the brain. In 2 cases (2/27; 12%) results from the MRI indicated a possible cause of dizziness. Ninety eight consultations were obtained for 80 cases (49%) of dizziness. A neurologic consult was obtained in 46 cases (28%) and a consult from an Ear, nose and throat specialist in 43 cases (26%). Consultations lead to a diagnosis in 40 cases. In most cases patients were discharged from the LED (144; 88,3%). Mean stay in the LED for patients that were not admitted to other wards was 4,3 (± 2.8) hours. Nineteen patients were admitted, predominantly to the neurologic ward (10/19; 52.6%). About one third of the diagnosis were "otogenic" (47 cases; 28.8%), thereof 31 cases of benign positional vertigo (BPV). A heart disease was considered to be the cause of dizziness in 22 cases (13.5%) and a disease in the central nervous system in 18 cases (11.0%). In 52 cases (31.9%) patients were discharged from the hospital without a diagnosis. Among patients who were diagnosed with BPV, blood tests were acquired in 62.5%, a CT scan of the brain in 51.3% and an EKG in 31.3% of cases. In only 6 cases (6/31; 18.8%) patients were diagnosed with BPV clinically without any investigations.
Conclusions: Dizziness is a common complaint in the LED. Patients with dizziness tend to be overexaminated. Skills for clinical diagnosis of BPV need to be improved.

B7-2

Nystagmus assessments documented by emergency physicians in acute dizziness presentations: opportunity for improvement?

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Objective: Dizziness is a common presenting complaint to the emergency department (ED), and emergency physicians (EPs) consider these presentations a priority for decision making support. Assessing for nystagmus and defining its features if present are important steps for any decision algorithm for acute dizziness. We sought to describe nystagmus documentation in routine ED care as a measure of EP diagnostic reasoning to determine whether efforts to improve nystagmus assessments are justified.
Methods: Medical records from ED visits for dizziness were captured as part of a dizziness surveillance study embedded within an ongoing population-based cohort. Visits with documentation of a nystagmus assessment were reviewed and coded by vestibular specialists for presence or absence, ability to draw a meaningful inference from the description, and coherence with the final EP diagnosis when a peripheral vestibular diagnosis was made.
Results: Of 1,091 visits for dizziness, 887 (81.3%) documented a nystagmus assessment. Nystagmus was

present in 20.9%. When nystagmus was present, no characteristics of it were recorded in 26%. The documentation of nystagmus (including all descriptors recorded) enabled a meaningful inference about the localization or cause in only 5.4% of the visits. The nystagmus description conflicted with the EP diagnosis in 80.7% of visits receiving a peripheral vestibular diagnosis.

Conclusions: Nystagmus assessments are frequently documented in acute dizziness presentations but details do not generally enable a meaningful inference. Recorded descriptions usually conflict with the diagnosis rendered. Efforts to optimize nystagmus assessments are justified and may represent an opportunity to support decision making in dizziness presentations.

B7-3

Do different symptom sets represent different sites of pathology or different types of patients?

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Objective: Many of the patients referred to us have non traditional complaints that are still thought to be of vestibular origin. While many give histories of true vertigo, many others voice complaints of debilitating nausea (i.e. symptoms of vestibular deficit predominating over signs). Some patients have no symptoms at all aside from newly developed motion sickness. These various complaints are not characteristic of semicircular canal disease and have been attributed to being indicative of otolithic pathology. We have wondered why different patients related different sets of complaints, and whether this suggests pathology in different anatomical regions of the inner ear, or if it represents similar pathology in patients with different sensitivities between the anatomical structures and pathways of the balance system.

Vestibular evoked myogenic potential (VEMP) testing measures a reflex loop that involves the saccule and not the utricle, while subjective visual vertical (SVV) testing is thought to be a measure of utricular pathology. With these two diagnostic tools at our disposal, it is technically possible to narrow down a patient's complaints as coming from one or the other (or both) structures, and we suggested that there might be a symptom set which could be characteristic for saccular or utricular pathology, either in the presence or the absence of semicircular canal disease.

In a recent study, we looked at patients' predominant complaints, and one finding was that 100% of patients with nausea predominating had a VEMP abnormality, and in all but one patient, it was the only diagnostic abnormality found. Complaints of nausea in the absence of true spinning vertigo are thought to be of otolithic origin (comparable to space motion sickness)

Methods: 100 patients were referred to our tertiary/ quaternary care centre for complaints that were thought to be of balance system origin. Referrals included medical legal patients referred to us through the legal system and also regularly referred medical patients. Patients were divided up into three groups:

- No head injury related to onset of complaints
- Whiplash type of injury (but no head strike)
- Traumatic head injury of some type.

Patients with neurological abnormalities or orthopedic impairment were excluded. Patients also had to speak English ability to the point where a satisfactory history could be taken.

All patients underwent Computerized Dynamic posturography, VEMP, SVV, and caloric testing after extensive history taking.

Patients were divided up into groups by history, with five categories that we feel may be distinct from each other:

- True spinning as a predominant complaint
- Nausea as a predominant complaint
- Imbalance as a predominant complaint
- Sensation of non spinning movement as a predominant complaint
- Newly developed visual vestibular mismatch as a predominant complaint

Patients were delineated into groups by their presenting complaints, and they were specifically asked what their main complaint was ("If one thing could be fixed, what would you pick").

Results: SVV and VEMP testing were frequently the only abnormalities found in the "non-traditional" groups of patients (many of whom have symptoms that are often debilitating, but who have no signs of vestibular disease on examination or in everyday life). We will delineate which diagnostic technique is more helpful at demonstrating abnormalities in these patients and show whether one of the assessment techniques showed abnormalities more often in a specific group.

Conclusion: This study will demonstrate whether different families of symptoms represent pathology in different areas or different structures within the vestibu-

lar complex, or whether interpatient variability (e.g. patients who are innately motion sick, and more easily nauseated) is responsible for dictating the different symptom sets in these patients.

B7-4

Otosclerosis among patients with dizziness

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Objective: The objective of this study was to identify otosclerosis in a population of patients seen because of vertigo as primary and most distressing symptom and to characterize its clinical presentation.

Patients and Methods: This is a retrospective chart review in a tertiary medical center. 40 patients with dizziness who represent 0.85% of those seen in the study period (2000–09) were diagnosed of otosclerosis. At inclusion the clinical status, auditory (pure tone hearing level and speech audiometry) and vestibular function (bedside, nystagmography, caloric test and rotator chair testing) were assessed. The results were analyzed using parametric and non-parametric tests and the c2 test.

Results: Clinical presentation was diverse: Meniere's syndrome in 12 patients (30%), spontaneous recurrent vertigo without hearing fluctuation in 11 patients (27.5%), positional vertigo in 13 patients (32.5%), chronic unrelapsing imbalance in 3 patients (7.5%) and acute unilateral vestibulopathy in 1 patient (2.5%). In all the patients there was a lag between hearing loss detection and the beginning of vertigo attacks or imbalance. Hearing loss as measured by bone conduction was significantly different in patients with Meniere's syndrome, spontaneous recurrent vertigo and positional vertigo.

Conclusions: Dizziness although frequent in patients with otosclerosis rarely is a cause for specific clinical assessment. There is a lag between hearing loss perception by the patient and the initiation of vestibular symptoms and there is not a specific clinical disorder. As such it can be seen as any of the most common vestibular disorders and in general vestibular function tests disclose a more severe vestibular dysfunction than in the idiopathic forms.

B7-5

Canal and otolith function testing in subjects with vestibular schwannoma

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Objective: To characterize canal and otolith function in pre-operative vestibular schwannomas, we recorded video-head impulses,Vestibular-evoked myogenic potentials and conventional vestibular function tests in 10 subjects with unilateral medium-large vestibular schwannomas.

Methods: All subjects underwent neurotological examination, caloric function testing, video head impulses, subjective visual horizontal (SVH) testing and VEMPs. oVEMPs were recorded from unrectified infra-orbital surface electromyography (EMG) during upward gaze. cVEMPs were recorded from rectified and unrectified sternocleidomastoid EMG during head elevation against gravity. Responses to AC clicks delivered via headphones and BC forehead taps delivered with a mini-shaker (bone-conduction vibrator) and a triggered tendon-hammer were recorded.

Results: A majority of subjects (6/10) had a normal neuro-otological examination. Positive bedside head impulses were observed in 2/10. Two subjects had head-shaking nystagmus beating away from the lesion and two towards the lesion. The SVH fell outside the normal range in 7/10 subjects. Caloric function tests showed a significant canal paresis localising to the affected ear in 8/10. VEMPs to air-conducted sound were abolished or asymmetrical in 9/10 subjects. VEMPs to bone-conducted vibration pulses were asymmetrical in 8/10 subjects. Video head impulses yielded significant gain asymmetries (0.4:1–0.55:1).

Conclusion: Video head-impulses and VEMPs enable detailed, non-invasive assessment of canal and otolith function in pre-operative vestibular schwannomas. These techniques could enable prediction of the likelihood of debilitating vertigo after surgical deafferentation and contribute to the post surgical management of subjects with Vestibular Schwannoma.

B7-6

Endolymphatic hydrops in patients with superior semicircular canal dehiscence syndrome

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The symptom entity of the semicircular canal dehiscence syndrome (SCDS) consists of vertigo, hyperacu-

sis and hearing loss. It is often associated with Tullio phenomenon and impairment of balance and gait instability, with sometimes rotatory attacks of vertigo. The pathophysiology of SCDS is not known in detail. We have recently operated 4 patients in whom the symptoms mimicked Meniere's disease. The aim of the present study is to describe the symptoms and case histories in patients and show that endolymphatic hydrops is relative common consequence of SCDS.
Case 1. A female with unilateral SCDS and SCDS confirmed in CT. She had attacks of rotatory vertigo and sensory neural hearing loss with Tullio phenomenon. The superior semicircular canal dehiscence was resurfaced through middle fossa approach with a bone chip, fascia and a bone pate. After surgery she continued with vertigo symptoms and her hearing deteriorated. Clinically her symptoms mimicked those of Meniere's disease.
Case 2 with unilateral SCDS with hearing loss and Tullio phenomenon. He was operate with middle fossa approach with resurfacing of the dehiscence. He continued vertigo with Tullio phenomenon and developed fluctuant hearing loss, that occurred also previously healthy opposite ear. He had severe gait problems and vertigo attacks caused by physical strain. The second stage of surgery was made and the superior semicircular canal was obliterated through transmastoid approach with bone pate, fascia and bone chips. The symptoms alleviated successively so that the hearing level in the opposite ear stabilized at 30 dB level. He could still periodically suffer from balance problems especially after physical strain. Intratympanic MRI indicated vestibular endolymphatic hydrops in the vestibular part of the dehiscent ear.
Case 3. Patient with unilateral SCDS had drop attacks and moderate hearing loss. Before surgical approach we performed intratympanic MRI. The results showed vestibular and cochlear hydrops. We thereafter obliterated the semicircular with canal bone wax and resurfaced the dehiscence with thick bone chip and bone cement. All the symptoms disappeared. He had about 30 dB hearing loss in the dehiscent ear.
Case 4. has bilateral SCDS and because of recurrent vertigo attacks he was treated with intratympanic gentamicin elsewhere. MRI revealed endolymphatic hydrops. This patient waits for surgery.
Conclusion: SCDS can be associated with endolymphatic hydrops. We advocate to obliterate the dehiscent canal with bone wax and use bone cement to close the dehiscence. Resurfacing seem not to be effective in reducing hydrops associated with SCDS. In one case the previously healthy ear opposite ear developed referred hydrops.

B7-7

Gait disorders associated with bilateral sensorineural hearing loss due to late chronic Lyme disease in 2 patients

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Objectives: Lyme disease, which is caused by the tick-transmitted spirochete Borrelia Burgdorferi, is a multisystem disorder most commonly affecting the skin, joints, nervous system, or heart. The infection often begins with an initial skin lesion (erythema migrans). Days to weeks later, acute neuroborreliosis occurs typically with cranial paralysis, more often facial paralysis, or peripheral radiculoneuritis. Months to years later, untreated patients may develop manifestations of late Lyme disease including chronic neuroborreliosis or arthritis. Our goals in this study were: (i) to definitely confirm the Lyme disease in 2 patients, (ii) to emphasize the possible occurrence of gait disorders and bilateral sensorineural hearing loss and discuss the site of the lesion responsible for these symptoms, (iii) to access the efficacy of treatment in late stage disease.
Methods: Two patients, who complained of gait disorders and bilateral hearing loss, had a complete check-up including otoneurological examination, auditory explorations, MRI scans, and extensive biological investigations in serum and cerebrospinal fluid (CSF).
Results: A 12-year-old boy was referred for a progressive disturbance of gait, without vertigo or headache, and bilateral hearing loss for 5 months. There was no history of tick bite or erythema migrans. Neurological examination revealed spastic paraparesis. Pure tone audiometry showed a bilateral sensorineural hearing loss. The results of speech discrimination score, auditory brainstem responses and otoacoustic emissions suggested an endocochlear hearing loss. MRI scan was normal in the brain and spinal cord. A CSF examination showed a predominantly lymphocytic pleocytosis with elevated protein. Serology for Lyme disease was positive in both plasma and CSF. Antibiotics associated with steroids were effective on hearing loss but not on the spastic paraparesis. CSF abnormalities were improved.
A 62-year-old woman had a previous history of vertigo with a mild bilateral hearing loss and migraine. At the

beginning of 2006, she complained of an aggravation of her headache, which became more permanent, and was depressed. During the summer 2006, her hearing loss deteriorated on both sides. At the beginning of 2007, she complained of gait disorders with a cerebellar syndroma on neurological examination. There was no history of tick bite or erythema migrans. Pure tone audiometry showed a bilateral moderate to severe sensorineural hearing loss. The results of speech discrimination score and stapedial reflex suggested an endocochlear hearing loss. MRI scan was normal. A CSF examination showed a predominantly lymphocytic pleocytosis with elevated protein. Serology for Lyme disease was positive in both plasma and CSF. Antibiotics associated with steroids had a good but not complete effect on gait disorders and hearing loss. CSF abnormalities were improved.

Conclusion: Lyme disease was definitely confirmed by the detection of high titer antibodies to Borrelia Burgdorferi in both plasma and CSF and the presence of a lymphocytic meningitis that reduced after treatment. The gait disorder was due to central neurological dysfunction either a spastic paraparesis or a cerebellar disorder. On the contrary, the site of the lesion responsible for the bilateral sensorineural hearing loss was probably the cochlea. Treatment was partly effective probably because the mechanism in late Lyme disease is infectious but also due to autoimmune process. We suggest early testing for Lyme disease in central gait disorders and/or bilateral sensorineural hearing loss.

B7-8

Gaze displacement and eye-to-foot coordination during voluntary reorientations in standing parkinsonian patients

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Objectives: Multi-segmental coordination during horizontal gaze transfers was investigated in mildly affected, standing parkinsonian (PD) patients. Subjects (Ss) voluntarily re-orientated eyes and body to targets of eccentricities up to $\pm$ 180°. We have asked which derangements in the pattern of this complex, clinically relevant motor behaviour compromise task performance.

Methods: Ss stood upright and when a central LED at eye level was turned off, they had to locate and reorient themselves to a second LED which was lit at one of seven, different positions, either right or left. When this second LED was then extinguished, they had to turn back to the initial LED. As in the second occasion Ss knew where the target was, the movement was for eccentricities larger or equal to 90 deg memory driven. The experimental design allowed thus evaluation of the effect of target visibility and predictability on the resulting movement parameters. The covariation pattern of eye-in-orbit, head-on-trunk and trunk-in-space horizontal angular displacement was quantified by means of principal components (PC) analysis.

Results: Patients' movement initiation latencies were normal. In most trials to initially non-visible targets, the primary gaze shift fell short of the target and more than 50% of the visual angle was covered by the sum of nystagmic fast phases and head-in-space displacement. While normal Ss frequently acquired targets with a single large gaze shift during predictable trials, patients were unable to do so. In both normal and PD Ss, the combined movement was stereotyped such that the first two PCs accounted for the whole data variance of combined gaze transfers up to about 330 ms, suggesting that the three mechanical degrees of freedom (eye-head-trunk) are reduced to two kinematic degrees of freedom. However, in patients the eye contributed overall more and the trunk less to the gaze shift as compared with normal Ss. Peak trunk velocity and as a consequence of that peak head in space velocity were significantly decreased in patients. Acquisition time was significantly prolonged. Foot rotations, though of reduced amplitude and velocity, showed normal stepping frequency and coordination

Conclusions: The overall pattern of movement during a whole body gaze re-orientations is preserved in PD. However, slowness in trunk rotation compromises target acquisition on average by more than 0.5s during the course of 180 deg pivot turns.

B7-9

How balance deteriorates in migraineurs

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Objective: To investigate by static posturography the balance disorder in migraineurs without vertigo longitudinally over more than 1 year.

Background: While balance disorders have been shown in migraineurs there is no longitudinal data to show whether this gets better or worse or stays the same over time.

Methods: After more than 12 months we re-studied using static posturography, postural sway, limits of stability and tandem walking in19 migraineurs and their age-, gender- matched controls.
Results: In the 2nd study postural sway was greater or same in all conditions (head straight, head back, head sideways and eyes open or eyes closed) except one. With eyes open on a firm surface with head straight and on foam surface with head sideways migraineurs swayed significantly more in the 2nd study. With eyes closed on firm with head back and on foam with head back and sideways, they swayed more in the 2nd study. Average reaction time, maximal excursion and directional control were all worse the second time but only the average reaction time and maximal excursion were significantly worse. With eyes closed tandem walk speed was significantly lower the second time than the first time.
Conclusion: The balance disorder of migraineurs not only persists but can progress and might indicate subclinical vestibulo-cerebellar dysfunction.

B7-10
Vestibular migraine – validity of clinical diagnostic criteria at long-term follow up
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Objective: Vestibular migraine (VM) has been recognized as a frequent cause of recurrent vertigo in patients with migraine. However, clinical recognition of VM is still hampered by the lack of generally accepted diagnostic criteria and because there is an overlap of symptoms with other vestibular disorders such as Menière's disease (MD) and benign paroxysmal positional vertigo (BPPV). The aim of this study was to test the validity of previously proposed diagnostic criteria for definite vestibular migraine (dVM) at long-term follow up.
Methods: We re-assessed 45 consecutive patients (41 women, mean age 55 $+/-$ 11y S.D., range 32–76y) who had been assigned a diagnosis of dVM at initial presentation to our dizziness clinic based on the following criteria [1]:

1. $\geqslant$ 2 attacks of vestibular vertigo
2. migraine according to criteria of the International Headache Society (2004)
3. accompanying migrainous symptoms during $\geqslant$2 vertigo spells
4. no evidence of other central or otological causes of vertigo

Patients with concomitant auditory symptoms were excluded if they met diagnostic criteria for MD according to AAO guidelines (1995). Sixteen patients with auditory symptoms but not fulfilling AAO criteria were included.
Patients with positional vertigo were excluded if they had positional nystagmus typical of BPPV or if a history of recurrent episodes of purely positional vertigo lasting a maximum of 1 minute was highly suggestive of BPPV. Patients presenting with atypical features such as additional spontaneous vertigo, duration of positional vertigo of $>$ 1 minute or atypical nystagmus on positional testing were not excluded. The median duration since onset of vestibular symptoms at initial presentation was 54 months (range 1–600 months). The mean follow up time was 104 $\pm$ 17 months.
At follow up, all patients underwent a repeat neurotological assessment including a structured interview, clinical neurotological examination, pure tone audiometry ($n = 45$) and caloric testing ($n = 34$).
Results: A diagnosis of dVM was confirmed in 39 out of 45 patients (87%). In six patients a competing vestibular or non-vestibular cause of vertigo could not be excluded. One patient reported vertiginous symptoms that could no longer be differentiated with certainty from non-vestibular dizziness due to an anxiety disorder. Five patients had developed hearing loss including the low-frequency range that fulfilled AAO criteria for bilateral MD (mean hearing level at 0.5–3 kHz $>$ 25 dB in both ears). Hearing loss was moderate in one patient (hearing level $\leqslant$ 45dB). In four patients hearing loss was unusually mild for longstanding MD (hearing level $\leqslant$ 35 dB). All five patients had migraine with aura and vertigo spells were always accompanied by at least one migrainous symptom. These five patients, thus, fulfilled diagnostic criteria for both MD and VM. Three patients presented with recurrent episodes of positional vertigo of $<$ 1 min duration which were sometimes accompanied by migrainous symptoms. All patients had clinical features unusual for BPPV (atypical positional nystagmus ($n = 2$), additional spontaneous vertigo ($n = 1$)) and, therefore, dVM was diagnosed.
Conclusions: Follow up confirmed a diagnosis of definite VM according to our proposed clinical criteria in 87% of cases. The main differential diagnoses of VM are MD and BPPV. Because of an overlap of symptoms, current diagnostic criteria for VM and MD do not suf-

ficiently discriminate the two disorders. An alternative hypothesis is that a common pathophysiological mechanism may be operative in a subgroup of patients with VM and MD.

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Oral Session C1 – Specific Gravity

C1-1

Gravity sensitive cupula: light/heavy cupula of lateral semicircular canal (LSC)

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Background: In recent years, a few Authors referred about steady intensity and persistent direction changing positional nystagmus (PDCPN) observed either rotating patient's head from side to side in the yaw plane while supine, or changing its bending angle in the pitch plane in upright position.

It has been suggested that this phenomenon could be caused by a modified density ratio between LSC cupula and the surrounding endolymph. It was hypothesized that the cupula is lighter than the endolymph (light cupula) in patients showing a geotropic PDCPN, and the cupula is heavier (heavy cupula) when an apogeotropic nystagmus is evoked.

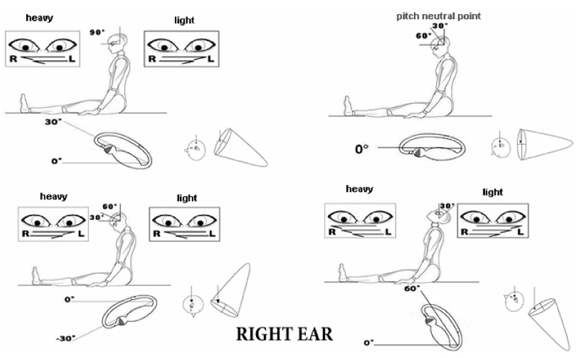
Objectives: two paradigmatic cases selected from a series of 22 patients are discussed showing their videonystagmoscopic recordings. A spatial model of the gravity sensitive cupula is drawn: a geometric representation of the cupular movements is proposed, comparing the observed nystagmuses evoked in different head positions according to the Ewald's laws.

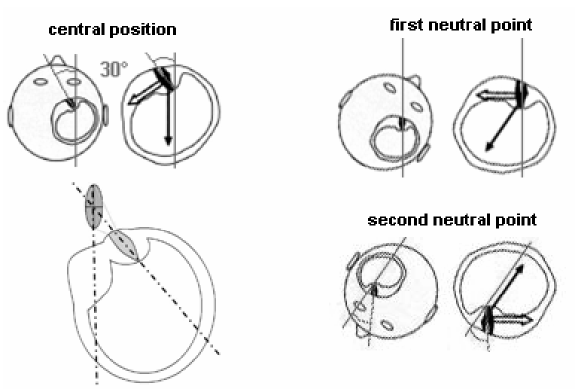
Methods: the patients are examined by infrared videonystagmoscopy (VNS). Firstly the patients are observed by VNS in the seated position, changing the head bending angle in the pitch plane. Then the patients are examined by VNS in the supine position rotating the head in the yaw plane. In this way a geotropic or an apogeotropic nystagmus is evoked and it is possible to distinguish which one is the involved ear: in fact, the stronger nystagmus beats towards the affected side, according to the Ewald Second Law.

Results: In upright position a horizontal nystagmus is observed. It decreases bending forwards the patient's head, it disappears reaching a forward bending angle of 30 degrees (neutral point in pitch plane upright) and finally changes its beating direction after the patient's head reaches a forwards bending angle of approximately 60 degrees. The nystagmus decreases by slowly returning the head backwards, reaching the neutral point again and reversing its beating direction after the head is back in axis with the trunk and is bent backwards (Fig. 1). The VNS examination in the supine position evokes a persistent direction changing positional nystagmus on each side, geotropic or apogeotropic. Two neutral points are identified rotating the head in yaw plane while supine: the first neutral point with the head rotated about 30° towards the affected ear, and the second one in the 180° opposite position (Fig. 2). The nystagmus reverses its beating direction once the head is rotated beyond each neutral point in the yaw plane.

Conclusion: According to previous studies on human fetuses by Curthoys and Oman we can suppose that the gravitational vector acts on a flat cone shaped cupola, having an elliptical base with two axes, the longer one based on the ampullary crista (Fig. 2). The cupula rotates around the fixed longer axis of its elliptical base, with one degree of freedom, like a door on its hinges. The gravitational vector moves the gravity sensitive cupula to and fro around the ampullary crista. Gravity acts on cupular faces, which are roughly comparable to the plane identified by two straight lines: the longer axis of the cupular basis and the straight line running through the centre of the cupular basis and its apex. If the gravitational vector is parallel with one of those two axes it is ineffective in moving the gravity sensitive cupula. The neutral points provide the clinical evidence of both geometrical conditions. The gravitational vector is parallel with the longer axis of the cupular basis at the neutral point in the pitch plane. The gravitational vector is parallel with the straight line running through the centre of the cupular basis and its apex at the two neutral points in the yaw plane.

Right LSC: PDCPN in the pitch plane





Right LSC cupula's axes and PDCPN in the yaw plane

C1-2

Can the nystagmus pattern in patients with a 'light cupula' in the lateral semicircular canal be reproduced during the stage of positional alcohol nystagmus I in hemilabyrintectomized subjects

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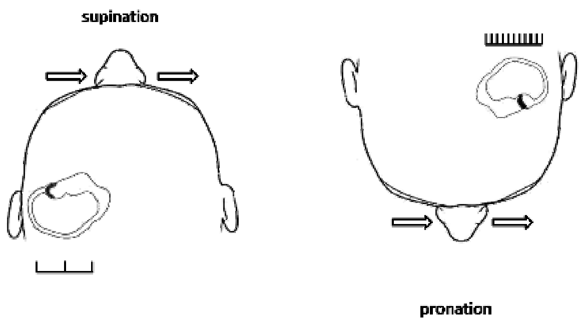
Conclusion: A positional nystagmus pattern compatible with a condition of a "light" cupula in the lateral semicircular canal found in clinical patients could only partially be reproduced in hemiabyrnithectomized subjects during the stage of PAN I. The pathophysiological mechanisms behind a "light" cupula have to be further studied. Objectives. To mimic the condition of a "light cupula" in the lateral semicircular canal by using unilaterally deafferented subjects during the stage of PAN I and compare the nystagmus directions at different head positions with the nystagmus found in patients with a "light" cupula. Patients and methods. By using alcohol as a cupula density changing compound five subjects who earlier had been submitted to labyrinthectomy were studied during PAN I with videonystagmography when they kept their head straight forward or turned sideways in prone and supine positions respectively. A zero zone where the geotropic nystagmus changed direction during slow head turn in supine position was also looked for. Results. The alcohol induced nystagmus pattern was compatible with that of a "light" cupula when the subjects were examined with the head turned to left or right in supine and prone position. However the nystagmus directions at head straight forward in prone and supine position as well as the localization of zero zones deviated from the pattern seen in patients with a "light" cupula.



Nystagmus direction in pitch plane during PAN 1

C1-3

Oculomotor deficits caused by 0.06% and 0.10% blood alcohol concentrations and relationship to subjective perception of drunkenness

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Background: The visual system is vital during critical activities such as driving. Studying how alcohol compromises the system physiologically is important for safety reasons.

Aim: The objective of the study is to investigate alcohol related impairments in performing visual tasks under controlled breath alcohol concentrations (BAC) to determine dose-dependent effects.

Method: Alcohol's effects on smooth pursuit and saccadic eye movements at 0.06% and 0.10% BAC were examined whilst recording alcohol levels by real-time measurements using a high precision breath analyzer. Oculomotor performance was recorded from 25 subjects by electronystagmography, comprising measurements of smooth pursuit gain, saccade velocity, saccade accuracy and two novel parameters further describing oculomotor performance.

Results: Alcohol deteriorated accuracy of smooth pursuit movements ($p < 0.001$) and saccadic velocities ($p < 0.01$) at 0.06% BAC. At 0.10% BAC, smooth pursuit gains ($p < 0.01$), saccade accuracies and saccade latencies ($p < 0.01$) were also affected. The ratio between saccade velocity and saccade amplitude decreased significantly under alcohol intoxication ($p < 0.01$). Self-perceptions of drunkenness correlated well with changes in smooth pursuit accuracy, but poorly with other oculomotor measures.

Conclusion: Several of the smooth pursuit and saccade functions were altered dose-dependently and small changes in BAC substantially changed the effects observed. Additionally, alcohol altered the relationship between saccade velocity and saccade amplitude, diminishing the capacity for saccades to reach high peak velocities. The alcohol-induced oculomotor deficits, which were found already at 0.06% BAC by our more sensitive analysis methods, may have safety implications for tasks that rely on visual motor control and visual feedback.

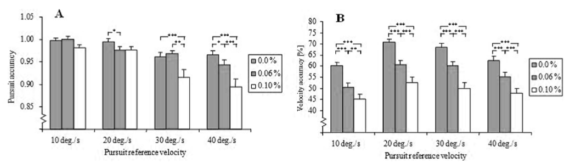

Figure 1A: Gain values between average smooth pursuit eye movement velocity and target movement velocity (mean and SEM) for four target velocities during different levels of BAC. A value of 1.00 represents perfect average smooth pursuit gain and a value below 1.00 represent that the average smooth pursuit velocity was below the target velocity. Figure 1B: Average smooth pursuit velocity accuracy values, representing the percentage of time the smooth pursuit velocity were within the target velocity boundaries of less than 20% absolute velocity error compared with the visual target velocity (mean and SEM), during different levels of BAC. A value of 100 represents that the smooth pursuit eye movement velocity were always within the boundaries of less than 20% velocity error. (*denotes P<0.025, ** denotes P<0.01 and *** denotes P<0.001).

C1-4

Dizziness and stand/gait unsteadiness in CSF hypovolemia

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Introduction: Cerebrospinal fluid hypovoremia (CSF hypovolemia, intracranial hypotension) is a condition caused by leakage of cerebrospinal fluid commonly as the result of traffic accident. Patients often consult the otorhinolaryngology department due to such symptoms as headache, dizziness, hearing loss, tinnitus, olfactory dysfunction, taste disorder, or visual disturbance. In the current study we examined the vestibular function in patients with CSF hypovolemia diagnosed by RI cisternography.

Objectives: It has been reported that dizziness and stand/gait unsteadiness in CSF hypovolemia was caused by vestibular nerve traction. The aim of the current study is to examine the vestibular function of this disease in order to clarify the cause of dizziness and stand/gait unsteadiness in CSF hypovolemia. Further we will exhibit patients in whom dizziness improved or disappeared by bed rest and/or epidural blood patch.

Subjects and Methods: 37 patients (13 males and 24 females, age ranged from 23 to 59, with an average 38.9 years) who were diagnosed as CSF hypovolemia using RI cisternography were analyzed. 17 patients were caused by traffic accidents, 3 by fall, 2 by collapse,3 by head injury, one as a result of operation and 11 with unknown cause. RI cisternogram showed an early appearance of radioactivity in the urinary bladder and/or decrease of RI residual rate. The tests conducted to see the vestibular function in these patients were observation of spontaneous or gaze nystagmus, eye tracking test, optokinetic pattern test, Caloric test, and stabilometer.

Results: The most frequent symptom seen in the patients was chronic light-headedness. Spontaneous or gaze nystagmus was not recognized in most patients. Eye tracking was smooth and optokinetic nystagmus was well released in most patients. Canal paresis was scarcely seen. As for stabilometer test, we found in our patients wide sway area and relatively short locus length per unit area both with eyes open and with eyes closed. Statokinesigram tended to be either diffuse or forward-backward type. Romberg ratio was not so high. Velocity vectors increased in the forward-backward direction.

Conclutions: The vestibular function test of the patients with CSF hypovolemia did not show any clear abnormal finding except in stabilometer test. Therefore, it seems that the vestibular nerve traction theory is not reasonable as to the cause of dizziness and unsteadiness of this disease. Stabilometer test was supposed to be useful for evaluating stand unsteadiness in the patients with CSF hypovolemia. Although most of the CSF hypovolemia was caused by traffic accident, some were caused by unknown origin. These patients tended to be treated such as Meniere's disease, perilymph fistula or psychogenic disease for a long time. We need to pay careful attention for these patients so that we might not miss the diagnosis of CSF hypovolemia.

C1-5

Obesity and postural sway during quiet upright stance

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Objective: To assess the influence of the body mass index group (lean/ overweight/ obesity) and the gender on the postural sway of adults and adolescents during quiet upright stance.
Methods: Ninety women and 90 men accepted to participate, they were between 12 and 67 years old (mean age 35.8 ± S.D. 12.1 years). Postural sway, during quiet upright stance, was recorded at 40Hz using a force platform, during 4 conditions: while adding or not a layer of foam rubber to the base of support, with the eyes open or closed. A multivariate analysis of covariance was performed for each surface condition, including the repeated measures with the eyes open or closed.
Results: Although the body mass index of women and men was similar, obesity was more frequent among women, while overweight was more frequent among men. During recordings on hard surface, when the eyes were closed, obese subjects showed a larger length, area and average velocity of sway than lean and overweight subjects. Although gender differences were found during the four sensory conditions, no interaction was observed between the gender and the body mass index group. Additionally, during recordings on the foam rubber, with the eyes closed, the age was related to the length, the average velocity and the length as a function of the area of sway.
Conclusion: The findings suggest that obese subject may be more dependent on vision to control balance, with no interaction with the gender.

Oral Session C2 – Motion Sickness

C2-1

Vertigo induced by downhill mountain biking and road cycling

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Injuries, which are mainly the consequence of falls, are reported both in road cycling and downhill mountain biking despite the consensual recommendation to wear devices to protect head, back, neck, elbows, knees and shoulders. In addition, benign paroxysmal positional vertigo has been observed after intensive mountain biking without head trauma. Displacement and/or dislocation of otoconia in the inner ear, possibly induced by vibrations and jumps, could explain this injury. Because vibrations and jumps are more common in downhill mountain biking than in road cycling, vertigo symptoms may occur more frequently in downhill mountain bikers than in road cyclists. The purpose of this study was therefore to investigate the prevalence of vertigo following competitions and training of downhill mountain biking and road cycling.In this prospective study, 111 downhill mountain bikers and 80 road cyclists filled in a questionnaire on the occurrence of vertigo induced by biking and bicycling practice, daily life activities and the possible determinants for its development. The participants were asked to describe specific bicycling events possibly involved in the occurrence of vertigo, such as falls, repeated intensive vibratory exposure (e.g. downhill on rough terrain), linear acceleration-deceleration events (high speed downhill), angular acceleration-deceleration events (set of multiple turns), jumps and exhaustion. The yearly riding time (in hours per year) of downhill mountain biking and road cycling was also gathered.Cyclists reporting vertigo after competitions and/or training were younger ($p = 0.020$) and practiced mainly downhill mountain biking ($p = 0.014$). Vertigo was associated with bicycling-related exhaustion in road cyclists ($p = 0.001$) and with repeated linear acceleration-deceleration events ($p = 0.094$) and falls in downhill mountain bikers ($p = 0.001$).The pathophysiological mechanisms generating vertigo might be directly related to the specific characteristics of each type of bicycling. The higher prevalence of vertigo in downhill mountain bikers may be explained by the bicycling practice conditions. Indeed, vibration impacts, acceleration-deceleration events, jumps and falls occur more frequently in downhill mountain bikingthan in road cyclists. In road cycling, effort related disturbance of homeostasis might induce vertigo. Dehydration is often observed in such sport activity and is known to generate important changes of homeostasis. The modifications of volume and composition of the endolymph in case of dehydration may alter vestibular input. Such mechanism as well as brain cortical perfusion changes might explain the vertigo reported by road cyclists. On the other hand, the duration of a downhill mountain biking run is very short often less than 5 min. Thus, exhaustion and dehydration are unlikely to be the main cause of vertigo. Moreover, vertigo occurred not only after falls, being themselves the strongest linear deceleration, but also after linear acceleration-deceleration events. The acceleration-deceleration events recorded by the head, as well as consequences of falls, might generate transient dysfunction of brain and of peripheral vestibular structures, particularly the otolith organs which analyze linear horizontal and vertical accelerations of the head. Despite the need to investigate more precisely the vestibular function of the downhill mountain bikers, the usage of adapted materials to absorb vibrations and jumps (frame, suspensions, wheels, tires) is recommended as well as helmet's wearing and responsible behaviors.

C2-2

Motion sickness and tilting trains

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Objectives: Trains can go faster around curves if the cars are tilted inwards to compensate for the centripetal acceleration, significantly decreasing travel time. But there is a speed-up/comfort trade-off, as many passengers complain of motion sickness on tilting trains. In a joint study with the Swiss Train System (Schweizerische Bundesbahn, SBB), we wished to determine why this occurs with the aim of developing tilting strategies that would significantly reduce the discomfort. The strategy that we tested was based on our investigations of a potent way to induce motion sickness by tilting the head in roll while rotating about a yaw axis (Dai et al., 2003). Preliminary data indicated that we could dramatically alter motion sickness sensitivity by changing the phase between yaw and roll. We postulated that inappropriate synchronization of roll with lateral acceleration as cars entered and left the turns was the responsible factor. A similar hypothesis has been proposed by Griffen (2007).

Methods: Physical data from accelerometers at different locations on the train and the subjects' heads were coupled with a survey by the SBB to measure motion sickness and travel comfort of the passengers riding under different conditions. The experimental train had three configurations: 1) 'No tilt', in which the trains simply rode the curves, generating substantial centripetal acceleration. 2) 'Reactive' Tilts, i.e., tilts initiated by accelerometers on the front wheels that detected the onset of the curves. This information then initiated the sequential tilts of the cars. The cars tilted 0.54°, 1.28° and 8° in the 'reactive' mode on separate rides. 3) 'Predictive' Tilts, i.e., tilts initiated by a system that detected the onset of curves from a 'look-up' table based on the position of the train on the track. Cars tilted 8° in the 'predictive' mode. SBB recruited two hundred subjects; one hundred had previously complained of having motion sickness while riding on tilting trains. The other one hundred had no complaints. Each day, a different set of forty subjects (20 motion sickness susceptible) rode four round trips between Winterthur and Gossau (St. Gallen) and rated their comfort level every ten minutes.

Results: Lateral acceleration was maximal in the 'no-tilt' condition, when the trains simply rode the curves, and there was no compensatory tilt of the cars. Passengers were most comfortable in the 'no-tilt' condition. This showed that lateral acceleration, itself, was not responsible for the induction of the motion sickness. Roll velocities were shorter, more precise, and had better-defined beginnings and endings with the 'predictive' than the 'reactive system'. Postural stability was also much better when standing or walking in the train in the predictive mode. Concomitantly, there was significantly less motion sickness when subjects rode in the predictive than the reactive mode, regardless of angle of tilt.

Conclusion: The finding that motion sickness was essentially abolished when roll and yaw velocities were well coordinated at the onset and end of the turns supports our initial hypothesis. It indicates that motion sickness can be reduced or eliminated on tilting trains by performing the compensatory roll tilts of the trains at the onset or in synchrony with lateral acceleration when entering and leaving turns.

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C2-3

Motion sickness and postural stability

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The most cited theory on motion sickness is the conflict theory by Reason and Brand [7], stating that motion sickness occurs due to a conflict between the senses and stored patterns of motion. In addition, there seems to be evidence for another theory stating that postural instability is a necessary and sufficient condition preceding motion sickness [9].

However, contradicting data have been published too [3,4,8,10]. Moreover, people without functioning organs of balance generally do not get sick from motion, while they do show more postural instability than healthy subjects do (e.g., Guerraz et al. [5]). Malfunction of the labyrinths, furthermore, also shows that even when laying down in bed such that postural stability is not at issue at all, Ménière patents may still suffer from sickness. Yet other, although mainly anecdotal, observations nuancing the postural stability theory concern the beneficial effect of mental distraction, the distraction unlikely causing postural instability first, only subsequently resulting in a reduction of sickness. Lastly, the postural instability theory also states that prolonged instability is required to get sick, while cross-coupled or Coriolis effects may cause sickness within seconds (e.g., Benson [1]), as may also do visual effects in, e.g., space, in which condition posture is not at issue either. These observations altogether do nuance the postural stability theory. Moreover, a conflict based framework presented first by Oman [6] and further elaborated by Bos and Bles [2] may explain why and when postural instability is correlated with sickness, and when it is not.

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C2-4

Subjective body alignment with G-vector seems independent of G-load

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In centrifuge-based flight simulation higher G-loads are produced by excentric rotation of the cabin. The acceleration acting on the pilot is the vector sum of the centripetal acceleration and gravity, i.e. the gravito-inertial acceleration (GIA). Normally, the algorithm that controls the orientation of the simulator cabin exactly aligns the cabin with the GIA, analogous to the physics of coordinated flight in the real aircraft. However, it is questionable whether such exact alignment is necessary form a psychophysical standpoint.

The purpose of this study was to determine how accurate humans can align a simulator cabin with the simulated g-vector. From studies on the subjective vertical we know that humans can adjust their own body orientation to the 1 g Earth-vertical with an accuracy of only a few degrees. We hypothesized that the alignment with a GIA higher than 1g would result in larger errors because of the higher background g-level.

Method: 18 male participants were asked to actively align the cabin of the Desdemona simulator with the

GIA at three different g-levels: 1 g, 1.4 g and 2 g. The g-levels 1.4 and 2 g were achieved by centrifugation of the cabin at a 4 m radius. At the beginning of each trial the cabin was misaligned around the roll-axis, the misalignment varying randomly between -12 and 12 deg between trials. Subjects then actively controlled the roll angle of the cabin using an active side stick until they perceived themselves aligned with the GIA (in aviation terms this means that they did not feel any side slip). In all conditions the projected out-the-window visual corresponded to an aircraft turn of 1.0 g (level flight), 1.4 g (45 deg angle-of-bank), and 2.0 g (60 deg angle of bank). The display was located at 1.5 m in front of the subject, and had a field-of-view of 120 deg x 32 deg, horizontal x vertical.

Results: The results showed that subjects were able to align themselves within 2 deg with the g-vector, independent of the g-level. The average misalignment amounted to $+0.8$, -1.4 deg and -1.6 deg in the 1.0 g, 1.4 g and 2.0 g conditions, respectively. These values were not statistically significant. Standard deviations did not statistically differ either.

Conclusion: Our results suggest that subjective body alignment with a g-vector does not depend on the g-level. Apparently, the perceptual invariant for perceiving deviations from the g-vector is the ratio between the longitudinal (gz) and lateral component (gy) of the g-vector, rather than the lateral component itself. Although not significant, the results also indicated small biases to negative misalignments in the higher g conditions, resulting in a slight undershoot. This observation may be due to the fact that in centrifuges with a short radius there is a considerable gradient of the g-magnitude along the body axis, because the subject's head is closer to the centre of rotation than his feet.

C2-5

Galvanic vestibular stimulation (GVS) as an analog of post-flight spatial disorientation in shuttle pilots

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Introduction: Our studies have shown that 20% of shuttle landings have been 'hot', with touchdown speed above the upper limit of 214 kts [1]. We have developed an analog of post-flight spatial disorientation in shuttle pilots utilizing GVS [2,3], which we recently tested in the Vertical Motion Simulator (VMS) at NASA Ames Research Center.

Methods: Performance of 11 subjects (2 veteran astronauts, 4 NASA test pilots, 4 veteran US Air Force pilots and 1 veteran US Navy pilot) was assessed during simulated shuttle landings in the VMS (used for shuttle pilot training). Subjects performed 8 pairs of identical landing profiles (final approach and touchdown; see Fig. 1a) with and without GVS, presented in a pseudorandom order (16 landings per subject; 176 total; 88 with and 88 without GVS). The landing profiles were taken from the training matrix for astronaut pilots with wind, navigational offsets, heads-up display failures, and ceiling variations based on actual shuttle landings. Simulation parameters were a landing weight of 226,244 lbs (the VMS uses Imperial units), 9910 ft initial altitude, 295 kts initial airspeed, and target touchdown at 204 kts ('good' range 194–209 kts) at a vertical sink rate of less than 3.5 ft/s. The GVS stimulus consisted of a sum-of-sines (0.16, 0.33, 0.43 and 0.61 Hz) limited to $\pm$ 5 mA.

Results: Touchdown speed was significantly higher ($p = 0.026$; ANOVA) with GVS (208.6 kts [SD 12.1]) compared to the no GVS condition (204.6 kts [SD 11.7]). The adverse effects of GVS on pilot performance were obvious. Unsuccessful (crash) landings increased from 2.3% (2/88) without GVS to 9% (7/88) with GVS. Hard landings, with touchdown speed in the 'red' (unacceptable) range ($>$ 214 kts), almost doubled from 14 (15.9%) without GVS to 27 (30.7%) with GVS; GVS also induced a 32% increase in the number of landings with a vertical sink rate in the unacceptable range ($>$ 5 ft/s), from 19 to 26.

The most critical portion of shuttle landing is preflare, where the pilot inputs a command (beginning at 2000 ft) to bring the shuttle nose up and transition from the steep (18°) outer glide slope to the shallow (1.5°) inner glide slope (Fig. 1a; shaded area). This presents a larger surface area to the oncoming airflow and slows the orbiter for touchdown. GVS induced erroneous roll inputs during preflare (Fig. 1b,c), likely due to the pilot perceiving the pseudorandom Galvanic current as roll perturbations of the shuttle. However, the effects of GVS were not confined to roll; erroneous pitch control inputs, including pilot-induced oscillations, were also observed (Fig. 1d,e). An example of this phenomenon during identical landing profiles with and without GVS (performed by a veteran shuttle commander) is shown in Fig. 1. Across all subjects there was a significant increase in both pitch command input (RMS $p <$ 0.00001; peak-to-peak $p = 0.0002$) and pitch velocity of the shuttle (RMS $p < 0.00001$; peak-to-peak $p = 0.0007$) during preflare with GVS relative to the no GVS condition.

Conclusion: GVS was an effective analog of decrements in shuttle pilot performance (in particular, 'hard' landings) following microgravity exposure. GVS induced erroneous pitch command input during pre-flare, perhaps due to the increased difficulty in resolving the changes in linear acceleration and angular velocity in the presence of added GVS 'noise'.

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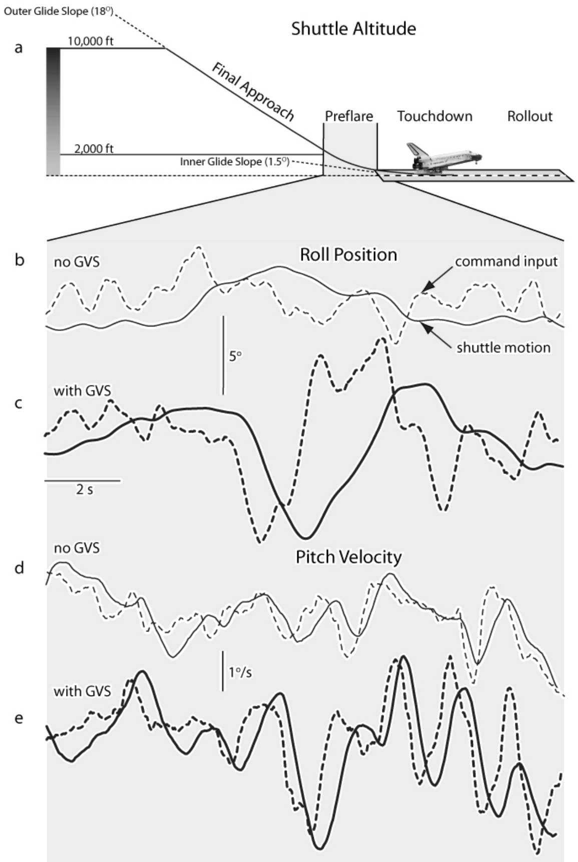

Landing data from a veteran shuttle commander

C2-6

Somatogyral illusions during flight: effect of the post-roll illusion on pilot's control behaviour

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Background: Due to the high-pass characteristics of the semicircular canals, the rotation sensation dies out during constant velocity rotation, and a sensation of rotation in the opposite direction arises when the rotation stops. This phenomenon is known as the somatogyral illusion. A model of the semicircular canal dynamics predicts that the magnitude of this illusion depends on the amount of per-rotary response-decay. This has been extensively studied for rotations about the vertical yaw axis, where the rate of decay is relatively low (due to velocity storage). In roll – where the sense of counter rotation is referred to as the post-roll illusion – the situation is different. Due to the absence of velocity storage the response-decay is faster, and noticeable after-effects may occur after shorter movements than in yaw. This has implications for flying, where short roll movements occur frequently. When unnoticed, the post-roll illusion may trigger the pilot to give erroneous control inputs leading to excessive aircraft bank.

Objectives: We hypothesized that the post-roll illusion is determined by both the duration and angular rate of roll motion. We investigated this by studying the effect of different roll stimuli on the control inputs of pilots who actively stabilized the aircraft bank in a moving-base spatial disorientation trainer.

Methods: In flight roll manoeuvres are often coordinated, meaning that the gravito-inertial vector is always aligned with the pilot, and the graviceptors do not provide roll cues. When aircraft roll is simulated by simply tilting a simulator relative to gravity this will give the sensation of uncoordinated flight, or sideslip. For that reason, we tilted the simulator backward as to orient the subject in a supine position with his roll-axis being earth vertical. In this situation, simulator roll was independent of gravity, simulating coordinated flight. Subjects ($n = 15$) were exposed to six different motion profiles (reference condition, 10°/s for 12 s, 30°/s for 2 and 6s, 60°/s for 2 and 6s) and were instructed to "hold attitude" following the roll movement, without any visual attitude reference. In other words: they had to cancel all perceived cabin motion following the roll movement. Three simulation conditions were investigated. In the first two, subjects were either blindfolded (BLIND) or viewed the interior of the cockpit (COCK-

PIT; no outside view or instruments) and roll motion was automated. In the third condition (LEAD) subjects actively performed the roll motion by following a lead aircraft that disappeared in the fog (no visual attitude information) after the desired movement. The subjects' control input and simulator movement following each roll movement were recorded.

Results: In general, subjects corrected for the perceived counter-rotation by inducing a roll in the same direction as the preceding movement. Effects were smallest in the BLIND condition and largest in the LEAD condition where the pilot was in the loop. The effect increased with roll rate and duration. These results reflected the semicircular canal dynamics and were in accordance with a semicircular canal based motion perception model.

Conclusion: The results indicate that the post-roll illusion affected the pilot's ability to maintain a stable attitude following a roll movement when visual attitude cues are absent. Although the effect is largest with sustained rolling motion, it is also present in shorter movements lasting only 2s. As far as we know, this was the first successful attempt to reproduce the post-roll illusion in a ground-based spatial disorientation trainer. Such demonstration may be useful in demonstrating this effect to student pilots.

Oral Session C3 – Neuro & Neck

C3-1
Classification of vestibular migraine

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Objectives: Vestibular migraine (VM) has evolved as a diagnostic concept over the past two decades and is currently recognized as one of the most common causes of recurrent vertigo. The diagnosis relies on symptom patterns as provided by the patient since specific clinical and laboratory findings are lacking. The Committee for the Classification of Vestibular Disorders of the Barany Society commissioned an international group of neurologists and ENT specialists to formulate explicit diagnostic criteria for VM.

Methods: The process was based on a review of published data on VM that led to a first draft of the classification. This draft was discussed and revised in two rounds of email exchange among the authors.

Results: The classification is divided into three main parts: 1. Diagnostic criteria for definite, probable and possible VM, 2. Notes that clarify how the criteria are applied, 3. Comments that provide background information.

Definite VM requires recurrent attacks with vestibular symptoms of moderate or severe intensity, a history of migraine according to the International Classification of Headache Disorders, and migraine symptoms during at least half of the vertigo attacks. For probable VM, patients must have recurrent vestibular symptoms of moderate or severe intensity with either a history of migraine or migraine symptoms accompanying the attack. For possible vestibular migraine, weaker evidence for a migraine origin of the vestibular symptoms is sufficient, such as a positive family history for migraine, migraine precipitants causing vertigo, or response to antimigraine drugs. A final criterion for all three categories of vestibular migraine is that the symptoms are not attributed to another disorder. The specificity of diagnosis is highest for definite VM, while sensitivity is higher for probable and possible VM.

Conclusion: By defining VM at different levels of sensitivity and specificity, the proposed classification may aid patient identification both in research and clinical settings.

C3-2
Enhanced motion detection in vestibular migraine

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Vertigo caused by migraine (vestibular migraine, VM) is a frequently diagnosed but poorly understood entity. No specific oculomotor or postural defect has been described in this disorder and its pathophysiology remains uncertain. Based on recent evidence that normal subjects generate vestibular-mediated percepts of head motion and reflexive eye movements using different mechanisms, we hypothesized that percepts of head motion may be abnormal in VM. We therefore measured motion detection thresholds in patients with VM, migraine patients with no history of vestibular symptoms, and normal subjects using the following paradigms: roll rotation in the supine position (activating the semicircular canals); static roll tilt (activating the otolith organs); and dynamic roll tilt (activating both the canals and otoliths). Thresholds were determined using a standard staircase paradigm, whereby the peak acceleration of the motion was decreased or increased based on accurate or inaccurate percepts of movement direction. We found a dramatic but specific reduction in motion thresholds in VM compared to normal and migraine subjects when the canals and otoliths were activated in tandem, but normal thresholds when the canals or otolith organs were activated in isolation. These findings indicate that the signal encoding head motion was amplified in VM relative to the migraine and normal subjects but only when both canal and otolith cues were modulated together. Given the specificity of this abnormality, we suggest that dysfunction in the dorsal cerebellar vermis may be responsible for enhanced motion detection in VM given its critical role in canal-otolith integration.

C3-3

Sensory dysmodulation in vestibular migraine: an otoacoustic emission suppression study

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Objectives: To seek evidence of sensory dysmodulation in auditory brainstem reflexes in patients with vestibular migraine by studying suppression of otoacoustic emissions (OAEs) by contralateral noise.
Study Design: Prospective case-control study.
Methods: The authors measured contralateral suppression of OAEs in a group of 33 interictal patients with definite vestibular migraine (migrainous vertigo) according to the strict diagnostic criteria of Neuhauser (2001), and compared them with 31 non-migrainous controls with matching age and sex distributions. Suppression values were then compared with previously published departmental normative data. In three patients, recordings were compared in the ictal and interictal states.
Results: Otoacoustic emission suppression was reduced in 11/33 patients, and 3/31 controls ($p = 0.022$, Chi squared test). Binary logistic regression analysis confirmed that presence of vestibular migraine was significantly associated with abnormal suppression, but no such relationship was seen for symptoms of phonophobia or disease duration. The amplitude of variability between the ictal and interictal state was out of the normal range in two out of the three patients in whom such recordings were made.
Conclusion: These results provide support for the notion of interictal auditory sensory dysmodulation in as yet unidentified subset of migraineurs with vestibular migraine.

C3-4

Treatment of the vestibular migraine according to the clinical picture

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Introduction: Recently some papers in the general practice and in journals specialized in headache analyzed the utility of drugs used for the treatment of migraine in Vestibular Migraine (VM), concluding that them are useful. We believed that Vestibular Migraine, like migraine itself is a multisympton disease and that the treatment should be tailored according to the clinical picture of the patient.
The clinical findings in the moment of the crisis - essential to make the diagnosis – can be divided in:

1. A harmonic peripheral vestibular syndrome, sometimes with light auditory symptoms (“fullness”, tinnitus) a Peripheral VM (Carmona, 2008, Carmona and Bruera 2009).
2. A central vestibular syndrome where the axial ataxia is almost always present (95% of the cases) and we will find a central nystagmus vertical up-beat or down beat, rotatory or horizontal, or a central positional nystagmus (von Brevern et al. 2005), a Central VM.

Material and Methods: We treated and follow up during a 1 year period 38 patients with Peripheral VM and 54 with the central form. The drug of choice was Topiramate 50 mg daily in the first group and Gabapentin,

600 mg daily in the second group. The average duration of the treatment was 9 months.
Results: The results were good in both groups, with dramatic reduction of both headache and vertigo crisis (90% in average, total group and each one), with minimum side effects.
Discussion: We choose Topiramate in the first group because previous experience demonstrates is useful with the Peripheral and auditory symptoms are present, perhaps due to carbonic anhidrase blocking effect. Since gabaergic deficit could be involved in the central forms of MV, gabapentin looked a good option.
Conclusion: Many drugs, prove to be efficacious in migraine headache are possibly useful in VM, we proposed to choose the drug according to the clinical picture.

C3-5

Experimentally induced deep cervical muscle pain distort head on trunk orientation

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Objectives: Interaction between vestibular, visual and proprioceptive information secure maintained balance control during performance. Cervical sensory input has a special importance, since it interacts with vestibular input for proper understanding of how head is moved in space and relative trunk. Distorted cervical information could therefore, due to sensory mismatch, under certain circumstances, cause dizziness, i.e. cervicogenic dizziness, but also cause improper motor command due to propriceptive deficit. Neck pain conditions are a feasible cause for improper sensory input. How much muscle tension and pain per se contribute to sensory impairment and thus be responsible for sensory changes and mismatch is still unknown.
Aim: We wanted to investigate the effect of experimental muscle pain on head on trunk orientation. Psychometric head repositioning tests make indirect evaluations possible.
Methods: We studied eleven healthy volunteers (6 men, 5 women, 24 year (19–33) in their ability to reproduce two targets (30° of rotation and neutral head position (NHP))[target position], for both right and left side [side], before, 2 minutes and 20 minutes after pain induction[pain state]. Muscle pain was induced by saline infusion (Natrii chloridum, 50 mg/ml) in paraspinal muscle at C2-level, left side, most likely the splenius muscle. Correct pain induction site was assured by palpation and thereafter by using a hypodermic needle connected to an EMG-amplifier. Head repositioning was measured by Zebris©, a 3-D motion analyzer, which consists of a helmet and shoulder cap and measures head relative the trunk by triangulation. Targets were introduced by the test leader and then reproduced six times by the volunteer. The volunteer pressed a button directly connected with the computer, each time when they considered themselves to be back at target. Before the pain induction a first repositioning test was made for familiarization (not used in analyzes).
Results: Directly after pain induction, accuracy for head on trunk repositioning was reduced for the 30° target on the side where pain was induced (p-value 0.032) but not on the other side (p-value 0.759). The GLM Univariate Analysis of Variance model indicated a significant interaction before and directly after pain induction between target position, side and pain state (p-value 0.001). GLM also found a significant interaction before and after 20 minutes between target position, side and pain state (p-value 0.033) and an interaction between target position and pain state (p-value 0.002).
Conclusion: Experimental induced pain distorts the position sense with less accuracy for the side affected by pain. The effect of impaired repositioning ability for the affected side is not seen for the other side. These results indicate a specific change of proprioceptive input occurring together with pain and there seems to be interplay between pain and impaired head orientation. Head on trunk orientation could consequently be affected by cervical pain and could thus be one possible cause for sensory mismatch and cervicogenic dizziness.

C3-6

Neuropathy is an integral component of the cerebellar ataxia neuropathy vestibular areflexia syndrome (CANVAS)

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Aim: The syndrome of cerebellar ataxia with bilateral vestibulopathy was delineated in 2004. Sensory neuropathy was mentioned in 3 of the 4 patients described. We aimed to characterize and estimate the frequency of neuropathy in this condition, and determine its typical MRI features.
Methods: Retrospective review of 18 subjects (including 4 from the original description) who met the criteria for bilateral vestibulopathy with cerebellar ataxia.
Results: The reported age of onset range was 39–71, and symptom duration was 3–38 years. The syndrome was identified in one sibling pair, suggesting that this may be a late-onset recessive disorder, although the other 16 cases were apparently sporadic. All 18 had sensory neuropathy with absent sensory nerve action potentials, although this was not apparent clinically in two, and the presence of neuropathy was not a selection criterion. In 5, the loss of pin-prick sensation was virtually global, mimicking a neuronopathy. However, findings in the other 11 with clinically manifest neuropathy suggested a length-dependent neuropathy. MRI scans showed cerebellar atrophy in 16, involving anterior and dorsal vermis, and hemispheric crus I, while two were normal. The inferior vermis and brainstem were spared.
Conclusions: Sensory neuropathy is an integral component of this syndrome. It may result in severe sensory loss, which contributes significantly to the disability. The MRI changes are consistent, and coupled with loss of sensory nerve action potentials, may aid diagnosis. We propose a new name for the condition, – CANVAS (Cerebellar Ataxia Neuropathy Vestibular Areflexia Syndrome).

C3-7

A spatial navigation bias due to a distorted internal representation of time

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Background: Humans can perceive changes in angular position using only vestibular cues of self-motion. Theoretically, perceived displacement could derive from a brainstem integration of the vestibular signal with this position signal being relayed to perceptual areas [1]. Alternatively (or additionally) vestibular-derived displacement perception may be obtained by a separate integration (of ascending head velocity signals) at perceptual level. Primate posterior parietal neurons possess the necessary signals and characteristics to function as a perceptual neural integrator for encoding signals associated with time, motion and space perception [2,3]. One prediction of a perceptual neural integrator in humans would be a role for interval timing mechanisms (i.e. time perception in the seconds domain) in deriving vestibular-sensed space. We thus assessed spatial performance in a vestibular orientation task (CLOCK task), vestibular motion thresholds (MOTION task), and motion duration perception (TIME task) in 2 patients with focal stroke and 10 healthy controls.
Methods: 1. Patients. Patient A: A 70yr woman with a right posterior parietal and contiguous insular stroke with moderate left hemispatial neglect. On first vestibular orientation testing there was only minimal neglect and none on repeat testing 2 months later. Patient B: A 58yr man with transient left arm sensorimotor symptoms from a right insular stroke.
2. Spatial orientation task. Subjects sat on a motorised "Bárány" chair surrounded by the numbers of a clock (1–12) on an external drum. Each experimental run started with the subject facing 12 o'clock in ambient light. The subject was passively rotated in the dark (with auditory white noise). The subject then indicated which number they were facing following the rotation. The light was then switched on to provide feedback. Finally, the light was extinguished and the subject returned to the start (12 o'clock).
3. Velocity perception task. Acceleration threshold perception was assessed in the dark using a staircase method. Subjects were required to indicate the onset and direction of perceived motion using a button press.
4. Time perception task. Subjects underwent a pair of rotations in the dark, which differed in duration (from 0 to $+/-$ 3s difference), and were asked to indicate verbally which rotation was the longer via a forced choice paradigm.
Results: Despite normal perceptual thresholds to angular acceleration (MOTION task), we found a significant impairment of spatial orientation for leftward rotations in patient A (right PPC lesion). In addition, patient A markedly overestimated the duration of leftward compared to rightward rotations. This temporal overestimation was congruent with the patient's error in overestimating angular displacement on leftward rotations. Patient A showed no spatial deficit for rightward rotations. The bias in patient A's CLOCK and TIME tasks persisted at 2 months. There was no evidence of

neglect on this second visit. Patient B showed normal performance on all tasks.

Discussion: The finding of normal angular acceleration thresholds in both patients implies that the posterior insular and posterior parietal cortices are not critically involved in the perception of vestibular signals of motion in humans. In contrast, our data suggest that the posterior parietal cortex may function as a perceptual neural integrator; i.e. where vestibular signals of motion are temporally integrated in rendering an estimate of angular orientation. The observed vestibular-spatial abnormality persisted despite the complete recovery of attentional deficit. This suggests that abnormalities in vestibular-spatial perception may be independent of the neglect phenomenon. In summary, vestibular-spatial function may be critically dependent upon an accurate internal clock.

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Oral Session C4 – Vestibular Loss and Little More

C4-1
Acute bilateral vestibular loss – a single subject experimental study

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Background: Acute unilateral vestibular loss results in vertigo, unsteadiness, nausea and vomiting, accompanied by contra-lesional spontaneous horizontal-torsional nystagmus, ipsi-lesional pathological head impulse test and ipsi-lesional lateropulsion. This is a well-known and common syndrome, for example as vestibular neuritis and after unilateral vestibular neurectomy or labyrinthecomy.

Acute bilateral vestibular loss is uncommon and in the textbooks stated to be characterized by unsteadiness and oscillopsia, but not by vertigo.

Study Design: The first author subjected himself to acute temporary bilateral vestibular loss by having simultaneous, bilateral, intratympanic lidocaine injections.

Results: Approximately one hour after the injections the subject started to feel unsteadiness. He showed marked ataxia, broad-based gait and was barely able to perform the Romberg test with closed eyes. The symptoms accelerated and within 10 minutes the subject was unable to walk and had to sit on the floor, stabilizing himself against the wall. He had no nystagmus. The ataxia was accompanied by oscillopsia and extreme autonomous symptoms with nausea, profuse vomiting and sweating. Any movements of the head exaggerated the symptoms. Seven hours after the injections the symptoms gradually disappeared and one hour later the subject was able to bicycle home.

Conclusions: Acute bilateral vestibular loss results in extreme ataxia, vertigo and autonomous symptoms, despite the absence of any nystagmus. It is probably very rare in the clinic.

C4-2
Vestibular perception after acute vestibular neuritis

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Introduction: Acute unilateral injury to the peripheral vestibular system results in severe vertigo and instability and sometimes, a debilitating effect on an individual's life. Recovery is variable with around 50% of acute vestibular neuritis patients developing chronic dizziness [1]. Traditional tests of vestibular function in the compensation stage following vestibular neuritis have focused mainly on brain stem and peripheral recovery manifest in the vestibular ocular reflex (VOR) responses. VOR function correlate poorly however with symptomatic recovery [2]. Recent functional imaging studies of the brain acute vestibular neuritis have demonstrated widespread changes in cerebral cortical activation [3], of which conventional vestibular physiology and clinical testing shed little insight. This study investigates the vestibular perceptual and VOR changes that occur after acute vestibular neuritis, in order to understand the involvement of perceptual brain regions (presumably cortical) in the compensation process.

Method: Acute vestibular neuritis patients were tested within 5 days of symptomatic onset ($N = 16$) and then again at 6–8 weeks ($N = 10$). Vestibular perception was measured by subjects indicating their perceived angular velocity via a tachometer wheel during $90\,^{\circ}$/s velocity steps in the dark whilst on a Bárány chair, and with accompanying white noise masking. Subjects were instructed to turn the wheel at maximal speed at the onset of their perceived vertigo, i.e. on starting (or stopping) the rotation, and to reduce the speed of turning concomitant with their vertigo sensation. Eye movements were recorded simultaneously with bi-temporal electro-oculography, thus allowing both perceptual and VOR time constant, duration and 'area under the curve' measurements to be calculated. Symptom load was also measured acutely and at follow up using the Dizziness Handicap Inventory (DHI) and Vertigo Analogue Scale (VAS).

Results: Normal time constant values for perceptual and ocular responses are circa 16 seconds [4]. Acutely perceptual time constants in patients were bilaterally and symmetrically reduced (contralesional 5.8s, ipsilesional 5.5s), with VOR time constants asymmetrically reduced towards the lesioned side (contralesional 11.1s, ipsilesional 7.6s). Duration and 'area under the curve' measurements show the same trend with a bilateral symmetrical perceptual and asymmetrical VOR reduction.

At follow up perceptual and VOR time constants increase, with perception remaining symmetrical (contralesional 9.3s, ipsilesional 9s) and VOR asymmetrical (contralesional 15.5s, ipsilesional 13.4s). Duration and 'area under the curve' values show similar increases. There is a concurrent reduction in symptom load score at follow up. The mean score (normalised) for the DHI was 2.1 acutely, decreasing to 0.6 at follow up. There was also a reduction in VAS scores from 8.8 acutely to 0.8 at follow up.

Conclusion: The reduction in perceptual responses at the acute stage, increasing at follow up, represents a perceptual mechanism, presumably cortical, that is actively engaged in the compensation process after a peripheral insult. This perceptual 'shut-down' may reflect a protective compensatory mechanism that is apparently more efficient than low level brainstem responses, shown by the extreme shortening of perceptual responses in comparison to the VOR.

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C4-3

Residual perception of motion and tilt in patients with bilateral vestibular function loss

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Introduction: Patients with bilateral vestibular function loss have to cope with proprioceptive and visual cues for static and dynamic spatial orientation. By suppressing visual cues and reducing proprioceptive cues, the aim of this study was to determine perception thresholds for angular acceleration, linear acceleration and tilts in patients with bilateral vestibular loss.

Methods: 30 patients with bilateral caloric areflexia, bilateral abnormal head impulse test and absent or strongly reduced responses at rotatory tests were included. Using a combination of rotation chairs and linear sleds, perception threshold for rotation, translation and tilt were determined. Obtained thresholds were compared to thresholds of an age related group control of subjects without prior vestibular complaint. All threshold tests were performed in darkness, masking all other than vestibular cues.

Results: Patients with bilateral vestibular loss showed significant higher perceptions thresholds compared to healthy subjects. Perception thresholds were still found in patients with complete abolished vestibular reflexes.

Conclusions: Even if proprioceptive input is difficult to determine, assessing perception thresholds could be more sensitive than testing vestibular reflexes to evaluate residual vestibular function. Indeed still substantial perception thresholds were found in patients with complete abolished vestibular reflexes.

C4-4

Crohn's disease in the inner ear. A histopathological approach to a special autoimmune inner ear disease (AIED)

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Patients with autoimmune inner ear disease develop rapidly progressive sensorioneural hearing loss over a period of several weeks or months often accompanied by vestibular loss. This disease can appear as a distinct clinical entity or in association with an underlying autoimune disorder, e.g. ulcerative colitis or Crohn's disease. Treatment comprises immunosuppression by corticosteroids, cytostatic drugs or TNF-alpha-antagonists. We report the case of a patient with AIED and underlying Crohn's disease being non-responsive to any treatment and who underwent surgery for bilateral cochlear implants. We found histopathological and immunohistochemical evidence for Crohn's disease in the inner ear.

C4-5

To investigate the influence of acute vestibular impairment following mild traumatic brain injury on subsequent ability to successfully complete a vestibular physical therapy trogram and remain on active duty one year later

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<Text Not Available>

C4-6

Recovery after acute unilateral vestibular loss and predictors for self-rated remaining symptoms after six months

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Objectives: To follow the recovery during the first six months after acute unilateral vestibular loss, and to determine predictors for self-rated remaining symptoms.
Methods: Forty-two consecutive patients (23 men, 19 women, mean age 54 years, age range 30–73 years) diagnosed with acute unilateral vestibular loss at Ear-, Nose- and Throat departments in two Swedish hospitals were included less than ten days after diagnosis. All subjects received instructions from a physiotherapist of a home-based vestibular rehabilitation therapy exercise programme to be performed twice a day. Static and dynamic clinical balance tests, visual analogue scales (VAS), UCLA Dizziness Questionnaire, Dizzness Beliefs Scale, European Quality of Life questionnaire (EuroQol), Dizziness Handicap Inventory, and Hospital Anxiety and Depression Scale were performed at inclusion and at seven follow-ups over six months. Subjects also rated their degree of symptoms on VAS in a diary at home daily during the first four weeks and weekly from the fifth to the tenth week. Videonystagmography was performed in the acute stage and after 10 weeks.
Results: Decrease of symptoms and improvement of balance function were larger during the first compared to the latter part of the follow-up period. VAS-ratings for balance problems were higher than for dizziness. A prediction model was created based on the results of four tests in the acute stage; standing on foam with eyes closed, standing on one leg with eyes open, VAS-rating of vertigo at rest, and EuroQol-rating of health-related quality of life. The prediction model identified subjects at risk of having remaining symptoms after six months with a sensitivity of 86% and a specificity of 79%.
Conclusions: Recovery mainly takes place during the first weeks after acute unilateral vestibular loss. Subjects rate more balance problems than dizziness. Some subjects report long-lasting symptoms. Self-rated remaining symptoms after six months can be predicted by clinical balance tests and subjective ratings in the acute stage.

C4-7

The Halpern syndrome of monocular visual vertigo: resurgence of a dorsal light reflex in the patient with central vestibular disease

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Aim: To elucidate the pathophysiology of Halpern syndrome.
Background: Halpern syndrome is a rare disorder characterized by vertigo, a tendency to tilt to one side, and spontaneous closure of the ipsilateral eye. Symptoms are exacerbated during monocular viewing with the ipsilateral eye and alleviated during monocular viewing with the contralateral eye. It has long been attributed to a mismatch between vestibular input and visual input.

Methods: Reexamination of Halpern syndrome in light of new concepts of visuo-vestibular disease.
Results: The visually-dependent postural disequilibrium in Halpern syndrome recapitulates the dorsal light reflex in fish, in which unequal luminance input to the two eyes evokes a tilt of the body toward the brighter side.
Conclusion: Halpern syndrome may result from reactivation of a vestigial dorsal light reflex in the setting of central vestibular disease.

Oral Session C5 – BPPV

C5-1
A new type of BPPV with only unsteadiness of gait: a 152 patients study

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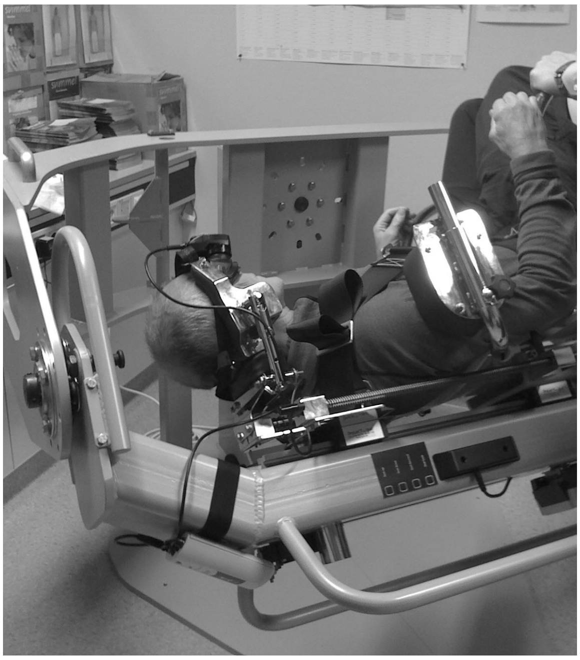
Aim: BPPV represent 35% of the vertigo and perhaps much more. A new device to treat patients who present some positional vertigo due to canalolithiasis has been elaborate and finalized. This prospective study must show a new type of BPPV thanks to the use of this new technical procedure in diagnosis and treatment of vertigo.
Material and Methods: This study was 12 months long and concerned 152 patients who presented some unsteadiness of gait. These patients were selected after rigorous clinical examination. Only dizzy patients with positional nystagmus without any rotating sensations were included. These patients could felt some unsteadiness, floating sensations, nausea, and others subjective sensations provoked by head movements or some head positions, especially looking downward, upward and during quick head rotation in horizontal plane.
This new arm-chair is a rotating chair able to swivel around two axes of vertical and horizontal rotations, the patient is completely interdependent of the arm-chair. It thus makes it possible to place the patient's head in position wished with a height degree of accuracy and facility, giving possibility to move the patient in all semi-circular planes' with maximum security, up to 360° rotation or more. Thanks to the use of this new equipment the patient is in "one-piece" moved with no risk to hurt the neck especially in our older's patients. An adapted repositioning manoeuvre is performed after that the diagnosis's manoeuvre gave topographic involvement from one or more of the semicircular canals. All manoeuvres were performed under video-goggles survey witch allows to control canalith's migrations and good efficiency of the therapeutic way. For the posteriors canalolithiasis a 270° Sémont manoeuvre was made, beginning on the involved side 45° under the horizontal plane and ending 45° over the horizontal plane. The lateral canalolithiasis was treated by a special barbecue manoeuvres called "dynamic barbecue" witch contain several rounds of 360° with successive strong accelerations and soft decelerations toward the safe side. A so manoeuvre permits to free the lateral canal of the littlest particles.
Each patient had a clinical examination three days later and eventually had a second repositioning manoeuvre or vestibular examination and sometimes MRI.
Results: No incident occurred during the repositioning procedures. One hundred nine patients of the 152 have a low expressive canalolithiasis. Ninety seven concern a lateral canal and 12 concern a posterior canal. Sex-ratio was 6.3 women for 3.7 men and age average was 62.2. Necessary repositioning manoeuvre average to be cured of any symptoms was 1.57.
Conclusion: Some patients still have an unsteadiness of gait after being treated by therapeutic manoeuvres. Often named otolithic syndrome it could be a simple BPPV with a very few particles in the lateral canal. This new device used in this study is a well efficient system on BPPV's management, even for diagnosis than therapeutic way. Handling is simple and no iatrogenic incident occurred. It permits to increase canalolithiasis diagnosis, particularly in limited laterals involvements. Some lightly dizziness but with some disabling symptoms and often chronic are more well investigated and can be efficiently cured. The systematic use of video-goggles and the suppression of proprioceptives entries by this "one-piece" mobilization's, permit to obtain a better rate of diagnosis in some of our dizzy patients. The explanation could be represented by the very comfortable conditions to analyse the very little nystagmus during Dix and Hallpike's and others diagnosis manoeuvres One of the mains interests of this new arm-chair is to improve the sensitive of diagnosis's manoeuvres and to be able to treat every patients, even if they are very old ore obese, and it gives more comfort for ENT physicians.



Patient treated by dynamic barbecue manoeuvre

Dix and Hallpike for left posterior SCC

C5-2

Visual dependence and BPPV

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Objectives: Some patients with acute vestibular disorders such as vestibular neuritis or BPPV develop long term dizzy symptoms, often with increased sensitivity to visual stimuli. However, it is not known whether these patients always had a high visual dependence, or whether the vestibular dysfunction triggered the enhancement. The aim of the study was to investigate whether or not visual dependence could be modified by an acute episode of vestibular dysfunction, namely a provoked attack of BPPV.
Methods: We measured visual dependence, before and after Hallpike manoeuvres (and repositioning procedures if appropriate) in 20 patients with active BPPV (Positive Hallpike group, mean age 60 $\pm$ SD 14 years), 20 age-matched normal controls (mean age 55 $\pm$ SD 12 years), and 20 patients with a history suggestive of BPPV in whom the Hallpike manoeuvre did not induce vertigo or nystagmus (Negative Hallpike group, mean age 53 $\pm$ SD 14 years).
Subjects performed subjective visual vertical (SVV) tasks with a tilted frame ('Rod and Frame' test – static visual dependence), and with a rotating background ('Rod and Disc' test – dynamic visual dependence). We also recorded posturography responses with eyes open (EO), eyes closed (EC) and while subjects viewed a rotating disc (ROTN). Questionnaires were used to quantify symptoms and motion sickness susceptibility.
Results: Static visual dependence increased with age for both patient groups, but there was no significant difference in frame dependence between any subject groups. Dynamic visual dependence (SVV) increased with age for all subject groups, and the Negative Hallpike group had a higher disc dependency than normal controls. The Positive Hallpike group showed a significantly reduced SVV disc-dependency post-Hallpike ($2.8^\circ \pm$ SD 5.6°). The Positive Hallpike group swayed more than normal controls in the EC condition, particularly post-Hallpike. Both patient groups had a higher Kinetic Quotient (KQ = ROTN sway / EO sway) than normal controls, but there were no significant differences between the patient groups. The normal controls and Positive Hallpike group both showed reductions in KQ post-Hallpike.
Conclusions: The increase in visual dependence with age, as seen during the perceptual tasks, may be ex-

plained by general age-related increases in proprioceptive and vestibular thresholds. The finding that Positive Hallpike subjects were more unstable than normals with their eyes closed, particularly after the Hallpike and repositioning manoeuvres, could be due to the disorientation induced by the positional vertigo.

Both patient groups had enhanced postural responses to the rotating disc - demonstrating an increased visual dependence in the vestibular patients. However, the vertigo provoked in the Positive Hallpike patients failed to induce a measurable increase in visual dependence. On the contrary, after the positioning manoeuvres, the normal controls and the Positive Hallpike group both showed a reduced KQ, probably caused by adaptation to the visual stimuli. The Positive Hallpike group also showed a reduction in visual dependency on the perceptual (Rod and Disc) task.

The Negative Hallpike group seemed to behave differently to the Positive Hallpike patients. They also had more symptoms of visual vertigo and migraine (on questionnaires).

Although a single BPPV attack does not increase visual dependence, it seems that a history of BPPV can enhance it. The study also shows that just a few exposures to disorienting visual stimuli can induce adaptation effects, in both normal subjects and patients with vestibular disorders. This has practical implications for rehabilitation programs based on desensitization treatments.

C5-3

Benign paroxysmal positional vertigo in mountain bikers

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Objectives: Four adult males suffering from benign paroxysmal positional vertigo (BPPV), occuring several hours after intensive mountain biking but without head trauma, are evaluated.

Results: The positional maneuvers in the planes of posterior and horizontal canals elicited BPPV as well as transitory nystagmus. This was attributed to both the posterior and horizontal semi-circular canals (SCC) on the left side in one case, in these two SCC but on the right side in another patient, and to the right posterior SCC in the other two patients. Symptoms disappeared after physiotherapeutic maneuvers in 2 cases and spontaneously in the 2 other patients. Cross-country or downhill mountain biking generates many frequent vibratory impacts, which are only partially filtered through the suspension fork as well as the upper parts of the body. Biomechanically, during a moderate jump, before landing, the head is subjected to an acceleration close to negative 1g and during impact to an upward acceleration of more than 2 gs.

Conclusions: Repeated acceleration-deceleration events during intensive off-road biking might generate displacement and/or dislocation of otoconia from the otolithic organs, inducing the typical symptoms of BPPV. This new cause of post-traumatic BPPV should be considered as an injury of minor severity attributed to the practice of mountain biking.

C5-4

Sitting-up vertigo and trunk oscillation in patients with benign positional vertigo but without positional nystagmus

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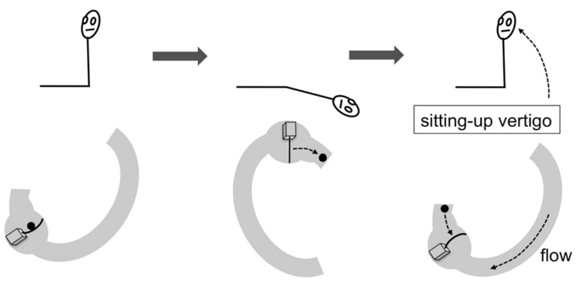
Presently, the unambiguous diagnosis of benign paroxysmal positioning vertigo (BPPV) requires the detection of positioning or positional nystagmus provoked by Dix-Hallpike (for vertical semicircular canals) or supine roll (for horizontal semicircular canals) maneuvers, which indicates canalo- or cupolithiasis of affected semicircular canals. There are patients, however, in whom – despite typical complaints of BPPV – no positional nystagmus can be documented; this is called ‘subjective BPPV’ (sBPPV). It is our clinical experience that these sBPPV patients usually have little or no vertigo in the Dix-Hallpike position, but complain of short vertigo spells during and after sitting up, sometimes with abnormal retropulsion of the trunk. In this study, we aimed to ascertain whether these patients in fact demonstrate abnormal sitting-up trunk oscillations when measured by posturography. Of 200 unselected patients with vertigo or dizziness, 43% had sBPPV with vertigo spells during sitting up, and 20% classical BPPV. Posturographic recordings were performed in 20 patients with sBPPV and sitting-up vertigo. Among them 7 had trunk oscillations during the act of sitting up and for a short time immediately afterwards. Based

on our findings, we propose a new type of BPPV, the so-called Type 2 BPPV (typical complaints of BPPV, no nystagmus in Dix-Hallpike positions but short vertigo spell during sitting up), which may be the result of chronic canalolithiasis within the short arm of a posterior canal. Furthermore, we suggest that Type 2 BPPV, which could be identical to sBPPV or constitute a major subgroup of it, occurs frequently among patients with vertigo. For therapy we recommend repetitive sit-ups from the Dix-Hallpike positions to liberate the short arm Hypothetical mechanism of Type 2 BPPV.



C5-5

Benign paroxysmal positional vertigo of horizontal canal about 30 ageotropic cases

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Objective: To assess if the therapeutic management and some external factors modify the recovery of AHVPPB.

Method: Over thirty cases of AHBPPV we try to estimate symptoms, videoscopics findings after treatment. With a Fisher test and average comparison we try to value our résults.

Results: In our serie the mean age was 58.6 years and the mean during symptoms was 11.6 days. In 63% of cases we found the side of the bppv with the slow phase velocity, in 56.66% with the dominant side of the vertigo and in 33.33% of cases with the medical history. For our patients a barbecue manoeuver on the side of the bppv was performed and after 8.6 days 15 patients was cured.

Number of manoeuver to the recovery was 1.6 for a young patient and 2.4 for an old patient ($p = 0.002$).The recovery wasn't faster when the patients respected positional advices ($p = 0.152$).Finally when the patients was treated quickly the recovery delay of ahvppb was shorter ($p = 0.032$)

Conclusion: In our experience the choice therapeutic or the therapist don't influence the results and the recovery of AHVPPB. But a young age and a therapy as soon as possible are most important.

C5-6

Characteristics of subjects with complex BPV treated on the Epley Omniax Rotator

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Objective: To describe the characteristic eye movement profiles, clinical observations and outcomes of 200 consecutive subjects who underwent assessment and repositioning on the Epley Omniax Rotator for Benign Positioning Vertigo.

Methods: 200 subjects with a history and/or examination consistent with BPV were referred to the Epley Omniax Rotator for diagnosis and treatment. Indications for referral included Posterior or Horizontal Canalithiasis that was refractory to bedside therapy, Canalithiasis affecting multiple canals, Cupulolithiasis, Anterior Canal BPV, musculoskeletal impediments to successful bedside repositioning and elusive BPV with multiple negative bedside tests. All subjects were assessed and treated on the Omniax Rotator, which is a power driven multi-axial chair with infrared video eye-movement recording system. Subjects underwent assessment of 3D eye position during Dix Hallpike and side-lying tests. Subjects whose eye-movement profile was consistent with posterior canal BPV underwent Epley particle repositioning manoeuvres followed by 360 degree backward rotations in the plane of the affected canal. Subjects with horizontal canal BPV underwent 360 degree barrel rolls towards the unaffected ear. Those with Anterior canal BPV underwent 360 degree forward rolls in anterior canal plane.

Results: 48% subjects had posterior canalithiasis affecting a single canal, characterised by upbeating geotropic torsional nystagmus with the affected ear down.

12% had bilateral posterior canalithiasis. 8% had horizontal canalithiasis characterised by horizontal nystagmus with either ear down, with a maximal slow phase velocity (SPV) with the affected ear down. 7% had horizontal cupulolithiasis, with apogeotropic horizontal nystagmus, maximal with the unaffected ear down.

2% had unilateral Anterior Canal BPV, with bilaterally positive Hallpike tests, and downbeating nystagmus with torsional quick phases towards the affected ear. 23% of subjects tested negative for BPV. 8% of subjects had low amplitude positioning nystagmus and disequilibrium without vertigo and responded to migraine preventative therapy. One subject with apogeotropic horizontal (positional) nystagmus and positional vertigo developed endolymphatic hydrops with low frequency hearing loss, which responded to diuresis and salt restriction.

Of the subjects who underwent treatment, 56% were treated successfully in a single session. 32.2% required 2–5 treatments. 12% required > 5 treatments. Six subjects were not successfully repositioned after 10 treatments. 3 of these subjects had horizontal cupulolithiasis. 2 had posterior canalithiasis and 1 had anterior canal BPV.

Ten subjects had BPV affecting multiple canals. 6 of these had post traumatic BPV. 9/10 subjects had successful symptom resolution after multiple repositioning manoeuvres ($n = 6$ on average). Six subjects had BPV secondary to vestibular neuritis; all but one were successfully repositioned in 1–2 treatments.

Conclusion: The Epley Omniax Rotator is a useful clinical tool that enables diagnosis and repositioning of BPV arising from all 3 canals. It also allows documentation of the characteristic nystagmus profile in subjects with atypical positioning vertigo.

Oral Session C6 – Meniere's & More

C6-1

The vestibular evoked-potential profile of Ménière's disease

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Objective: To define the vestibular-evoked potential profile of Menieres's Disease (MD), we recorded ocular and cervical vestibular-evoked myogenic potentials (oVEMP and cVEMP) to air-conducted (AC) sound and bone-conducted (BC) vibration in 56 patients, classified by audiometric stage, and 35 controls. The relationship between VEMPs, audiometry, caloric function and the subjective visual horizontal (SVH) was explored.

Methods: oVEMPs were recorded from unrectified infra-orbital surface electromyography (EMG) during upward gaze. cVEMPs were recorded from rectified and unrectified sternocleidomastoid EMG during head elevation against gravity. Responses to AC clicks delivered via headphones and BC forehead taps delivered with a mini-shaker (bone-conduction vibrator) and a triggered tendon-hammer were recorded.

Results: In clinically definite unilateral MD ($n = 39$), the prevalence of depressed or absent reflexes was 48.7%, 7.7% and 13.2% for AC click, BC minitap and tendon-hammer evoked oVEMPs, 38.5%, 21.6% and 8.3% for AC click, BC minitap and tendon-hammer evoked cVEMPs. The most commonly observed profile was abnormal reflex asymmetry on AC stimulation alone (33.3%), followed by abnormalities to both AC and BC stimuli (25.6%). Isolated reflex asymmetry to BC stimuli was rare (5%) and limited to the minitap cVEMP.

Significant caloric asymmetry was observed in 76.3% of clinically definite MD patients and SVH abnormalities in 21.1%. The prevalence of caloric asymmetry and AC cVEMP abnormalities was significantly correlated with audiometric disease stage. There was no correlation between SVH and any of the VEMP, caloric or hearing results.

Conclusion: Predominance of abnormalities in oVEMP and cVEMP responses to AC sound is characteristic of MD and indicative of saccular involvement. The combined sensitivity of AC cVEMP, AC oVEMP and calorics was 89.7% compared to 76.3% for caloric testing alone. Based on these findings we recommend the addition of AC oVEMPs and cVEMPs, to standard caloric testing, in order to improve the detection of vestibular impairment in MD. The addition of tendon-hammer VEMPs to this battery may yield the typical evoked potential profile (AC>BC abnormalities) and enable separation of MD from other common peripheral vestibulopathies.

C6-2

Meniere's Disease patients show enhanced eye velocity and altered VOR dynamics in response to high acceleration head rotations

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Background: The changes which occur in the labyrinth during Meniere's Disease (MD), especially

early MD, are still poorly understood. In this study we sought to test semicircular canal function by using a new technique in MD patients even during the acute MD attack. We used high-speed light-weight head-mounted cameras to measure eye velocity during brief, passive, unpredictable, yaw head rotations in response to high acceleration stimuli- the video head impulse test (vHIT). This test has been validated by direct comparison against scleral search coil measures [2]. This vHIT test and video camera system has been in use in the MSA ENT Academy Center at Cassino (FR) Italy, for a year and been used on over 670 ENT patients and healthy subjects.

Objective: How does early MD affect the eye velocity response to horizontal canal stimulation during normal values of passive head acceleration (around 4,000 deg/s/s)? To use high speed video techniques to provide objective validated measures of the eye velocity response to the head velocity stimulus during brief, unpredictable, passive head rotations in early Meniere's patents during quiescence and during an acute attack and compare these to measures on healthy subjects.

Methods: In the present study patients meeting guidelines set down by the Committee of Hearing and Equilibrium of the AAO-HNS criteria for stage 3 (Definite MD) were enrolled. 30 early MD patients were tested during quiescence and 13 during an MD attack. In addition 49 healthy subjects in the same age range were tested as controls. We sought to minimize variability by restricting testing to patients who were less than two years into the disease (early MD patients). None of them were long-term ("burnt out") patients.

Results: Most patients showed low velocity spontaneous nystagmus (SN) with quick phases directed away from the affected ear. In healthy subjects the eye velocity during a head impulse closely matches head velocity. However in the 13 MD patients at attack all showed an enhanced eye velocity response, so that during the initial increasing head velocity, the eye velocity increase at a faster rate than head velocity. Similarly during decreasing head velocity the eye velocity decreased at a faster rate than in normals. This enhanced gain was usually accompanied by altered VOR dynamics. 18 of 30 patients tested during quiescence showed a similar pattern.

Discussion: In MD patients, the presence and direction of the spontaneous nystagmus suggests that the affected ear has reduced function whereas the eye velocity response to high acceleration stimuli suggests that the affected ear has enhanced function (i.e. greater sensitivity). What could be responsible for such a pattern? We suggest the following hypothesis; that increasing endolymph pressure may cause the cupula to be displaced and even to become detached from the wall of the ampulla. If the cupula is displaced in an ampullofugal direction, then the spontaneous nystagmus will be away from the affected ear, as found here. If the cupula is detached from the wall of the ampulla then, when a high acceleration head impulse is delivered, the cupula will show an unusual dynamic response, which may involve greater sensitivity and different dynamics. The physiological effects of cupula detachment have been demonstrated recently by Rabbitt et al. [1].

Conclusion: The enhanced eye velocity response and its altered dynamics to high acceleration head rotations may be an early indicator of Meniere's Disease.

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C6-3

Tinnitus in Menière's disorder

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innitus is often one of the most prominent symptoms in Menière's disorder and, among members of the Finnish Menière's Association, it was reported by 94.3% and listed as the most important symptom by 37.6%. It is a symptom often difficult to treat and we were concerned to define its impact on the patient and the most relevant approaches to its management.

In our study tinnitus was assessed by a question from the neuro-otology questionnaire (Kentala et al, 1997) which was worded 'How much handicap does tinnitus cause in your life?' with a 5-point scale ranging from 'No handicap' to 'Very severe handicap(completely disrupts my life)'. We included in the analysis items related to impairment of activity, participation restriction caused by the impairment, an instrument measuring impact on generic health (Euroqol 5D), sense of

coherence and a disease specific impact measure. In addition we analyzed positive aspects of the disease, if any(Stephens et al. 2009).
Tinnitus severity correlated strongly with rated severity of the condition ($\tau = 0.36$) and also significantly with Euroquol TTO (($\tau = -0.20$) and Euroquol VAS ($\tau = 0.23$). To desing measures against the burden of tinnitus we examined factors related to tinnitus. The decision tree analysis showed that the severity of tinnitus was associated with anxiety, hyperacusis, hearing loss and deterioration of balance. These factors explained 30.1% of the variance in the severity of tinnitus. Thus, to alleviate the severity of the tinnitus, a treatment program for each of these individual associated symptoms should be designed. We therefore performed a linear regression analysis to study the significant determinants for anxiety. In this analysis vitality was the most significant single factor explaining anxiety, followed by hyperacusis, hearing loss and postural instability. We also searched for attitudes towards tinnitus by evaluating the sense of coherence and positive attitudes toward the illness. While sense of coherence did not explain severity of tinnitus, the positive attitude measure indicated several questions related to the severity of tinnitus and could explain 17.6% of the impact of tinnitus in Meniere's disorder.
In an attempt to alleviate tinnitus, hearing rehabilitation, attitude change and increased vitality are the key issues in tinnitus therapy. These approaches are seldom used in tinnitus therapy. As anxiety was the key determinant for tinnitus and loss of vitality was the most important consequence of the burden, relaxation with physical activation of the patient may provide better results than current therapies.

C6-4

Clinical characteristics of delayed endolymphatic hydrops in Japan: a nation-wide survey by the peripheral vestibular disorder research committee of Japan

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To clarify the characteristics of delayed endolymphatic hydrops (DEH) in Japan, clinical information of 198 DEH cases was collected by 5 nationwide, multi-center surveys conducted by the Peripheral Vestibular Disorders Research Committee of Japan. The incidence of the ipsilateral type of DEH was almost equal to that of the contralateral type. In both types of DEH, three common diagnoses of precedent deafness were deafness of unknown cause with onset in early childhood, sudden deafness and mumps deafness. The distribution of time delay of the onset between precedent deafness of unknown cause with onset in early childhood and DEH was significantly different from that between precedent sudden and mumps deafness and DEH. Two thirds of DEH cases with precedent deafness of unknown cause with onset in early childhood developed DEH symptoms within 40 years after the precedent deafness. In spite of the diagnosis of precedent deafness, virus labyrinthitis may build up the late endolymphatic hydrops in most DEH cases up to four decades. On the contrary, one third of DEH cases with precedent deafness of unknown cause with onset in early childhood developed DEH symptoms over 40 years after the precedent deafness, which may be associated with occasional Meniere's disease.

C6-5

Shorter CCTTT repeats at promoter of NOS2A gene decrease risk for Ménière's disease in European population in a case-control with replication study

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Ménière's disease (MD) is characterized by episodes of vertigo associated with tinnitus and low frequency, fluctuating sensorineural hearing loss. Although endolymphatic hydrops (ELH) is usually found in human histopathology, loss of spiral ganglion neurons (SGNs) is more severe than inner hair cells loss at the apical region in a guinea pig model of ELH. This finding suggests that SGNs are damage before than hair cells. Nitric oxide synthase type 2 (NOS2A) is a high output, Ca2+ independent enzyme, expressed in SGNs during oxidative stress and up-regulated in SGNs in this model of ELH.

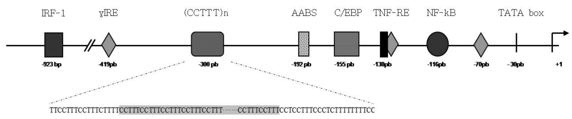
We explored the association of a functional polymorphic CCTTT repeat (rs3833912) at the promoter of NOS2A gene in patients with MD in a case-control study (Fig. 1).

Two independent cohorts including a total of 268 (group southeast 157, group northwest 111) unrelated patients with MD were compared with two groups of 510 controls from the same geographically-matched areas to replicate the association. After DNA isolation, samples were genotypes by a specific amplification protocol to determine the length of CCTTT. Forward and reverse primers were 5'-ACCCCTGGAAGCCTACAACT-3' and 5'-GCCACT GCACCCTAGCCTGTCTCA-3' respectively. The forward primer was 5'-labelled with 6-FAM. PCR aliquots (2 μl) were mixed with 9.25 μl formamide and 0.25 μl internal size standard (GENESCAN-500 LIZ). Samples were analyzed by capillary electrophoresis in a 3130 XL Genetic Analyzer with Data Collection Software V3.0. (Applied Biosystems, AB, Foster City, CA).

Shorter alleles CCTTT with 6–8 repeats were significantly more frequent in mediterranean (OR = 0.36 (CI, 0.20–0.69), corrected $p = 0.022$) and Galicia (OR = 0.08 (0.02–0.27), corrected $p = 1.8 \times 10^{-7}$) controls than in patients with MD. Metanalysis estimated that the (CCTTT) 6–8 repeats occurred in 11% of controls and 3% of patients (0R = 0.23 (0.13–0.40), corrected $p = 1.1 \times 10^{-8}$).

Our data show that the shorter CCTTT repeats at NOS2A promoter decrease risk for MD.

Acknowledgements: This study was funded by a FIS PI07/0035 Research Project from ISCIII, Spain. JALE has been partially funded by the ISCIII research grant INT09/229. The 3130 XL Genetics Analyzer was funded by grant IF06/37291 from Ministry of Science.



Structure of the promoter of NOS2A gene

C6-6

Blockage of endolymph by saccular otoconia in Meniere's disease

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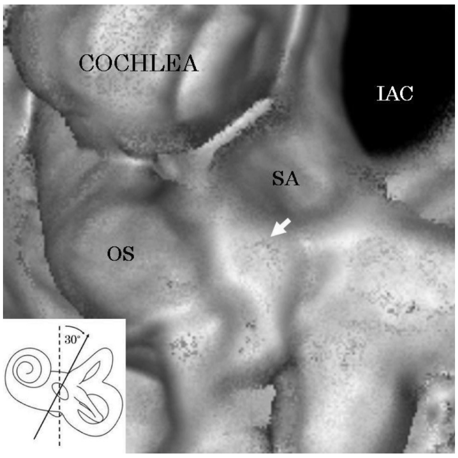
Objective: There is no effective strategy for diagnosing Meniere's disease other than the clinical criteria. Reuniting duct has been considered one of the lesional sites involved in Meniere's disease. This study investigated a more specific, objective and simpler strategy to diagnose Meniere's disease by assessing the reuniting duct.

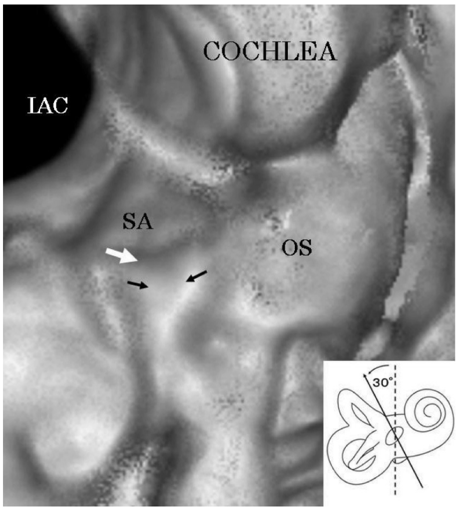
Methods: We examined the ears of twelve patients with definitely diagnosed unilateral Meniere's disease in stage 3 based on Meniere's disease criteria proposed by the committee on hearing and equilibrium of the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS), and the ears of 12 normal control subjects using three-dimensional(3D) cone beam CT.

Results: The bony groove where the reuniting duct is lodged between the saccule and cochlea visualized in all control subjects but its aspects varied. However, the saccular orifice to the bony groove could not be visualized in the affected ear of Meniere's patients with significantly greater frequency compared with those of the non-affected ears and control ears ($p < 0.01$). This orifice was not patent in 66.7% (8 of 12 ears) on the lesional side but all non-lesional ears of the patients and normal control ears are all patent.

Conclususion: The saccular orifice to the bony groove of ductus reuniens (reuniting duct) could not be visualized in the Meniere's ear with significantly greater frequency compared with normal subjects. The reuniting duct is not the groove itself, but tissue lodging on the groove, which suggests that the reuniting ducts is affected by radio opaque substances in CT findings.



Lesional side ear of Meniere's disease



Non-lesional side ear of Meniere's disease

Oral Session C7 – Ageing & Balance

C7-1

Reference values of static and dynamic clinical balance tests

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Objectives: To evaluate age- and sex-specific reference values of static and dynamic clinical balance tests in healthy subjects.
Methods: In this cross-sectional study 180 healthy volunteers aged 20–79 years (15 men and 15 women in each 10-year-interval) participated. In the static clinical balance tests the length of time subjects managed to stand with eyes open or closed were measured in the following positions: Romberg's position with the feet together, sharpened Romberg's position with the non-dominant foot on a line right in front of the dominant foot, normal standing on a foam cushion, and standing on one leg both right and left. The tasks were timed until the subject moved his feet from the given position, touched the wall, opened his eyes on the eyes closed conditions or reached the maximum time of 30 seconds. To evaluate dynamic balance function the tests tandem walk and walking in a figure-of-eight were used. Subjects performed a tandem walk of 15 steps at a self-chosen speed forward and backward along a line and the number of incorrect steps was counted. When walking in a figure-of-eight subjects walked between two lines in a figure of two circles put together to form an "eight". The speed was given by a metronome and the number of incorrect steps was counted. All tests were performed without shoes, with three trials, and mean values were used for analysis. All tests have shown good test-retest and inter-rater reliability in previous studies.
Results: Reference values are given for the static and dynamic clinical balance tests in the following age intervals: 20–29, 30–39, 40–49, 50–59, 60–69 and 70–79 years. Mean values and standard deviations are presented as well as the 10th percentiles used to identify cut-off values for identification of subjects with subnormal balance function.
Conclusions: The reference values obtained can be used in clinical practice to identify persons with subnormal static and dynamic balance function.

C7-2

The relationship between accelerometer scores, age, and status (patient versus control) during standing

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Purpose: Accelerometers have been used for over 10 years for research, but the technology is now reasonably priced for clinic use. The purpose of the project was to determine if accelerometry outputs are related to age and balance disorder.

Subjects: Eighty-one control subjects (51 females) ages 19 to 85 years old (47.8 ± 21.2 years; 66.3 ± 3.7 inches) participated. Eighteen patients with vestibular dysfunction (12 females) age range 43–73 years, mean age 60.4 ± 8.5 years, and mean height 66.5 ± 4.0 inches participated.

Methods: Pelvic accelerations were recorded using a custom accelerometer system that was self-powered and featured Bluetooth data transmission. The sensor was a dual-axis accelerometer that was oriented to capture mediolateral and anteroposterior accelerations. The Bluetooth module wirelessly transmitted each axis at 100 Hz. The accelerometer system was affixed to a gait belt around the waist using Velcro. Both patients and control subjects were asked to stand as steady as possible during 4 conditions: 1) Romberg eyes open (EO), 2) Romberg eyes closed (EC), 3) Romberg on a foam pad EO, and 4) Romberg on a foam pad EC for 70 second trials. Subjects were permitted up to 3 trials to attain the 70 second trial. Data analysis: The effect of subject (healthy vs. balance disorder) and age group (younger than 60 years, 60 years and older) on average postural sway velocity (units) was tested independently across four sensory conditions with repeated measures analysis of variance.

Results: Sensory conditions 1–4 were completed by 57 healthy subjects and 11 subjects with a balance/vestibular disorder. Within all subjects there was a significant increase in mean sway velocity on condition 4 (eyes closed-foam surface) compared with conditions 1–3 ($p < 0.01$). There was no significant difference in mean sway velocity between healthy subjects and subjects with balance disorders on any test condition. There was a significant effect in mean sway velocity due to age group ($p < 0.01$). Mean sway velocity was greater in older subjects compared with younger on condition 2 (EC-solid surface), condition 3 (EO-foam surface) and condition 4 (EC-foam surface).

Discussion: There are differences in average postural sway as measured by accelerometry within subjects across four sensory test conditions defined by vision and support surface. Changes in postural sway due to sensory condition were not affected by balance disorder. The lack of a balance disorder effect on sway velocity may be due to the low number of subjects able to complete all four test conditions and many of the patients had chronic vestibular disorders (> 6 months duration). On three of four conditions, sway velocity was greater in subjects older than 60 years.

Conclusion: Acceleromerty has promising applications for persons with balance and vestibular disorders.

C7-3

Psychophysical responses to earth-vertical rotations in the elderly

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Psychophysical techniques are extraordinarily sensitive in detecting hearing loss with aging, but they have not been used to evaluate loss of balance function in the elderly. We used a two-interval, two-alternative forced-choice paradigm to determine detection and discrimination thresholds for responses of the horizontal semicircular canals in young people and subjects over 55 years old. Older subjects had normal vestibular responses on rotational chair testing, caloric irrigations, and cervical VEMP testing. Subjects were rotated sinusoidally about an earth-vertical axis at reference velocities ranging from 0 to 150 deg/sec peak velocity. Thresholds did not distinguish between the two groups at peak velocities of 0 and 20 deg/sec but were significantly different at higher velocities. At a reference velocity of 60 deg/sec, for example, the average threshold of younger subjects was 5.1 deg/sec and older subjects was 7.2 deg/sec. Psychophysical testing is much more sensitive than conventional reflexive tests of vestibular function for identifying canal hypofunction in the elderly. The prevalence of age-related peripheral vestibular loss may be underestimated using conventional measures of vestibular function.

C7-4

Vibrotactile postural control in patients that have sit-To-stand balance deficit and fall

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Purpose/Hypothesis: The purpose of this study was to determine if the force platform vibrotactile device has clinical value in training patients in postural control of sway, balance, and mobility required for refining or relearning large movement tasks such as sit-to-stand, and if training patients with the device influences rate of falls. Vibrotactile displays have been found to be beneficial in improving balance test scores that correlate with a decrease in fall rate in laboratory studies. Investigations of these devices have been limited to upright stance and have not been done in clinical settings. Furthermore, transitional movements facilitated by vibrotactile displays, such as forward lean and rise found in sit-to-stand, have not been investigated. Hypothesis: there is a difference between standard care physical therapy plus vibrotactile treatment, and standard care physical therapy only.

Number of Subjects: Subjects included 30 community-dwelling adults, 11 males and 19 females, aged 60 to 79 years.

Materials/Methods: The force platform vibrotactile device communicates real-time sway feedback to reference spatial orientation, from data gathered from gravity and velocity. This prospective study investigated the relationship between force platform vibrotactile intervention and balance test scores, sit-to-stand and falls in subjects with abnormal NeuroCom Sit-to-Stand test results and 2 or more self-reported falls within the last 6 months. The cohort was a prospective case/control study using Pearson r, paired sample t-test, multivariate analysis of variance (M)ANOVA), and Wilcoxon signed rank analysis to determine the relationship between standard of care physical therapy plus vibrotactile force platform device treatment and standard of care physical therapy only. The Berg Balance Scale (BBS), Dynamic Gait Index, functional independence measure-motor (FIM-Motor), NeuroCom Sit-to-Stand normative ratios, NeuroCom Comprehensive Report, and self-reported falls quantify change over time with repeated measure study design.

Results: The study found a significant beneficial effect in the device intervention group which realized 39.5/56 to 51.2/56 mean score increase in Berg Balance Score, increase in mean Dynamic Gait Index from 11.7/24 to 19.8/24, mean increase in FIM-Motor from 16.4/21 to 19.5/21 and decrease in self-report falls from 4 to 2 by intervention Day 14.

Conclusions: These findings encourage further investigation of vibrotactile force platform devices.

Clinical Relevance: Vibrotactile cueing from force platform data referenced to gravity may be a link to improvement in small movement static standing sway, thought to be beneficial in habituating vestibular deficits, or in large movement dynamic postural control needed for activities of daily living. Vibrotactile cueing gives additional or enriched information to complement postural and mobility decisions. Consistent, repetitious, meaningful vibrotactile feedback is currently not available in standard care physical therapy.

C7-5

Visual vertigo and vestibulopathy – oculomotor and posturography findings

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Background: Patients with vestibulopathy often experience dizziness when they are exposed to dynamic visual inputs, known commonly as visual vertigo (VV). Although subjective complaints of dizziness due to visual stimulation from the environment are pronounced, the influence of VV on oculomotor and balance responses is not well defined or understood.

Goals: To compare oculomotor responses in different postures, between subjects with and without VV and/or vestibulopathy and to assess if the presence or absence of VV in vestibulopathy subjects affects their ability to maintain balance.

Methods: Ten people with vestibulopathy and VV, 11 with vestibulopathy and no VV, and 10 age-matched healthy controls participated in the study. All subjects completed a questionnaire specific to VV. We investigated oculomotor responses with 2-dimensional video-oculography (2D-VOG). Subjects were exposed to dynamic visual inputs consisting of vertical bars sweeping across a screen (towards the affected ear and to the opposite) at 20 deg/sec. Measurements were done in sitting and in Romberg positions, under 2 visual conditions: gazing at a screen with exposure to dynamic visual inputs first without a fixed target and then with a fixed target in the middle of the screen. Oculomotor responses were quantified by the frequency, mean amplitude and gain of the optokinetic nystagmus. We investigated postural sway with computerized dynamic posturography (CDP) under 6 different visual and surface conditions using the sensory organization test (SOT).

Results: In the Romberg position, VV subjects had a higher nystagmus frequency than the healthy controls, in both visual stimulation conditions with a fixed target (7 ± 7 vs. 1 ± 2) or without (41 ± 9 vs. 28 ± 10) ($P < 0.05$). In the sitting position, VV subjects had a higher nystagmus frequency than the healthy controls only when there was no fixed target (37 ± 9 vs. 24 ± 9). When in the Romberg position, the optokinetic nystagmus gain was significantly higher ($P = 0.009$) in the VV group (0.8 ± 0.2) compared to the healthy control group (0.6 ± 0.2) when there was no fixed target. There was no significant difference between the three groups in mean nystagmus amplitude. The VV group had significantly more difficulty maintaining balance than the vestibular and healthy control groups in the first four of the six conditions of the SOT test ($P < 0.05$). With eyes closed during the sway-referenced condition, the VV group had also significantly more difficulty maintaining balance compared to healthy controls ($P = 0.004$), and a trend toward increased postural sway was present in the vestibular group as well.

Conclusions: Subjects with VV had significantly increased optokinetic nystagmus responses (frequency and gain) compared to healthy subjects. While trying to maintain balance, VV subjects tended to depend on visual inputs even though their dizziness was increased by visual stimulation from the environment. Treating VV subjects by using controlled optokinetic stimulation in different positions, in order to decrease visual dependence should thus be considered in vestibular rehabilitation.

C7-6

The role of positive experiences in Menière's disorder

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Most studies on disease effects have focused on the negative aspects of such effects. In recent years there has been increasing interest in the positive effects of disease and, elsewhere, we have investigated these in terms of hearing impairment, tinnitus, vertigo and in Menière's disorder. However, these elements are not generally apparent unless specific enquiry is made.

On the basis of an open-ended study on positive experiences in Menière's disorder (Stephens et al., 2007), together with our earlier studies on hearing impairment, tinnitus and vertigo, we developed a structured questionnaire comprising 27 questions. This was sent to a further set of members of the Finnish Menière's Association of whom 423 responded. A factor analysis indicated six factors involving more than one question and which explained 59% of the total variance. These factors could be labeled 'Personal development', 'Self-help Association', 'Disease perspective', 'Acceptance', 'Beneficial life-effects' and 'Use condition to self-advantage'. Of these, only 'Disease Perspective' related significantly to measures of the impact of the Menière's disorder (Stephens et al., 2010). Further analyses indicated three important elements to the questions, namely 'Relaxation', 'Menière's disorder perspective' and 'Support' (Stephens et al., 2009).

We have subsequently investigated the proportion of variance in Quality of life measures which can be explained by positive experiences. Here we have found that they explain 20% of Euroquol TTO variance, 28% of Euroquol visual analogue scale variance and 34% of the variance in Menière's disorder severity rating. When we added ratings of the severity of the Menière's disorder symptoms to the analyses, the percentages of these variances explained increased to 42, 42 and 50%. This was greater than the proportions of the variances explained by either the symptoms alone or by the positive experiences alone.

These results suggest an additivity of symptoms and positive experiences in explaining the quality of life in Menière's disorder. It suggests that any therapy for the condition should be focused on both alleviation of the symptoms and on enhancement of the patients' positive attitudes.

C7-7

Cell phone based vibrotactile feedback system for home-based vestibular rehabilitation balance training

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Objective: Real-time trunk-based vibrotactile feedback has been shown to significantly decrease postural sway during quiet and perturbed stance in healthy individuals, older adults, and individuals with vestibular deficits. To date, laboratory based vibrotactile sensory augmentation platforms have comprised costly and bulky high fidelity inertial measurement units and computational processors, making them impractical for use outside of the research setting. We have designed and developed a cell phone based vibrotactile feedback system for use by an individual in his or her home to conduct prescribed balance exercise training. The cell phone based system is portable, easy-to-use, and relatively low in cost, and is capable of providing real-time vibrotactile cues for informing corrective responses. This proof-of-concept study quantitatively assesses the effectiveness of the cell phone-based balance aid in improving postural stability during a standard balance exercise.

Methods: Four naïve subjects (2 male, 2 female with age $38 + 11.5$ yrs) with vestibular involvement participated in this study. Three subjects were unilateral vestibulopathic patients, and one subject had bilateral vestibulopathy. Subjects were instrumented with the cell-phone based balance aid and asked to complete a block of Semi-Tandem Romberg stance trials with or without feedback with their eyes closed. Prior to data collection, subjects completed a lengthy practice session involving Semi-Tandem Romberg stance and vibrotactile feedback. A single tactor (i.e. pager motor) was placed on both the right and left external obliques at approximately the L4/L5 lumbar level of the spine. Vibrotactile feedback was provided when the subject exceeded a medial-lateral (M/L) trunk sway threshold equaling 1.0°. Subjects were instructed to move away from the vibration. Each subject performed eight 30 s trials with eyes closed. The first and last two trials were performed without feedback. The four middle trials were performed with feedback. M/L and anterior-posterior (A/P) root mean square (RMS) sway (i.e. trunk tilt) as well as percentage time spent within the 1.0° no feedback zone were used to quantify performance. RMS was computed by taking the square root of the time average of the squares. Percentage time in zone was defined as the fraction of time that the M/L tilt was located within the 1.0° no feedback zone.

Results: Mean normalized M/L RMS sway was significantly smaller (−35%) when feedback was provided; there was no change in the A/P RMS sway. The mean percentage time within the 1.0° no feedback zone was significantly greater (+25%) when feedback was provided compared to the no feedback condition. Statistical significance was defined as $p < 0.05$.

Conclusion: Our preliminary findings suggest that the low fidelity cell phone based balance aid can be used during Semi-Tandem Romberg stance with M/L vibrotactile feedback to increase stability in the M/L direction. Future studies are planned for evaluating the effectiveness of the cell phone balance trainer in a home-based setting during a broad range of balance exercises.

C7-8

Enhancing vestibular function by imperceptible levels of electrical stimulation

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Loss of neural function is a common problem with aging and disease. Aging is associated with loss of vestibular and peripheral sensory function. Reversing this loss of neural function could greatly improve quality of life. A novel paradigm that has been shown to improve sensory perception is the use of stochastic noise applied at the sensory receptor. Our hypothesis was that applying stochastic noise to the vestibular nerve would improve vestibular function and balance control. To determine if imperceptible levels of stochastic noise galvanic electrical stimulation could improve vestibular function we measured ocular counter-roll during stimulation and control trials. We found that stochastic noise increased ocular counter roll, a vestibular-mediated eye reflex during lateral tilts, in 8 elderly subjects (Mean 23%, Range 4–60%) in contrast to 7 younger subjects (Mean +1%, Range −16–27%). The increase was linearly related to baseline measures (R = 0.67, P = 0.007), indicating that greater improvement was seen in those with low initial values.

In addition, elderly subjects were also assessed for postural sway using the the modified clinical test of sensory interaction on balance (mCTSIB) during randomly assigned subsensory vestibular stimulation trials (two trials without stimulation and two trials with stimulation). Postural stability was assessed during four sensory conditions: 1) Eyes open upon a firm surface; 2) Eyes closed upon a firm surface; 3) Eyes open upon an unstable surface (foam pad); 4) Eyes closed upon an unstable surface (foam pad). During the most challenging condition, eyes closed on foam surface, elderly subjects demonstrated a significant improvement in Equilibrium Scores (Control: 42 ± 6 vs Stimulation: 49 ± 6, $p < 0.05$). Similarly they tended to demonstrate a decrease in anterior-posterior sway (Control: 0.99 ± 0.08 vs Stimulation: 0.92 ± 0.08 degrees, $p = 0.08$) and mediolateral sway (Control: 0.91 ± 0.12 vs Stimulation: 0.77 ± 0.10 degrees, $p = 0.13$). Further, in a group of young subjects their ability to maintain a sharpened Romberg stance (toe to heel) increased 53 ± 18%, $P < 0.05$ in stand time during the stimulation trial.

These results demonstrate that stochastic noise applied as electrical stimulation that is imperceptible to the subject produced significant improvements in both vestibular function and functional measures of postural control. These data demonstrate that increased ocular counter-roll had a functional effect. However, this study involved a limited number of subjects. Future work is needed to examine the possible use of this paradigm as treatment for neural loss in aging and disease.

C7-9

Trunk sway reductions in young and older adults using multi-modal biofeedback: randomized controlled trials

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Aims: These studies investigated whether real-time biofeedback of angular trunk displacement could alter balance performance among healthy older and young adults.
Objective 1: In the first study we examined the direct effect of biofeedback.
Methods 1: Healthy community-dwelling older adults ($n = 32$) and healthy young adults ($n = 32$) were included in this randomized control trial study. Both groups were first assessed with a battery of 12 stance and gait balance tasks and then split randomly into control and intervention groups. This assessment was used to compute population means. The intervention group then received combined vibrotactile, auditory and visual biofeedback of angular trunk displacement in real-time during training on a battery of 12 stance and gait balance tasks and during the subsequent post-training balance re-assessment. The thresholds for feedback were set at 40, 80, and 150% (centre to side or front-back), respectively for each feedback mode, of the population amplitudes of sway for each task. The control group received balance training and were re-assessed in the absence of real-time biofeedback of their trunk displacement. The 90% range of angular trunk displacement was calculated for each balance task pre- and post-training.
Results 1: Significant age related differences were observed independent of the intervention. Biofeedback intervention significantly reduced the angular displacement of the trunk for both young and older participants on a number of balance tasks compared to control treatment (40–60% reduction in angular displacement). In some cases, biofeedback improved balance in older adults, but not younger adults. Generally, the reduction was proportional to the amount of sway observed during the first assessment.
Objective 2: The second study investigated the carry-over effect of biofeedback over a period of 6 weeks for trained and untrained stance and gait tasks.
Methods 2: Healthy community-dwelling older adults (to date $n = 7$, planned 16) participated in this study. Subjects were first assessed with a battery of 14 stance and gait balance tasks. 7 of these tasks were used for training with biofeedback 3 times a week, every other weekday, for 2 weeks. Subjects were then reassessed on the 14 stance and gait balance tasks without biofeedback at the end of each training week, as well one week, and four weeks post-training. The same protocol for trunk angle biofeedback was used as study 1, except that thresholds were based on individual and not population sway values.
Results 2: Similar effects of biofeedback were noted as in study 1. In addition a carryover effect was noted in the weeks following training with biofeedback. For example, decreased roll angle and roll velocity during tandem stance with eyes open and decreased roll angle in tandem stance with eyes closed were observed even up to 4 weeks post-training with the biofeedback system.
Conclusions: Balance intervention in the form of vibro-tactile and auditory biofeedback of trunk sway significantly changed the angular displacement of the trunk for both young and older participants on a number of balance tasks compared to control treatment (40–60% reduction in angular displacement). Biofeedback carry-over effects remained even after training in older adults for a period of up to 6 weeks. It remains an open question whether biofeedback needs to be permanently available or repeated training sessions may be adequate to improve balance in the elderly.

C7-10

Effectiveness of variations on repositioning treatments for benign paroxysmal positional vertigo

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Many papers about the canalith repositioning maneuver (CRP) and exercises describe variations on the techniques. The basic CRP has been shown to be more effective than a sham treatment [1]. In this study we tested the hypothesis that any treatment that moves the head through the necessary motions, with sufficient speed, will be effective in treating posterior canal benign paroxysmal positional vertigo (BPPV), regardless of the details. Patients with BPPV ($n = 118$) were assigned to one of five treatment groups: CRP, CRP for patients with lateral canal and posterior canal involvement, CRP plus home Brandt Daroff exercise, modified CRP, self-CRP home exercise. The modified CRP group was based on a computational model of the ideal CRP by Rajguru et al. [2]. The self-CRP exercise was based on the description by Radtke et al. [3]. The self-CRP home exercise was also compared to previous data on the Brandt Daroff home exercise. Dependent measures were intensity and frequency of vertigo, presence or absence of response to the Dix-Hallpike maneuver, computerized dynamic posturography, and scores on the Vestibular Disorders Activities of Daily Living scale (VADL). Subjects were pre-tested, treated or trained immediately, and then returned in one week, three months, and six months. The groups did not differ significantly on any measures. Vertigo scores and Dix-Hallpike responses decreased significantly from pre-test to one-week post-tests and did not change significantly after that. The VADL and posturography scores improved significantly from pre-test to one-week post-tests and did not change significantly after that. Age and length of time having vertigo did not affect the results. Because CRP and CRP plus home program did not differ significantly a home program is not necessary after out-patient treatment to maintain effectiveness, These data suggest that all of these treatments are equally effective, so variations in performance of repositioning does not affect treatment outcome. All of these treatments are effective. Therefore, the clinician has a choice among several options for treating BPPV, depending on the needs of the patient. The patient's age will not affect the effectiveness of care.

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Oral Session D1 – Drugs in Ear

D1-1

Vestibular PREHAB and gentamicin before schwannoma surgery may improve long-term postural function

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Unilateral vestibular deafferentation (uVD), as performed in vestibular schwannoma surgery, results in a chronic vestibular deficit, though most of the insufficiency can be compensated by other sensory input. By vestibular training (prehabituation) performed before surgery, motor adaptation processes can be instigated before the actual lesion. The adaptation processes of the altered sensory input could be affected if the vestibular ablation and surgery was separated in time, by pre-treating patients that have remaining vestibular function with gentamicin.

Objective: To determine whether pre-surgical deafferentation would affect post-surgery postural control also in a long-term perspective (6 months).

Method: 41 patients subjected to trans-labyrinthine schwannoma surgery were divided into 4 groups depending on the vestibular activity before surgery (with no clinical significant remaining function $n = 17$; with remaining function $n = 8$), whether signs of central lesions were present ($n = 10$), and if patients with remaining vestibular activity were treated with gentamicin with the aim to produce uVD before surgery ($n = 6$). The vibratory posturography recordings before surgery and at the follow-up 6 months after surgery were compared.

Results: The subjects pretreated with gentamicin had significantly less postural sway at the follow-up, both compared to the preoperative recordings and to the other groups.

Conclusion: The results indicate that by both careful sensory training and separating the surgical trauma and the effects of uVD in time, can adaptation and habituation processes develop more efficiently to resolve sensory conflicts, not only resulting in a reduction of symptoms directly after surgery, but also perhaps up to 6 month afterwards.

D1-2

Selective oval window gentamicin to spare the cochlea in Meniere's disease

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Objectives: To develop a minor surgical procedure to ablate vestibular function while protecting the cochlea in patients with incapacitating Meniere's disease that failed to respond to transtympanic gentamicin.

Methods: Less than 5–10% of patients have remaining vestibular function and continuous vertigo attacks after repeated transtympanic gentamicin Although few these patientshave anincapacitating Meniere's disease These patients will normally be offered a labyrinthectomy or a vestibular nerve section, depending on if there is serviceable hearing or not. As the route to the vestibular sensory end organs are through the oval window while the round window access the scala tympani, it would be preferable to administer an ototoxic agent to the oval window specifically, while protecting the round window. We therefore by means of an endaural exploration of the middle ear, placed gelfoam with gentamicin in the oval window nische and around the stapes, while protecting the round window with gelfoam soaked in saline in 6 patients- 5 with serviceable hearing, PTA $<$ 55 dB- not responding to transtympanic gentamicin.

Results: In 5 out of 6 patients, vestibular function was ablated and vertigo attacks disrupted without further deterioration on hearing. The last patient, who before surgery did have PTA $>$ 90 dB, did not respond to the procedure and underwent a labyrinthectomy.

Conclusion: Although a small materiel, this procedure of 'specific oval window gentamicin application' offers a possible option to enhance the presentation of gentamicin to the vestibular apparatus and ablate vestibular function while saving hearing, in those patients that do not respond to transtympanic gentamicin.

D1-3

Unilateral intra perilymphatic iInfusion of substance P facilitates vestibular functional recovery against AMPA-induced vestibulotoxicity

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Substance P (SP) is an undecapeptide belonging to a class of neuropeptides, entitled tachykinins. In the inner ear, though many previous studies concerning localization of SP were reported in the nineteen- nineties, showing that SP exists abundantly in the vestibular endorgans, functional role of SP in the inner ear is still unknown. We previously reported that unilateral intra perilymphatic infusion of SP enhanced ipsilateral vestibulo-ocular reflex (VOR) gains in sinusoidal rotation test. SP often acts as a neuromodulator in the CNS and can directly influence the neuronal excitability. Furthermore, SP also acts as a neurotrophic factor. We hypothesized that SP may possess protective effects against some kinds of inner ear disorders. The aim of the present study was to investigate the effect of SP, locally applied in guinea pig unilateral inner ear, on AMPA-induced vestibulotoxicity.

Hartley white guinea pigs with normal tympanic membranes and normal Preyer reflexes were used in this study. In each animal, a tiny hole was made adjacent to the round window in the right ear. A polyethylene catheter filled with 10 mM AMPA and connected to a syringe filled with the same agent was inserted into the hole. The syringe was set on a syringe pump and infusion was done at 0.6 ml/h for 5 min. Twelve hours after AMPA-infusion, 10 mM SP was infused through this hole by osmotic pump (SP group). As a control, after AMPA-infusion, artificial perilymph was used in osmotic pump (control group). Spontaneous nystagmus was observed after AMPA-infusion. Rotation tests were performed before treatment and 3 days, 1 week and 2 weeks after treatment, and VOR gains were calculated.

All animals showed spontaneous nystagmus after AMPA-infusion. In SP group, spontaneous nystagmus number decreased significantly. Moreover, SP group showed a rapid recovery of VOR gains 3 days and 1 week after treatment.

These results indicate the possibility that SP may possess protective effects against AMPA-induced vestibulotoxicity.

D1-4

Topical application of IGF1 for the treatment of inner ear disorders

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Previous studies have demonstrated the potential of several growth factors for the treatment of inner ear

disorders; however, their clinical application has rarely realized. We focused on insulin-like growth factor-1 (IGF1), which is a mitogenic peptide that plays essential roles in the regulation of growth and development in the inner ear, and conducted basic experiments to reveal its effects on inner ear hair cells followed by clinical investigations. In vivo experiments using animal models for noise- and ischemia-induced injury have demonstrated that topical application of IGF1 using gelatin hydrogels efficiently attenuate hair cell damage resulting in significant recovery in hearing. Ex vivo studies using explant culture systems have revealed the capability of IGF1 for protection hair cells against ototoxic drugs and involvement of the Akt pathway in promotion of hair cell survival by IGF1. Based on findings in basic studies, we designed a cohort study of phase I-II clinical trial (UMIN-CTR: R000001118) to examine the safety and efficacy of topical IGF1 application for corticosteroid-resistant acute sensorineural hearing loss. Twenty five cases including 12 males and 13 females were registered and the average of age was 47.2 $\pm$ 12.7 (SD). Topical IGF1 application was performed 23.1 $\pm$ 4.6 days after the onset of acute hearing loss. Under local anesthesia, pieces of gelatin hydrogels that had been immerced with IGF1 were placed in the round window niche after tympanotomy. The therapeutic effects are evaluated 12 and 24 weeks after the treatment, using pure tone audiometry. The criteria for hearing improvement, which was determined by the sudden deafness research committee of the Japanese Ministry of Health, Labour and Welfare in 1984, is used in this study. Complete recovery is defined as recovery of a hearing level within 20 dB at all five frequencies tested: 0.25, 0.5, 1.0, 2.0 and 4.0 kHz or recovery to the same level as the opposite side. Marked recovery is defined as more than 30 dB recovery in the mean hearing level at the five frequencies tested. Slight recovery is defined as recovery of 10-29 dB in the mean hearing level at the five frequencies tested. No response is defined as less recovery than 10 dB in the mean hearing level at the five frequencies tested. The recovery rate was calculated as patient numbers with complete, marked or slight recovery divided by a number of total registered patients. Statistically, the null hypothesis was that the recovery rates would be 33%. The recovery rates with 95% confidence limits were 48% (28–69; $P = 0.086$) at 12 weeks and 56% (35–76; $P = 0.015$) at 24 weeks. No serious adverse effects were observed. Floating sensation was found in 11 cases (44%), which continued for 6 $\pm$ 5.8 days, and inflammation in the middle ear was found in 7 cases (28%), which were cured on 9.4 $\pm$ 6.3 days after the onset. In conclusion, present findings indicate that clinical efficacy of topical IGF1 application for the treatment of inner ear disorders.

D1-5

Validation of a specific drug against g-level transition induced spatial disorientation and orthostatic intolerance: the ESA SPIN-D study

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Spaceflight is known to induce vestibular and cardiovascular deconditioning. Consequently, astronauts suffer from orthostatic intolerance and spatial disorientation upon return to a gravitational environment. Although pharmaceutical countermeasures against these symptoms are currently being given to astronauts, the effects of the administered drugs on the different parts of the vestibular system, as well as on autonomic function and cognition, haven't been thoroughly investigated so far. This was the aim of the ESA SPIN-D study. The final purpose of this clinical study is to identify the most appropriate pharmaceutical countermeasure against the aforementioned symptoms.

The double blind placebo controlled study was conducted on 20 healthy, male volunteers. Following medications were of interest: baclofen (10 mg), meclizine (50 mg), dimenhydrinate (40 mg) in combination with cinnarizine (20 mg), promethazine (25 mg) combined with dextro-amphetamine (5 mg). The effects of the drugs were investigated by a series of specific tests.

The function of the semicircular canals was evaluated by means of the elektronystagmography (ENG). To determine the effects on the oculomotor system and the vestibulo-ocular reflex (VOR), several parameters were measured and included in the analysis: latency, maximal velocity of the eye movements, VOR gain, VOR phase, VOR asymmetry, and the sum of the slow component velocity on the warm and cold caloric irrigations. Saccular function was investigated by means of the cervical vestibular evoked myogenic potentials test (cVEMP test) and following parameters were measured: VEMP response amplitude, mean rectified voltage, p13 and n23 latencies (including the difference) and the VEMP threshold. The integrity of the utricle was evaluated by performing a unilateral centrifugation test (UC test) and characterised by: adaptation and cupular time constant, bias, utricular gain, utricular asymmetry and velocity storage time constant. The head up tilt-test was conducted in order to evaluate the autonomic response of the subjects during orthostatic stress. Cardiovascular parameters (diastolic and systolic blood pressure DBP-SBP, RR-interval RRI) were recorded during the protocol and included in the analysis. Several computerised cognitive exercises made it able to determine the effects of the medications on the cognitive functioning of the subjects. These tests were not included in this preliminary analysis.

For each type of medication, the different tests were spread over two half, consecutive days and executed on the same hour to exclude time effects. The plasma concentration of the drugs was determined by taking blood samples on three fixed times: 10 am, 15 pm and 17 pm. This enables us to correlate the results of the several tests with the plasma values in order to identify the true effects of the medications. The subjects were also asked to complete several questionnaires so that the magnitude of the experienced side effects due to the medications (e.g. drowsiness) and the tests (motion sickness, depersonalisation and derealisation) could be determined.

Data from the meclizine arm showed a significant correlation between the plasma concentration and the VOR gain of the ENG. Analysis of the data from the combination of cinnarizine and dimenhydrinate showed a significant correlation between the plasma values and the sum of the calorics measured during the ENG. Thirdly, although just not significant, a trend was observed in the promethazine and d-amphetamine arm that indicated a correlation between the amplitude of the VEMP response and the plasma values.

Based on these first observations it can be concluded that an extensive analysis of the gathered data, with the plasma values taken into account, is needed in order to elucidate the real effects of the drugs on the vestibular and autonomic system. Results of the analysis will be included in the presentation.

Oral Session D2 – Ageing & Balance

D2-1

Longitudinal study of normal subject postural control, age, gender, and vestibular dysfunction

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Introduction: Postural stability decreases with age. What are the major contributors?

Objective: Study postural control of normal subjects as a function of age.

Methods: Three groups were studied using Computerized Dynamic Posturography: A: Data from a cross-sectional study of dynamic posturography (N $=$ 214, 7–81 yrs) [1] were compared statistically [2] with B: another cross-sectional cohort from a Baltimore Longitudinal Study of Aging (BLSA) (N $=$ 190, 20–80 yrs). Both groups were compared to C: a 30-year longitudinal study of a subset group from the first (Group A) cross-sectional study (N $=$ 47, 17–80 yrs).

Results: No age effects were observed in the three groups under fixed platform conditions. However, age effects were observed in all three groups during sensory organization test (SOT) conditions 5 & 6 which require vestibular inputs for postural control. In both cross-sectional (A & B) groups, postural instability began in the late 5th or 6th decade and increased with age. Gender differences were detected in both the BLSA and the longitudinal study groups. The BSLA study demonstrated that the gender differences occur only in the lower 50th%tile. In the longitudinal study (Group C) SOT 5 sway increased about 50% (t $=$ 3.81, 46 df, P $=$ 0.0004) and SOT 6 increased about 20% (t $=$ 2.05, 46 df, P $=$ 0.046). Fifty percent changes such as those observed in SOT 5 would be detectable with a power $>$ 90%.

Discussion and Conclusions: The three studies demonstrated significant effects of age, gender and test session (SOTs 5 & 6) on postural control. The age effects occurred only on SOTs 5 & 6, suggesting failing vestibular function with increasing age. Because sway increases and falls during SOTs 5 & 6 occurred in all decades in the longitudinal study, the vestibular effects were clearly independent from age. Gender differences appear to affect only those subjects who perform below the population mean (lower 50th%tile), with women affected earlier (beginning in the late 4th decade)

than men (6th decade). These results have important implications for fall risk and prevention.
Supported by NIH/NIDCD DC00205, NASA NAG9-1254, LHS RAC, and NIH/NIA IRP.

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D2-2

Presbyequilibrium in the oldest olds, a combination of vestibular, oculomotor and postural deficits

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Objectives: To evaluate the association of vestibular symptoms to vestibular findings evaluated with video-oculography (VOG) and posturography.
Design: Clinical investigation
Setting: One residential care facility.
Participants: Thirty-eight oldest olds ($\geqslant$ 85 y, mean age of 89) living in a Koukkuniemi residential home in Tampere, Finland.
Measurements: The vestibular symptoms were taken with a structured questionnaire, the Mini Mental State Examination (MMSE) was scored and falls were recorded during a period of 12 months after the examination. Posturography was measured with force platform technique and eye movements including positional testing and voluntary eye movements was measured with video-oculography.
Results. During the follow up period of 12 months, in 19 elderly (19/38), one or more falls were recorded. In the majority of the elderly, vestibular abnormalities were found, as reduced vestibulo-ocular reflex gain 6/38, spontaneous nystagmus 5/38, gaze deviation nystagmus 5/38, head shaking nystagmus 9/38, pathologic head thrust test 10/38 and positional nystagmus in 17/38 of the elderly. Of the positional nystagmus 9 (9/17) was classified as peripheral and 8 (8/17) of central type. The posturography demonstrated two major findings: the body support area was severely limited, at approximately 5 cm2, and the use of vision for postural control was strongly reduced. In principal component analysis, 4 major factors could be retrieved describing concept of presbyequilibrium.
Conclusions. In oldest olds positional vertigo frequently accompanied other types of vestibular and oculomotor pathologies. The postural confidence area was severely restricted and the use of vision to assist postural control was limited. As the problems with vertigo, dizziness and postural imbalance are prominent, a need for new expertise has been recognized for which specialized health care staff should be trained for.

D2-3

Change of body movement coordination during cervical proprioceptive disturbances in older adults

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Objective: About one third of every older adult above 65 years old reports a fall at home each year. This amounts to a number of fall-related injuries, ranging from minor to fatal and an accumulative cost of about $32 billion by 2020 in the United States alone. Understanding the mechanisms relating to balance deficits in older adults is crucial. Also, kinematical analysis can offer a more comprehensive assessment of standing postural control than typical Centre of Pressure recordings.
With old age, the sensory systems deteriorate and this is one of the fundamental reasons why older adults often fall. Older adults are particularly susceptible to falls from unexpected, externally-induced balance perturbations during dynamic transitions. Proprioception is one of the key senses as it signals to the Central Nervous System widespread movement of the body. Different locations are involved in signalling different standing characteristics, for example calf muscle afferents are mainly involved in the maintenance of equilibrium whereas neck muscle afferents are mainly involved in the regulation of body orientation. Older adults have difficulty with equilibrium and orientation, though it is of interest whether key proprioception at the calf and neck contribute differently to whole body kinematics as we get older.
The objective of the study was to investigate whether the standing postural coordination strategy to Calf or Neck vibration was affected by old age.
Anterior-posterior body movements were captured at five locations (ankle, knee, hip, shoulder and head) from 18 younger (mean age 29.1 years) and 16 older (mean age 71.5 years) adult subjects using a 3D movement measuring system. There was 30s of Quiet Standing before 50s of pseudo-random Calf or Neck vibration pulses to perturb balance with Eyes Open (EO)

or Eyes Closed (EC). The movements from the knee, hip, shoulder and head markers were correlated to determine the standing postural coordination.

Results: In Quiet Standing, older adults had greater correlation between the head and trunk than younger adults. There was an age effect in postural coordination when balance was perturbed. Older adults had a different postural coordination with Neck vibration with Eyes Open and Closed involving mainly more independent knee movements, indicating balance difficulty. There was no difference in postural coordination between older and younger adults with Calf vibration.

Conclusions: Older adults are more dependent on neck proprioception for maintaining their postural coordination than younger adults. Further, perturbations of neck proprioception (orientation) influence postural coordination in older adults more than perturbations of calf proprioception (equilibrium). Our findings prove that dynamic transitions to body orientation in older adults are particularly threatening to standing balance. As a defensive measure to falls in old age, rehabilitation techniques focusing on body orientation should be recommended. Also, older adults have increased neck rigidity in Quiet Standing. This is perhaps indicative of compensation to underlying vestibular damage. Patients tend to restrict movement of the head by increasing neck rigidity when the vestibular system is damaged to limit dizziness.

Postural coordination for older (A and B) and younger (C and D) adults in Quiet Stance (0–30s) and vibration (30–80s) with Eyes Open (EO) and Eyes Closed (EC).

D2-4

Aging effect on galvanic vestibular-evoked myogenic potentials

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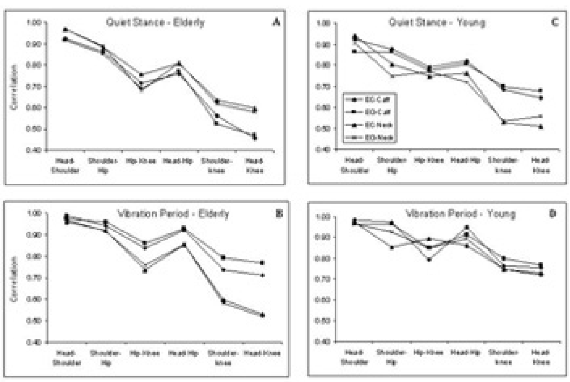

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Objective: This study compared the characteristic parameters of vestibular-evoked myogenic potentials (VEMPs) via galvanic vestibular stimulation (GVS) in healthy subjects of various ages to measure the effect of aging on GVS-VEMPs.

Methods: Fifty-two healthy subjects were divided into five groups by age. Each group consisted of 10 subjects in one decade except 12 subjects in the group of 60-69 years. All subjects underwent VEMP testing via galvanic stimulation with an intensity of 5 mA for 1 ms.

Results: All 10 subjects (20 ears) in each group aged 20–29, 30–39, 40–49, and 50–59 years exhibited clear GVS-VEMPs, while 20 (83%) of 24 ears in the group aged 60-69 years had clear GVS-VEMPs, exhibiting non-significant differences in terms of prevalence between the groups of subjects younger and older than 60 years. The mean p13 and n23 latencies, and p13–n23 amplitude of the subjects in the groups aged 20–29, 30–39, 40–49, 50–59, and 60–69 years differed significantly among the five groups: the p13 and n23 latencies of the group aged over 60 years was significantly longer than those of subjects younger than 60 years and their p13–n23 amplitude was lower.

Conclusion: The decline of the amplitude and prolongation of the latencies in GVS-VEMPs after the age of 60 may, at least in part, be due to the decrease in the number of vestibular afferents and their caliber.

D2-5

Vibrotactile neurofeedback for vestibular rehabilitation in patients with presbyvertigo

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Objective To clarify the significance of vibrotactile neurofeedback for vestibular rehabilitation in patient with presbyvertigo.

Method: 16 patients in Germany and one patient in Japan with presbyvertigo participated in this study. These patients underwent an individualized vestibular rehab program with the vibrotactile neurofeedback device, Vertiguard®-RT. Individualization of the rehab program started with a body sway analysis during 14 different everyday life stance and walking conditions. The results of the body sway analysis were compared with inbuilt age and gender related normative values and six tasks, which showed the most pathological results, were included in the training program. The individual feedback thresholds for these tasks were stored in the device.Training was performed daily over 2 weeks (10 sessions, weekend was excluded). A training session consisted on 5 repetitions of the selected training tasks (each repetition lasted 20 seconds). The patient received a vibrotactile feedback signal during the training in those directions which showed a higher body sway than the preset threshold. Results of the free field body sway analysis, the sensory organization test (SOT) and the vertigo symptom scale (VSS), were compared before and after the rehab program. In the Japanese patient, the results of Japanese version of functional balance scale (FBS) and dizziness handicap inventory (DHI) were compared instead of SOT and VSS.

Results: In total, patients significantly decreased their body sway in 82 out of 90 training conditions. The mean reduction of sway in all successful conditions was 39.5% in pitch and 32.4% in roll direction ($p < 0.000$). The results of the VSS were reduced significantly ($p < 0.05$) and those of the SOT were increased significantly ($p < 0.05$). The result of the FBS and the DHI showed also a clear improvement.

Conclusion: Free field vibrotactile neurofeedback training with the Vertiguard®-RT device seems to improve the balance in everyday life conditions with minimal efforts for the patients.

This is especially important for patients with presbyvertigo. Further studies should investigate the long term follow-up.

D2-6

Clinical investigation of presbyastasis patients using the cross test

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Objective: To investigate the equilibrium function of elderly patients experiencing dizziness caused by age-dependent physiological vestibular dysfunction (presbyastasis) and evaluate the effects of a vestibular rehabilitation program the author conducted a new balance training program, the cross test.

Method: Thirty patients aged over 65 years with presbyastasis who had complained of equilibrium dysfunction for at least 3 months were enrolled in this study. The standing balance training system with gravicorder was used to examine their equilibrium. The cross test indicates the equilibrium function based on ankle mobility and the center of gravity when individuals move forward, backward, right and left in turn on the gravicorder. The cross test was carried out once a month at least more than 5 times, and the resuts were subjected to statistical analysis.

Results: After undergoing the vestibular rehabilitation program, the range of ankle motion improved in 27 out of 30 patients compared with the pretraining values ($p < 0.05$).

Conclusion: These findings suggested that the cross test is a reliable methods to estimate the equilibrium function and the effects of a balance training program for patients with presbyastasis. Furthermore, it appears that it is associated with prompt improvement of equilibrium dysfunction and thus is an effective therapeutic option along with medication and conventional vestibular training programs.

Oral Session D3 – Epidemiology

D3-1

Balance and dizziness problems and falls in the United States: results from the 2008 National Health Interview Survey (NHIS)

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Objective: To assess prevalence and co-morbid conditions in U.S. adults who reported dizziness and balance problems during the past year.

Methods: The 2008 NHIS Balance and Dizziness Supplement is the first nationally-representative household interview of U.S. adults (18+ years) to include extensive coverage of disturbances in balance/vestibular function. Conducted by the National Center for Health Statistics (NCHS), NHIS is the principal source of health information for the U.S. civilian population, comprising information from ≈30,000 households each year with an over-sampling of selected racial/ethnic minorities. A subset of NHIS participants (N = 21,782) were asked questions on dizziness/imbalance symptom character, severity and timing; provoking and palliating factors; use of balance aids; physical and psychological problems; medicine and drug use; conditions associated with episodes; health care utilization; diagnoses conferred; use of treatments; outcomes; limitations of activities; days of school or work missed; numbers of falls in the past 1 and 5 years; injury from falling. Questions referring to characteristics of particular symptoms (e.g., severity and timing) were asked only about the most "bothersome" symptom when subjects reported multiple symptoms during the past year, such as vertigo *and* light headedness *and* unsteadiness. Statistical analyses adjusted for the complex sample design to ensure estimates accurately represent percentages of the U.S. population and that variance estimates were suitable for testing significance and calculating 95% confidence intervals (CI).

Results: The 2008 NHIS Balance and Dizziness Supplement revealed that 14.8% of U.S. adults (33.4 million) report they had a problem with dizziness or balance during the past year. The prevalence was higher for women (18.3%; 21.3 million) than for men (11.1%; 12.1 million) and increased with age up to 27.7% of adults (4.8 million) aged 75 years and older. Symptoms designated as most bothersome were 'unsteadiness' (28.0%), 'feeling lightheaded' (18.4%), 'feeling you are about to pass out' (16.3%), 'vertigo or spinning feeling' (13.5%), and 'blurred vision when moving head' (5.2%). The least bothersome was a 'floating or spacey feeling' (3.7%), and a few subjects (1.1%) had multiple symptoms but couldn't choose which was most bothersome. Other respondents (13.8%) reported a dizziness or balance problem but indicated their problem was not characterized by one of the specific symptoms listed. For the most "bothersome" symptom, follow-up questions were asked: a) age symptom first occurred, b) length of time with the problem, c) how often the problem has occurred in the past year, d) how long each bout or spell lasts, e) what triggers the problem. Only one-third of subjects reported a diagnosis for the "cause" of their problem. Just 14.4% of subjects with dizziness or imbalance problems reported they had *ever* gone to the hospital for emergency room (ER) care. Only half (48.9%) of the subjects with a dizziness or balance problem had *ever* seen a health care professional or visited the ER for care. Subjects reporting balance/dizziness problems during the past year had a relative risk of 5.0 (95% CI: 4.5, 5.6) for falling one or more times during the past year.

Conclusion: Dizziness and imbalance have a high prevalence as nearly 15% of U.S. adults reported symptoms of balance/vestibular dysfunction. Since these symptoms are common, disabling, and costly, this survey will be repeated periodically to track Healthy People 2020 objectives that promote increased utilization of health care for diagnosis and treatment of people with these problems.

Funding: The 2008 NHIS Balance and Dizziness Supplement was conducted by NCHS/CDC with collaboration and funding from NIDCD/NIH; CCDS was supported by NIDCD R01-DC9255.

D3-2

Prevalence and impact of bilateral vestibular deficiency (BVD): results from the 2008 United States National Health Interview Survey

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Background: Profound bilateral loss of vestibular sensation disables the vestibulo-ocular and vestibulo-spinal reflexes that normally maintain stable gaze and posture. Affected individuals suffer oscillopsia (illusory movement of the visible world during head movement), chronic disequilibrium and postural instability that interfere with otherwise routine activities such as walking or driving (Minor, 1998). Accurate estimates of prevalence and incidence have been difficult to generate, due to the lack of regular reporting mechanisms focusing on balance/vestibular dysfunction, such as the national health interview and examination surveys that are used to track the prevalence of hearing loss/deafness and vision loss/blindness in the United States.

Objective: Assess the prevalence and impact of severe-to-profound bilateral vestibular deficiency (BVD) from results of a large, nationally representative sample of adults.

Methods: Responses from adult (18+ years old) participants in the first ever 2008 Balance and Dizziness

Supplement to the United States National Health Interview Survey (NHIS) conducted by the U.S. National Center for Health Statistics (NCHS) formed the data for this study. Sets of questions defining a constellation of symptom characteristics typical of BVD were incorporated intentionally into the NHIS to allow accurate estimation of the prevalence of this disorder. Supplemental questions further defined symptom character, severity and timing; provoking and palliating factors; use of balance aids; physical and psychological problems; medicine and drug use; conditions associated with episodes; health care utilization; diagnoses conferred; treatments offered; compliance with treatment; outcomes; limitations of activities; days of school or work missed; number of falls in the past 1 and 5 years; and injury sustained due to falls. Statistical analyses adjusted for the complex sample design to ensure that estimates accurately represent percentages of the U.S. population.

Results: Of 21,782 adults surveyed, 21 respondents reported a history consistent with chronic, disabling, severe-to-profound BVD (i.e., all of the following: dizzy in the past year, visual blurring during head movement despite little/no problem reading a newspaper [presumably while still], unsteadiness, symptom duration $\geqslant 1$ year, and severity of problem "big" or "very big"). This yields an estimated point prevalence of 81/100,000 adults, which equates to a prevalence of about 183,000 severe/profound BVD adults in the United States, 500,000 in the U.S. and Europe combined, or 3 million worldwide (by simple extrapolation of U.S. estimates to the adult European and World population). Of those respondents reporting a BVD symptom complex, 42% reported that they had changed their driving habits or stopped driving due to their symptoms; 84% reported falling during the past 5 years. This equates to an age-adjusted 6.4-fold increase in fall risk (95% CI: 2.3–18.2) among those with BVD in comparison to those with dizziness/imbalance but not BVD, and a 24-fold increase in fall risk (95% CI: 6.1–93.7) in comparison to the nationwide average.

Conclusions: As estimated from self-reported symptoms obtained during a comprehensive interview about balance/vestibular dysfunction in a nationally representative survey of U.S. adults, the apparent prevalence of chronically symptomatic severe-to-profound bilateral loss of vestibular sensation is much higher than previously believed. Individuals reporting a constellation of symptoms consistent with BVD are at increased risk for falls.

Support: The 2008 NHIS was conducted by the NCHS, CDC with collaboration and funding from the National Institute on Deafness and Other Communication Disorders (NIDCD), NIH. CCDS was supported by NIDCD R01DC9255 and R01DC2390.

D3-3

Investigation of the relationship between migraine, vertigo, unsteadiness and dizziness in a clinical cohort

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Background: Diagnostic criteria for migrainous vertigo (MV) have been proposed but never validated. Emerging data from epidemiologic studies in the general population support a link between migraine and vertigo that may be strongest in individuals with aura and discrete episodes of vertigo. In contrast, the association between non-migrainous headache and unsteadiness or dizziness appears to be weaker. Further support for a potential link between migraine and vertigo is needed from well-characterized clinical populations to better understand the relationship between migraine and specific vestibular symptoms. Data also are needed about key diagnostic characteristics that identify MV and differentiate it from other neurotologic illnesses.

Objectives: 1) To examine the potential link between migraine and vertigo in a well-characterized clinical cohort of patients referred to a tertiary dizziness and balance center, and 2) to identify key diagnostic features that characterize MV and differentiate it from other neurotologic illnesses.

Methods: We retrospectively reviewed records of 600 consecutive patients referred to our tertiary medical center with complaints of vertigo or dizziness from April 2008 through July 2009 and identified 245 subjects diagnosed with migraine, Ménière's disease, benign paroxysmal positional vertigo (BPPV), or chronic subjective dizziness (CSD). All patients underwent comprehensive neurotologic examinations, vestibular testing, audiometric assessments, and neuroimaging. We extracted predetermined demographic, historical, examination, and vestibular laboratory variables from the medical record and verified diagnoses by consensus conference. Descriptive and comparative analyses were conducted on 115 subjects with clinically significant headache symptoms after dividing them into three groups: 1) definite or probable MV by Neuhauser criteria; 2) migraine headaches unrelated to vertigo, unsteadiness, or dizziness (unrelated migraine); and 3) non-migrainous headache.

Results: In the cohort of 245 subjects, 115(47%) had a headache disorder. 81(33%) had migraine by IHS criteria. 40(16%) had MV, including 20 with definite and 20 with probable MV. Thirteen MV patients had migraine with aura (MA), 27 without (MO). 41(17%) subjects had unrelated migraine, including 9 with aura and 32 without. 34(14%) subjects had non-migrainous headache. The demographics of subjects with MV were typical for a migraine population. The average age of MV patients was 48 years (range 19–79 years); 97% were Caucasian; 80% were female. Median age of headache onset was 22 years. Vertigo or dizziness was present for a median of 3.3 years prior to evaluation.

Temporal patterns of vertigo, unsteadiness, and dizziness varied systematically across the three headache groups. MV patients were more likely to have discrete episodes of rotational or translational vertigo lasting hours with residual unsteadiness lasting days. Subjects with unrelated migraine tended to have episodic vertigo lasting minutes to hours with constant unsteadiness or dizziness. Subjects with non-migrainous headaches reported episodic vertigo lasting only seconds. Their predominant symptom was constant unsteadiness or dizziness.

There were no statistically significant differences between MA and MO patients in the MV group, but there was one finding in concordance with population data that identified the closest association between MA and episodic vertigo. In the MV group, a numerically greater fraction of MA (9/13, 69%) than MO (13/27, 48%) subjects had migraine as their only neurotologic diagnosis. The remaining subjects had BPPV, Ménière's disease, or CSD as co-existing causes of symptoms.

Conclusions: The results of this clinical study parallel previously presented population data on the relationship between migraine, vertigo, and dizziness. A systematic relationship between type of headache (MV, unrelated migraine, non-migrainous headache) and type of vestibular symptom (episodic vertigo, chronic unsteadiness, chronic dizziness) was identified. These findings support a potential causal link between migraine and vertigo, but suggest that other conditions may be important causes of unsteadiness and dizziness, even in patients with migraine.

D3-4

Development of screening tests of the vestibular system for epidemiologic and post-flight studies

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In the United States no large-scale epidemiologic studies of the vestibular system have ever been performed. Hence, at a time when health care administrators are coping with reduced budgets to plan future health care services, no local data are available to guide their decision-making about the future needs of people who have or will have vestibular disorders. One reason such studies have not been performed is the paucity of simple, inexpensive, rapid, but valid and reliable screening tests of the vestibular system. Similarly, no such tests are available for flight surgeons to use when examining astronauts at remote landing sites shortly after return from long-duration space flight. The goal of this study is to develop a valid and reliable screening battery that will a) indicate the presence or absence of a vestibular impairment, b) take no more than 15 minutes, and c) be performed and interpreted with minimal equipment, by staff without significant technical expertise in the vestibular system.

The new battery includes a test of dynamic visual acuity for indirect testing of the vestibulo-ocular reflex [1], a battery of standing balance tests: the Clinical Test of Sensory Interaction on Balance (CTSIB) [2] sharpened by adding conditions with yaw and pitch head motions, and three tests of walking balance: tandem gait with eyes closed [3], walking with yaw head rotations, and the shortened version of the Functional Mobility Test [4,5]. Kinematic measures are obtained from IMU sensors attached to the head and torso during the performance of these tests Subjects are 50 normals, aged 21 to 79, and 50 patients with unilateral caloric weakness or post-acoustic neuroma resection. Preliminary analyses suggest that patients with vestibular impairments are significantly impaired on performance of at least some subtests compared to normals. On CTSIB the conditions on foam with head movement are more sensitive than other conditions. Inter-rater reliability = 0.9.

These data support previous work showing that performance of some balance tests is sensitive to vestibular disorders and will be useful for screening. Statistical analyses of the final data set will be used to determine which tests from the screening battery will be used in the final, reduced test battery. The final battery will use the Dix-Hallpike maneuver, the head thrust test and the selected tests from the new battery. After that, a small epidemiologic study will be performed.

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D3-5

Prevalence of vestibular function and balance abnormalities among HIV-seropositive and HIV-seronegative women and men

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The goal of this study was to determine the prevalence of vestibular function and balance abnormalities among HIV seropositive and seronegative men and women in the United States. Subjects were participants at two of the sites (Baltimore, MD and Washington, DC) in ongoing prospective studies of the natural and treated histories of HIV infection (men: Multicenter AIDS Cohort Study (MACS); women: Women's Interagency HIV Study (WIHS)). We examined how age, race/ethnicity, history of antiretroviral medication use, CD4 cell count, and HIV RNA viral load are associated with the prevalence rates. Participants, recruited during their routine semiannual visits, included 265 men (median age (IQR): 54.3 years (48.5, 60.8); 42% HIV-seropositive, 58% HIV-seronegative) and 152 women (median age (IQR): 43.4 years (37.7, 52.4); 79% HIV-seropositive, 21% seronegative). A screening questionnaire, which was used as part of the 2008 Balance and Dizziness Supplement to the National Health Interview Survey, was administered to subjects. Study clinicians, who were physician assistants, performed the test battery. The test battery was comprised of head thrusts, Dix-Hallpike maneuvers, tandem gait, and the Clinical Test of Sensory Interaction and Balance. Participants who had positive findings were then referred to one of two clinical laboratories for further diagnostic testing. Results of the analyses will be described and the implications for management of HIV care will be discussed.

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D3-6

Quality of life(QoL) of patients with bilateral vestibular loss

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Introduction: It is often thought that severe bilateral vestibular loss is centrally compensated or substituted by other senses in such a way that quality of life is hardly affected. The aim of our study was to assess the Quality of life(QoL) in patients with bilateral vestibular function loss.

Study Design: QoL was assessed in thirty patients with confirmed bilateral vestibular loss. During individual interviews Short Form-36 (SF-36), Dizziness Handicap Inventory(DHI), Short Falls Efficacy Scale-International(Short FES-I) and a self developed questionnaire assessing oscillopsia were submitted to patients. Outcomes of Sf-36 and Short FES-I were compared to normative data. Oscillopsilla severity was correlated with DHI.

Results: Scores of 6 out of 8 items of the SF-36 were significantly reduced in patients with bilateral vestibular loss compared to age related healthy subjects. Short

FES-I scores were slightly increased compared to age related healthy subjects. Oscillopsia severity is correlated to DHI scores.

Conclusions: Bilateral loss of vestibular function has a significant negative impact on QoL of most patients. Oscillopsia is the main complaint; its severity correlates well with the patients' self-perceived handicap. The risk to fall is slightly increased. Those findings emphasize the need for therapeutic solutions such as the vestibular implant.

Oral Session D4 – Vestibular Reflexes

D4-1
Unilateral centrifugation by head tilt

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Unilateral centrifugation induced by body translation during fast rotation has been used to assess asymmetries in utricular otolith function [1–5]. In this paper we explore an alternative to assess utricular asymmetries by using head tilt during rotation instead of translation of the body and head en bloc.

During stand still and during 360 deg/s Earth vertical on-axis rotation, 12 healthy blindfolded subjects had their heads being tilted slowly from upright to their left and right shoulders about 30 degrees and back to upright again by means of a controllable head tilt device mounted on a Barany chair. At 30 degrees of head tilt, one inner ear was positioned approximately on the spinal body and chair rotation axes, thus experiencing no centripetal acceleration, while the other did so with a value of about 2.5 m/s2, resulting in a tilt of the gravito-inertial acceleration at that point of approximately 14 degrees. During two minutes in each orientation, we measured the subjective vertical (SV) by means of a joystick six times. Average SV-results per subject and condition during stand still were subtracted from those during rotation, thus eliminating somatosensory (neck and body) and idiotropic (egocentric) effects, the latter referring to the tendency of the SV to tilt with the head. During stand still, the SV tilted about 4 degrees on average with the head when tilted over 30 degrees. During rotation, the SV tilted about 9 degrees on average, the difference with respect to stand still of 5 degrees being highly significant.

Unilateral utricular otolith function has thus been demonstrated in healthy subjects using head tilt during rotation, which may be applicable for the clinical diagnosis of utricular asymmetries. From a technical point of view the advantage of using head tilt only, instead of whole-body translation, is its simplicity. From a fundamental point of view the advantage is that results can be compensated for somatosensory and idiotropic effects using head tilt, but not during translation. Therefore, the head tilt paradigm allows for a more unbiased unilateral utricular assessment. Moreover, the use of SV-measurements further simplifies the application of unilateral centrifugation in patients as compared to ocular torsion measurements.

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D4-2
Vestibular stimulation during active head movements: Perceptual and motor findings and proactive-reactive fusion model

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Objectives: Human motor activities often serve two functions at a time, which are (1) performing a voluntary movement while (2) simultaneously compensating for external disturbances. For example, when performing a targeting head or arm movement, reaching the goal may require compensation of external disturbances such as motion of the arm's or head's support (e.g. trunk rotation or translational acceleration), external or movement-contingent force fields (e.g. effects related to gravity), and contact forces (e.g. impact of a push). The multitasking of 'proactive' (voluntary) and 'reactive' (compensatory) mechanisms requires fusion of the two controls. This fusion is not well understood, to date. We investigated it in a combined sensorimotor and psychophysical study.

Methods: In the sensorimotor part of the study, we investigated horizontal head movements in darkness towards previously flashed visual targets and studied the effect of movement-contingent additional vestibular stimulation produced by rotating the turning chair on which the subjects were sitting. To this end, head-trunk position was measured and used as input to the chair rotation device, so that the chair rotation occurred in fixed register with the head movement. An interleaved computer randomized chair rotation direction (left or right) and amplitude (gain factor: 0, 0.18, 0.35, or 0.54). Prior to each trial, subjects indicated their visual straight ahead (VSA) direction using a remote-controlled light spot projection. Eccentricity of the head target was referenced to the VSA. After the head movement was finished, with head and chair (trunk) still in eccentric position, the psychophysical part started. Subjects were to reproduce the previous VSA in space using again the light spot projection. The experiments were performed in six healthy subjects and two vestibular-loss subjects.

Results: In the trials where the chair remained stationary (factor 0), subjects' head movements undershoot target in a way that is typical for this kind of head pointing experiments; subjects unconsciously perform gaze shifts where the eyes hit target and the head undershoots it. Compared to these unperturbed head movements, subjects decreased head velocity and displacement when the chair was rotated in the direction of the head movement, and increased them with counter chair rotation, thereby compensating to a large extent the external disturbances. The compensation was missing in the vestibular loss subjects. Retrospective request revealed that they did not consciously experience the chair rotation. Interestingly, also normal subjects did not experience the chair rotation in many trials although they compensated for it. Furthermore, the VSA reproduction at the end of each trial was approximately correct in normals, whereas it did not reflect the chair rotations in the vestibular loss subjects.

Conclusions: For abstracting, the findings of normal subjects were compared to simulations obtained using a dynamic head movement model. It built on a previously developed model of self-motion perception during passive head and trunk rotations (Mergner et al., 2001, EBR 141). In this model, neck proprioceptive and vestibular signals are fused in two steps: They obtain first an internal estimate of trunk-space rotation (trunk in space rotation), before this is then used in a further processing for the estimate of head-space rotation. The model was extended and modified such that the head-space estimate now is used for feedback control of the head movement, together with a desired head-space signal (set point input of the feedback loop), calculated from remembered head-target error. The simulations predicted well both the head movement results and the perceptual results of normals. The findings are discussed in relation to general principles of the proactive and reactive movement controls and their fusion and to the fact that an efference copy is not a prerequisite for this fusion.

D4-3

Vestibular predominance and post rotatory nystagmus in figure skaters

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Background/Objective: An advanced figure skater can effortlessly perform double, triple or even quadruple jumps and also rotate in high velocity spins for many seconds without falling to the ground or loosing their orientation when exiting the spin. Under international federation rules skaters are always required to turn in the same direction in performing their rotations in jumps and spins. Most figure skaters (ca 90%) prefer to rotate in the counter clock wise (CCW; yaw left) and 10% in the clock wise (CW; yaw right) direction. In 2003 Dieterich et al. proposed that the vestibular system's hemispheric dominance, which matures early during ontogenesis, probably determine right- or left-handedness and is located in the opposite hemisphere, i.e. right hemispheric dominance of the vestibular cortical system in right-handers. The aim of this study was to investigate differences in the ability to suppress the vestibular reflexes from the inner ear in figure skaters and to correlate these findings with the direction of preference for rotation, right or left handedness and compare the results with non-skaters.

Methods: Twelve right handed figure skaters (11 female, 1 male; mean age 14 years; range 9–21 years) and 5 healthy control subjects (1 female, 4 male; mean age 15 years; range 11–19 years) were rotated for 60 seconds at 150 or 250 deg/s in an on axis rotational chair (yaw) either in CW or CCW direction in a randomized order. Rotation tests were preformed in the dark when the subjects had their eyes closed or in the light with eyes open. Horizontal eye movements were recorded with electronystagmography during and 60 seconds after the cessation of rotation. The gain of the VOR, i.e. the ratio between maximum slow phase eye velocity and head angular velocity, and the time constant of the exponential decrease were measured, as was the number of beats or seconds of post rotatory nystagmus. Nine of the 12 skaters had CCW rotation as their preferred rotational direction.

Results: The ability of figure skaters to suppress post rotatory nystagmus through visual fixation was incomparable better than for non figure skaters (a few nystagmus beats compared to many seconds for the control subjects). Many of the control subjects could not finish the complete test session because of severe nausea and/or vomiting. After being rotated in light where visual fixation was possible after the end of the rotation, all skaters except one had fewer post rotatory nystagmus beats in their preferred rotational direction than in the other direction. After rotations in the light at 250 deg/s in the preferred rotational direction the skaters had a mean 6 ± 12 post rotatory nystagmus beats compared to 23 ± 18 beats after rotations in the non-preferred direction ($p = 0.033$).

Conclusions: This study confirms and clarifies earlier findings from the 1960s about the superior ability of figure skaters compared to control subjects to suppress post rotatory nystagmus through visual fixation. However, this ability is more pronounced after rotations in the preferred rotational direction of the skaters. These findings may indicate that vestibular hemispheric dominance could influence the choice of preferred rotational direction and thereby nystagmus responses in skaters. However, the preferred rotational direction did not seem to be correlated to the handedness of the skaters.

D4-4

Vestibular asymmetry as the cause of idiopathic scoliosis: a possible answer from xenopus

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Human idiopathic scoliosis is characterized by severe deformations of the spine and skeleton. The occurrence of vestibular-related deficits in these patients is well established but it is unclear whether a vestibular pathology is the common cause for the scoliotic syndrome and the gaze/posture deficits or if the latter behavioral deficits are a consequence of the scoliotic deformations. A possible vestibular origin was tested in the frog Xenopus laevis by unilateral removal of the labyrinthine endorgans at larval stages. After metamorphosis into young adult frogs, X-ray images and three-dimensional reconstructed micro-computer tomographic scans of the skeleton showed deformations similar to those of scoliotic patients. The skeletal distortions consisted of a curvature of the spine in the frontal and sagittal plane, a transverse rotation along the body axis and substantial deformations of all vertebrae. In terrestrial vertebrates, the initial postural syndrome after unilateral labyrinthectomy (UL) recovers over time and requires body weight-supporting limb proprioceptive information. In an aquatic environment, however, this information is absent. Hence, the lesion-induced asymmetric activity in descending spinal pathways and the resulting asymmetric muscular tonus persists. As a consequence the mostly cartilaginous skeleton of the frog tadpoles progressively deforms. Lack of limb proprioceptive signals in an aquatic environment is thus the element, which links the Xenopus model with human scoliosis because a comparable situation occurs during gestation in utero. A permanently imbalanced activity in descending locomotor/posture control pathways might be the common origin for the observed structural and behavioral deficits in humans as in the different animal models of scoliosis [1].

In order to further examine that hypothesis, we recorded the activity of extraocular and spinal motor nerves during passive head rotation and during spontaneous fictive swimming at various post-lesional time. The extraocular and spinal nerves that were modulated by the previously intact side, were silent during passive head rotation following UL at all post-lesional time. On the other hand, the same nerves were rhythmically bursting during spontaneous fictive swimming as in controls. Alexa Fluor Dextran retrograde labeling of the vestibulo-spinal neurons demonstrated the loss of almost all contralateral projecting ipsilesional vestibulo-spinal neurons in rhombomeres 2/3 and 5/6 after UL. These results demonstrated that the permanent asymmetric vestibular drive of the extraocular and spinal motoneurons and the asymmetric posture after UL in Xenopus are causally related to the degeneration of vestibulo-motor pathways. It likely occurred because of the combined loss of labyrinthine and proprioceptive inputs in some second-order vestibular neurons during development. The degeneration of the central vestibular neurons produces in turn a persistent imbalance in descending pathways, an asymmetric pulling of axial and limb muscles. The resulting asymmetric growth of cartilage and future bones will then cause scoliotic deformations of the entire skeleton.

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A scoliotic Xenopus following UL at larval stage

D4-5
Self-tilt thresholds match (or outperform) standard maximum-likelihood predictions

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Sensory signals include noise and are often ambiguous. Given these challenges, signals from multiple sensory modalities are merged to improve performance. For example, humans combine visual and haptic cues in a manner consistent with maximum likelihood weighted averaging, and combine semicircular canal and otolith cues nonlinearly using internal models. In this study we investigated sensory fusion of signals from semicircular canals and otolith organs by measuring roll tilt thresholds directly influenced by signals from both semicircular canals and otolith organs, which sense rotation and gravity, respectively. We set out to investigate the sensory integration mechanisms underlying roll tilt thresholds. Specifically we set out to determine if roll tilt thresholds could be explained by a "strong fusion" (internal model) mechanism, maximum likelihood weighting, or requires both internal models and maximum likelihood.

In order to assess rotation and tilt sensory modalities separately and in combination we measured direction-recognition (i.e., left or right) thresholds using three different classes of unidirectional motion stimuli: 1) "quasi-static" and "static" roll tilts ("otolith") using angular velocities far below canal and other sensor thresholds, 2) dynamic (0.1 to 5Hz) roll rotations of the supine head and body about an earth-vertical axis ("canal"), and 3) dynamic (0.05 to 5Hz) roll tilts ("canal-otolith") by rotating the upright head and body about an earth-horizontal axis. For "quasi-static" motions, unidirectional smoothed-ramp motion stimuli with constant velocity of 0.125° were used with peak acceleration and jerk of 0.05°/s2 and 0.03°/s3, respectively. For "dynamic" motions, single cycle sinusoidal angular accelerations were used, which yield unidirectional cosine-bell velocity profiles and sigmoid-like displacements. Thresholds were obtained for eight normal subjects (4 females, 4 males, mean age 38, range 28 to 59 years) for all three classes of motion stimuli. Thresholds for two patients (39 and 59 years of age) suffering severe idiopathic bilateral vestibular loss were obtained for "quasi-static" and slow (0.1Hz) roll tilt to ensure that slow roll tilt perception is primarily determined by otolith organs. Each test session was performed in the dark using a one-interval, two-response recognition design embedded in a 3-down 1-up staircase paradigm targeting the subject correctly recognizing motion direction 79.4% of trials at threshold.

An average threshold of 1.32° was measured during quasi-static tilts ("otolith"). The roll rotation ("canal") thresholds were consistent with earlier reports for yaw rotation – showing thresholds that increased as frequency decreased. Specifically, at 5 Hz, the average displacement at threshold was just 0.05°; at 0.1 Hz, the average displacement at threshold was 11.7°. The roll-tilt thresholds we measured matched or were lower than ($p = 0.012$, one-sided Wilcoxon signed rank test, $n = 11$) those predicted by maximum likelihood weighting of these canal and otolith thresholds. More specifically, we found roll tilt thresholds between 0.15 and 0.5 Hz that were significantly lower than predicted ($p = 0.016$, one-sided Wilcoxon signed rank test, $n = 6$).

To explain this performance, we developed a signal detection model combining maximum likelihood weighting with strong fusion sensory integration, where strong fusion simply means that the output of one sensory modality is directly influenced by signals from another modality. In our case, this strong fusion was implemented via an internal model that uses angular velocity signals to help predict/estimate the orientation of gravity. This model combines this internal model with maximum likelihood weighting to match our roll tilt threshold data. Consistent with earlier modelling, our findings suggest that internal models and linear optimal weighting synergistically yield lower thresholds than either in isolation.

D4-6

Modification of the cervico-ocular reflex (COR) by visual-cervical interaction

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COR gain increases after semicircular canal plugging are specific to the plane of the damaged canals and to the frequencies at which the gain of the angular vestibulo-ocular reflex (aVOR) is deficient (Yakushin et al., 2009). We have recently shown that low frequency COR gain that increased after canal plugging could be further modified by visual-cervical mismatch induced by in- or out-of-phase oscillation of the body and visual surround. Moreover, larger COR gain changes can be induced using longer adaptation periods (Kolesnikova et al., 2009, SFN). Although this procedure is effective, it can cause discomfort associated with head fixation and prolonged head on neck rotation. Here, we investigated whether similar increases in COR gain could be induced after all six canals had been plugged in two paradigms. In the first, head-free monkeys sat in a primate chair while wearing x2 magnifying glasses. Their bodies were sinusoidally oscillated while they watched a lighted screen in an otherwise darkened room. When viewing the screen, their heads counter-rotated relative to the body, and tended to remain fixed in space. In the second paradigm the head was fixed and the body was oscillated in-phase with vertical stripe movement at the same velocity on the computer screen. COR gains were tested before and after the 2 hr adaptation period in both paradigms by oscillating the body under stationary head in darkness at frequencies from 0.02 to 6 Hz. COR gain changes obtained with both techniques were comparable ($\approx$ 20–30%). Thus, the gain of the COR could be effectively increased in head-free animals in the same way as in animals with the head fixed. Thus, large increases in COR gain can be induced using magnifying glasses while leaving the head-free. If similar increases in COR gain changes can be induced in vestibular-deficient humans with magnifying glasses, it could be an effective tool in the armentarium of vestibular rehabilitation.

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D4-7

Cognitive influences on motion perception

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Spatial orientation includes central integration of motion cues from both sensory (e.g., vision, vestibular organs, and proprioception), and non-sensory sources (e.g., efferent copy, cognition) whose information can be ambiguous or conflicting. Here we expand upon earlier studies that have demonstrated an influence of cognition on tilt/translation resolution [2,3] with two experiments: one in darkness and another with combined motion and visual cues. Both experiments were performed on a servo-controlled parallel swing using a motion profile that allowed us to modulate the relative inter-aural (y-axis) and dorso-ventral (z-axis) force. By careful selection of radius (1.22 m and 0.38 m) and frequency (0.45 and 0.8 Hz, respectively), the tangential acceleration could be tailored in opposition to gravity so that the combined y-axis gravitoinertial force (GIF) variation was "nulled" below putative perceptual threshold levels [1]. Magnitude estimation techniques were used to measure subjects' perceived horizontal translation, roll tilt, and radius.

For the first experiment [1], we examined motion perception in darkness. For some trials, a radial linear acceleration at twice the tilt frequency (0.25 m/s2 at 0.9 Hz, 0.13 m/s2 at 1.6 Hz) was applied to also reduce the z-axis force variations. For other trials, the phase was reversed so that the z-axis force variations were doubled. Results showed that subjects' perceptions of tilt and translation were nearly veridical when both y- and z-axis forces were present. Y- and z-axis force nulling caused a decrease in perceived motion, while z-axis force doubling caused an increase in perceived

motion. In all cases – even when subjects reported their motion with significant errors – motion perception was remarkably consistent with the geometric constraints of swing motion. Might similar cognitive influences be found for visual and vestibular cue combinations, and would these be attenuated by confirming or conflicting visual cues?
In the second experiment, we sought to answer this question by combining dynamic visual scenes with dynamic motion stimuli that blend translation and tilt of the head. The visual scenes, presented on a flatscreen monitor with a monocularly-viewed 40° field of view, showed visual motion with a rotation radius either the same as or different from the subject's actual rotation radius. There were 3 categories of trials: 1. Trials in the dark with no visual cues; 2. Trials where the projected visual scene matched the actual motion; and 3. Trials where the projected visual scene showed swing motion at a different radius. Results showed that when the visual and vestibular cues differed, subjects reported perceptions that were geometrically consistent with a radius between the radii of the visual scene and the actual movement. Even when the subjective sensation did not match the visual or vestibular stimuli, subjects reported motion consistent with swing motion, which suggests that the perceived motion was constrained to be consistent with learned cognitive knowledge of the device capabilities. Finally, subjects were generally unable to detect cue conflicts or judge their own visual-vestibular biases, which suggests that the visual and vestibular self-motion cues are not independently accessible.
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Oral Session D5 – Vestibular Rehabilitation

D5-1

Static, dynamic balance and well being after acute unilateral vestibular loss

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Objective: The aims of this study were to evaluate long term (after 6 months) results of static and dynamic balance, occurrence of hypertension, headache, disturbed sleep and physical exercise habits in subjects who had undergone successful vestibular rehabilitation for acute unilateral vestibular loss (AUVL).
For comparison a healthy reference group was used.
Design: Prospective controlled study
Setting: Audiology department. Sahlgrenska University Hospital Sweden
Subjects: An AUVL group of 42 and a healthy reference group of 56 subjects. Main outcome measure: Static and dynamic balance performance was assessed using Romberg, sharpened Romberg test (SREC), standing on one leg with eyes open/closed (SOLEO/SOLEC) and 10 meters walking test, with and without head movements.
A questionnaire concerning occurrence of hypertension, headache, disturbed sleep and physical exercises habits was used.
Results: The AUVL group walked significantly slower and took shorter steps (p 0.001) compared to the subjects in reference group. Significantly impaired performances were found in the AUVL group in SREC (p 0.01), SOLEC, (P 0.05) compared to the reference group. A significantly larger proportion of patients with AUVL (26%) used anti-hypertensive medication compared to the reference group (4%) (p 0.01).
Conclusions: This study demonstrates that AUVL patients have more problems with hypertension compared to the reference group and vestibular rehabilitated AUVL patients after 6 months, have long-term static and dynamic balance problems.

D5-2

Comparison of the effects of visual and vibrotactile feedback on postural stability during balance rehabilitation exercise training

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Objective: Balance exercises, as part of vestibular rehabilitation therapy, have been shown to decrease dizziness and improve balance and gait stability in individuals with vestibular loss. However, patient compliance with prescribed home exercise programs is variable; patients often do not perform the exercises correctly or they lack the motivation to continue the exercises for the prescribed time, which can lead to worsening of symptoms, increased duration of symptoms, and poor functional outcomes. Real-time feedback of exercise performance offers the potential to improve the ability of a patient to perform the exercise properly, increase exercise motivation, and positively impact rehabilitation outcomes. Visual, auditory, vibrotactile, and electrotactile feedback have been used individually to provide real-time feedback of trunk movement during quiet and perturbed standing and locomotor activities. The goal of this study is to directly compare the effects of visual and vibrotactile feedback on postural stability to inform the selection of an optimal feedback modality for inclusion in a home-based vestibular rehabilitation assistive tool.
Methods: Five (3 male, 2 female) well-compensated subjects participated in this study. Four subjects had unilateral vestibular loss and one subject had bilateral vestibular loss. The average age of the subjects was $41.2 + 12.2$ years. Subjects were asked to perform 30 second Tandem Romberg stance trials with their eyes open, barefoot, and on a flat solid surface with the following feedback conditions: 1) No Feedback, 2) Visual Only, 3) Vibrotactile Only, 4) Visual & Vibrotactile, and 5) Continuous Visual. For trials that included Vibrotactile feedback, subjects were instrumented with a system composed of: a belt with four tactors (i.e. pager motors) positioned on the right and left external obliques, navel, and spine approximately at the L4/L5 lumbar level of the spine; an off-the-shelf inertial measurement unit; and a laptop. Conditions 2–5 used a proportional plus one half derivative control signal and provided feedback in the direction of trunk tilt when this tilt exceeded a one-degree activation threshold. Trials involving visual feedback used a white screen with targets located at the 12, 3, 6, and 9 o'clock positions that were illuminated when subjects exceeded the activation threshold in these directions. The Continuous Visual condition additionally displayed a moving ball that continuously showed the subjects' trunk movement. The Visual & Vibrotactile feedback condition simultaneously provided subjects with both vibrotactile and visual feedback.
Results: The root mean square (RMS) of trunk tilt in both the anterior-posterior (A/P) and medial-lateral (M/L) directions as well as the percentage time spent within the one-degree feedback activation threshold zone (PTZ) were used to quantify performance. Subjects significantly decreased their mean A/P and M/L RMS tilt values and significantly increased their PZ values for each feedback type in comparison with the no feedback condition. All performance metrics were significantly better during Continuous Visual feedback than all other feedback types. Performance using Visual Only feedback did not significantly differ from performance using Vibrotactile Only feedback.
Conclusion: Preliminary results indicate that continuous visual feedback of trunk tilt produces the smallest RMS and largest PTZ values. However, the feedback implemented here involves tracking a moving target and should be considered carefully for use in vestibular rehabilitation programs, since viewing moving targets can further induce dizziness in some patients with vestibular deficits, as some subjects noted in the current study. There was no difference among Visual Only, Vibrotactile Only, and Visual & Vibrotactile feedback for the eyes-open Tandem Romberg exercise. Given that not all exercises are performed with eyes open, vibrotactile feedback can offer more flexibility than visual feedback.

D5-3

The effect of additional otolith specific exercises to standard vestibular rehabilitation protocols for adults with unilateral vestibular dysfunction

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Background: Vestibular rehabilitation (VR) is effective for adults with unilateral peripheral vestibular dysfunction (UPVD), but little is known about its specific components. In the labyrinth of each inner ear, otolith organs are sensitive to linear acceleration while semicircular canals are sensitive to angular acceleration. Traditionally, exercises predominantly stimulating the semicircular canals are prescribed in vestibular rehabilitation protocols.
Objectives: The primary aim of this study was to investigate the role of otolith-specific exercises when added to exercises given in standard vestibular reha-

bilitation therapy. The research questions were -i) do otolith specific exercises further improve outcomes of physical performance and self- report measures when added to a standard VR program; and ii) are these further improvements maintained at a six- month follow up assessment? Secondary questions were: what are the effects of anxiety and adherence to an exercise program, and what is the responsiveness to change of a new questionnaire on the effects of vestibular rehabilitation?

Methods: A single blind randomized control study was conducted at a tertiary referral centre. Forty-eight participants with UPVD were randomized into an experimental or control group. Outcome measures were taken at baseline, nine weeks and at a six-month follow up session. The outcome measures were: questionnaires for the Vestibular Symptom Index (VSI), Dizziness Handicap Inventory (DHI), Spielberger State and Trait Anxiety Index, the Activity Specific Balance Confidence scale (ABC) and the Vestibular Rehabilitation Benefit Questionnaire (VRBQ), which is a new scale that measures global response to VR. Physical performance measures were: timed Tandem stance with eyes closed, single leg stance with eyes open, Neurocom Smart Balance Master (composite and eyes closed on foam sway), step test, timed ten metre walk with and without head turns and the Functional Gait Assessment. Control group participants were given a standard individualised vestibular therapy home exercise program (HEP). Experimental group participants received the standard HEP with additional exercises designed to stimulate the otolith organs. All participants were asked to perform these exercises for three sessions daily for nine weeks. During this time they attended two review sessions to monitor progress and record adherence with the HEP.

Results: No significant differences were found between the two groups with respect to baseline demographic characteristics, duration of symptoms or vestibular function test results. Twelve participants withdrew from the study before the conclusion of the nine week intervention period. After the nine week intervention period, both groups improved significantly on outcome measures. For the Vestibular Symptom Index and the ten meter gait test, the group with additional otolith exercise improved significantly more than participants in the group that received only standard vestibular exercises ($p = 0.036$ and $p = 0.045$, respectively). For the small number of participants who completed the six month reassessment, this analysis shows that for most measures, both groups maintained the improvements they had gained at nine weeks. The VRBQ had a Standardised Response Measure of 0.77. High adherence was associated with significantly improved DHI and Tandem stance with eyes closed ($p = 0.012$ and $p = 0.038$ respectively). Low anxiety at baseline was associated with significantly improved ABC ($p = 0.010$).

Conclusions: We recommend clinicians use otolith specific exercises in VR. They are simple and safe to use and show benefit in increasing walking speed and in reducing the severity of perceived vestibular symptoms. To maximize the benefits of VR, we recommend that clinicians emphasize the need to adhere to prescribed exercise programs of at least three fifteen minute sessions a day, and the early identification and treatment of high anxiety. The VRBQ is recommended for use in this population.

D5-4

The vibrotactile labyrinthine substitution system (VLS): indications for placebo effects of vibrotactile biofeedback in improving balance in bilateral vestibular loss patients

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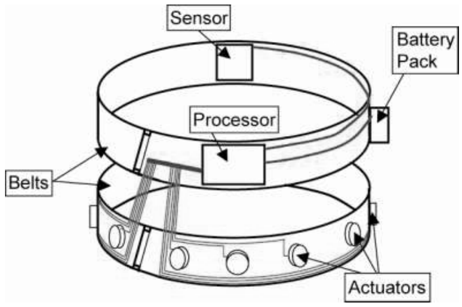
A potent aid for patients with severe vestibular dysfunction might be an artificial labyrinth to restore the feedback of linear and angular accelerations of the head or body to the brain. Artificial feedback might be accomplished using implantable electrodes which directly stimulate the vestibular nerve or using sensory substitution. For clinical application we have developed a light weight ambulant Vibrotactile Labyrinthine Substitution system (VLS) to improve postural stability in patients with bilateral vestibular dysfunction by use of vibrotactile feedback.

Study Objectives: To explore in a placebo-controlled study the effect of vibrotactile biofeedback on body sway during stance and gait in patients with severe bilateral vestibular hyporeflexia.

Methods: A tilt sensor mounted on the head or trunk is used to detect head or body tilt and activates via a microprocessor 12 small vibrators that are placed around the waist with a mutual distance of 30°. Two

positions of the tilt sensor (head and trunk) and three types of biofeedback (normal, full and random) were evaluated, besides no biofeedback. In normal mode the VLS codes body tilt magnitude and direction into the activation of specific actuators. In full mode only body tilt magnitude, and not tilt direction, is translated into activation of all 12 actuators. In random mode the activation of vibrators is semi-random. Both full and random modes are used to assess if improvements in body sway are caused by cognitive effects.
The VLS was tested on 30 adult patients (17 males, 13 females, age 39–77 years) with partial or complete bilateral vestibular areflexia – severe balance problems, no responses to caloric irrigations (30 °C and 44 °C), absent (BAR) or strongly reduced responses (BHR; gains 0–0.2) to sinusoidal stimulation of the horizontal and vertical canals on the rotational chair (0.1 Hz, Vmax = 60°/s) -.
Body sway during stance was assessed by stabilometry on a force platform while standing with eyes closed and bare feet on a 6 cm thick foam pad (Airex balance-pad) as still as possible for 45 second with the feet at hip width and the arms hanging by the sides. Body sway during gait was assessed with eyes open in all patients, and performance was scored using 3 standardized gait velocity tests (slow tandem gait, fast tandem gait, normal gait on 2 cm foam) in our clinical movement laboratory with a 9 m long and 1 m wide horizontal track using the Sybar videosystem. Body sway was scored in 7 different conditions: without biofeedback (1), with biofeedback and sensor on the trunk in normal (2), full (3) and random (4) mode, and with biofeedback and sensor on the head in normal (5), full (6) and random (7) mode.
Results: Significant improvements in balance during stance and during gait were shown in our patients using biofeedback and sensor on both the head and the trunk in the 3 operational VLS biofeedback modes. During stance, in 40% of our patients body swaypath decreased significantly per individual. During gait, in only 10% of our patients a significant individual gait improvement was present. But in the majority of our patients it increased confidence and a feeling of balance.
Conclusions: This study indicates the feasibility of vibrotactile biofeedback for vestibular rehabilitation and to improve balance during stance and gait. But, the improvement with true biofeedback was only observed in those subjects where an improvement was present in placebo mode as well. The improvement was, at least partially, caused by other effects than biofeedback, like training, increased self-confidence or alertness.



Schematic overview of the VLS system

D5-5
Vestibular rehabilitation by vibrotactile neurofeedback in otolith disorders
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Objectives: Vestibular rehabilitation strategies are often not successful in patients with isolated otolith disorders. Previous studies have shown an improvement of postural control in some patients by a sensory substitution with an acoustic signal [1]. The present study was aimed at investigating a more effective and feasible neurofeedback method for the reduction of body sway in otolith disorders.
Methods: Patients with an uncompensated unilateral otolith dysfunction performed a body sway analysis during 15 different every day life stance and walking conditions by using the diagnostic function of the Vertiguard®-RT. The results were compared with inbuilt age and gender related normative values. Six tasks, which showed the most pathological results, were selected for the training program and the related individual feedback thresholds were stored in the training device (Vertiguard®-RT). The training was performed daily over 2 weeks (10 sessions, without weekend). A training session included 5 repetitions of the selected training tasks (20 seconds per repetition). The patient received a vibrotactile feedback signal during the training in that direction, which showed a higher body sway than the preset threshold.
Results of the free field body sway analysis and the vertigo symptom scale (VSS) were compared before and after the rehabilitation program.
Results: Thirteen out seventeen patients showed a significant reduction of their body sway in more than 60% of all training conditions. In total, the rehabilitation program was successful in 60 out of 85 conditions.

The mean reduction of sway in all successful conditions was 34.9% in pitch and 35.9% in roll direction ($p <$ 0.000). Most successful tasks were "standing on foam with eyes closed", "walking tandem steps on foam" and "walking while rotating head".
The results of the VSS were reduced significantly ($p <$ 0.05) after the rehabilitation program.
Conclusion: The present data suggest that the new free field vibrotactile neurofeedback method, performed with the Vertiguard®-RT, improve the balance in everyday life conditions in otolith disorders significantly with minimal efforts for the patients. The method seems to be well suited for home or group training since the tasks are easy and all relevant values are stored in a small body-worn device.
Further studies should investigate long term training effects and a useful follow-up schedule.

Reference

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D5-6

Vestibular physiotherapy outcomes in patients with and without migrainous vertigo. A prospective single blinded controlled study.

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Vestibular physiotherapy (VP) programs do appear to play a role in the treatment of dizziness in patients with migraine associated dizziness. However anecdotally, the post treatment outcomes in these patients seem poorer or more variable compared to other patients, in particular the subjective outcomes.
Aims: This prospective study aimed to assess the efficacy of VP in patients with migrainous vertigo compared to patients with vestibular symptoms without a history of migraine. In addition to more conventional VP outcome measures, we also documented the contribution of anxiety levels and motion sickness susceptibility in both groups of patients.
Methods: A total of 36 patients with significant daily vestibular symptoms received a customized vestibular physiotherapy exercise program. Twenty of these subjects were categorized into the definite migrainous vertigo (DMV) group according to the Neuhauser et al criteria (2001). The remaining subjects had no history of migraine (VD). Each subject attended a series of 5 VP appointments occurring at initial, 2 weeks, 4 weeks, 9 weeks and 6 months. Outcome measures were taken at baseline, 9 weeks and 6 months. Main subjective outcome measures were the Dizziness Handicap Inventory, the Activities-Specific Balance Confidence Scale, Speilberger State and Trait Anxiety Index, Vestibular Symptom Index and the Vestibular Rehabilitation Benefit Questionnaire. Main physical performance measures: Functional Gait Index, Static posturography, tandem/single leg stance, time and steps taken to perform a ten meter walk $+/-$ head turns. A questionnaire measuring motion sickness susceptibility was also administered.
Results: Using principle component analyses, three main components were derived which represented an overall outcome measure/composite score, a subjective outcome measure and a measure representing the 'vestibular' physical performance measures (i.e. a high representation from all balance measures obtained with eyes closed and the measures from the ten meter walks). Repeated measures ANOVA showed that the composite score improved significantly with time ($p < 0.001$) but the DMV group was significantly worse ($p < 0.05$). For the subjective outcome measure, the DMV group were significantly worse ($p < 0.05$). The vestibular weighted physical performance measure (i.e. balance measures with eyes closed) where not significantly different between the groups but did improve significantly over time ($p < 0.05$). The degree of change (improvement) at either 9 weeks or at 6 months was not significantly different between the groups for all outcome measures.
Pre treatment anxiety measures and motion sickness susceptibility scores for the VD and DMV groups were compared to a group of migraine only subjects ($N = 14$) and a control group ($N = 19$). There was a significant group effect on anxiety levels ($p < 0.05$) where patients with vestibular symptoms (DMV and VD) showed the highest trait and state anxiety levels. Motion sickness scores also showed a group effect with the highest scores shown for the DMV group.
Conclusions: This study has validated the use of vestibular physiotherapy in patients both with and without migrainous vertigo, with both groups benefitting equally. However the overall starting level of outcome measures was significantly poorer for the DMV patients and this difference was maintained even after 6 months. This may suggest that patients with migrainous vertigo may benefit from a continuance of VP beyond 6 months, but this needs to be confirmed with a longer

term study. The DMV group had significantly poorer subjective scores, yet this difference was not reflected in the vestibular weighted physical performance measures. The underlying causes of this observation may be related to the higher anxiety levels and susceptibility to motion sickness also found in the DMV group. As such the benefits to additional behavioral therapies in conjunction with VP may be worth investigating in this population.

Oral Session D6 – Vestibular Rehabilitation

D6-1

Pilot studies on treatment of Mal de Debarquement (MDD)

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Four female patients (ages 30–74) with symptoms of mal de debarquement (MDD) for one to four years were adapted with visual-vestibular stimuli. Three of them had a clear history of MDD after a cruise, while one simply had rocking without clear motion exposure. All had rocking sensations when standing or walking. The MDD patients were adapted with unidirectional OKN (10 deg/s) while they rolled their heads at a very low frequency (0.05 Hz), assisted with audible cues. The direction of OKN was determined from the subjective sensation during a rocking sequence. Thus, for example, pitching forward, followed by rocking to the left and back, was regarded as a rotation to the left from the subject's perspective. On average, patients had a ten minute session twice a week. The rocking sensation was dramatically reduced immediately after treatment, but returned to the previous or a lower level one hr to one day afterward. The patient without a clear MDD history was free of the rocking sensation after three treatments, while the two with clear MDD history were free of symptoms after eight treatments. Two MDD patients reported worsening of their symptoms when the direction of OKN rotation was reversed. We also tested four normal male subjects, who had no preceding history of motion sickness or rocking sensations, with low magnitude vestibular stimuli for two minutes (rotation at 4 deg/s, while rolling the head while rotating at 0.1 Hz) to produce a rocking sensation. These normal subjects did not report any motion sickness during or after the test, but they experienced mild back and forth rocking sensations for up to 5 minutes when standing with closed eyes. Positional vertical eye movement and static postural data will be presented and possible mechanism for induction of MDD will be discussed.

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D6-2

Vestibular rehabilitation with vibrotactile neurofeedback training in patients with Parkinson's disease

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Objectives: In patients with Parkinson's disease (PD), balance impairment involves considerable morbimortality from the numerous falls that may result. In an earlier postural study we detected that a deteriorated processing of vestibular input is implicated [1]. Vestibular rehabilitation with computerized dynamic posturography (CDP) in PD has shown to be effective in improving the activities of daily life, gait velocity and balance, as well as in reducing the risk of falls [2]. However rehabilitation with vibrotactile neurofeedback training allow us to perform dynamic tasks, in which commonly occurs the falls in PD patients. So the aim of the present study is to assess the effectiveness of vestibular rehabilitation with vibrotactile neurofeedback in improving overall stability in PD patients.

Methods: PD patients (mean Hoehn & Yahr scale 3.2) which suffered from severe loss of postural control underwent an individualized vestibular rehabilitation program with the vibrotactile neurofeedback device Vertiguard®-RT. Individualization of the rehabilitation program started with a body sway analysis during 12 different everyday life stance and walking conditions (results were compared with inbuilt age and gender related normative values). Up to six tasks, which showed the most pathological results, were included in the training program and individual feedback thresholds were stored in the device. Training was performed daily over 2 weeks (10 sessions, weekend was excluded). A training session consisted on 5 repetitions of the selected training tasks (each repetition lasted 20 seconds). The patient received a vibrotactile feedback signal during the training in those direction which showed a higher body sway than the preset threshold. Results of the free field body sway analysis, the sensory organization test (SOT) of the CDP, the dizziness handicap inventory (DHI) and the activities-specific balance confidence scale (ABC) were compared before and after the rehabilitation program.

Results: All 5 investigated patients significantly decreased their body sway in a total number of 23 out of 25 training conditions, the mean reduction of sway in all successful conditions was 55.9% in pitch and 58.8% in roll direction, ($p = 0.001$). The DHI was reduced from 69.5 ± 3.4 to 55.5 ± 4.6 and the ABC was increased from 480 ± 218 to 823 ± 133. The average balance score of the SOT was also increased from 39.3 ± 14.6 to 67.3 ± 11.8.

Conclusion: Our preliminary results showed that a free field vibrotactile neurofeedback training with the Vertiguard®-RT device seems to improve the balance in everyday life conditions very effectively in PD patients. Further studies should investigate the long term follow-up.

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D6-3

The effects of vibrotactile feedback on protective stepping responses in Parkinson's disease patients

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Objective: Parkinson's disease (PD) patients are characterized by slow, short-stepped, shuffling, forward-stooped gait, which often results in a high incidence of falling. When facing a sudden perturbation, they frequently experience difficulties with generating the initial protective step to maintain balance. A vibrotactile feedback prosthetic device to improve step generation has been developed [J Neurol (2007) 254:1555]. The present study has two aims, a) to characterize the Parkinsonian stepping response to unpredictable postural stimuli and b) to assess whether vibrotactile feedback enhances protective stepping responses of PD patients.

Methods: 20 mild PD patients (67.5 ± 8.8 years; Hoehn-Yahr stage I-II), 7 advanced PD patients (68.6 ± 11.3 years; Hoehn-Yahr stage III or above), and 17 elderly volunteers (67.5 ± 10.4 years) were recruited in the study. Subjects were instructed to stand on a motorized, computer controlled moving platform. Unpredictable acceleration of the platform, either forwards or backwards, perturbed subjects' balance, requiring a protective step to maintain balance. Subjects wore an elastic cap which incorporated two DC pancake vibrating motors (as used in mobile phones; frequency ≈ 200 Hz) as feedback to encourage them to take a protective step. Vibration of the forehead or occiput prompted subjects to take a forward or backward step respectively. Stepping reaction time (SRT) and length of the first protective step during the perturbation were analyzed and compared with repeated measured ANOVA statistics.

Results: Backward stepping reaction times were significantly shorter than forward SRT (forward SRT 0.46 ± 0.09 s, backward SRT 0.27 ± 0.07 s, $p < 0.001$) but there were no differences amongst the three subject groups. Backwards step length was significantly shorter than forwards step length in all subject groups (forward step length 27.49 ± 9.36 cm, backward step length 21.72 ± 9.83 cm, $p < 0.001$). The advanced PD patients deployed significantly shorter steps than the healthy elderly and the mild PD patients (advanced PD 17.41 ± 8.25 cm, mild PD 31.25 ± 8.73 cm, elderly controls 27.21 ± 7.55 cm, $p < 0.05$) both forwards and backwards. No significant differences due to vibration feedback during the perturbation were observed in any group.

Conclusion: PD patients in later clinical stage demonstrate shorter length steps, both forwards and backwards. At initial stages they show no significant difference on step length in comparison with elderly controls. Furthermore, backwards protective steps are quicker but shorter and this characteristic, probably dictated by bio-mechanical constrains, is preserved in all stages of PD. Since latencies are preserved, the critical abnormality of protective stepping reactions in PD is insufficient (ie short) step length, especially at the later stage of PD. The study showed that this abnormality is present in unpredictable conditions and in the forwards and backwards direction. Unfortunately, step abnormalities were not improved by the prosthetic vibrotactile device.

D6-4

Reduced posturographic differences during anticipation of a postural threat between patients with Phobic Postural Vertigo and healthy subjects

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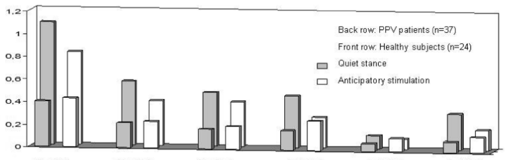
Objective: Patients with phobic postural vertigo (PPV) have deviant postural behaviors as compared to healthy subjects. The movement pattern of PPV patients contains more high frequency sway than a healthy control group and the patients are more sensitive to vibratory proprioceptive stimulation. However, confronted with a difficult balance task they exhibit similar postural performance as healthy subjects. Those findings indicate that the postural behavior for those patients might be an important target of treatment. For patients with this symptomathology and patients with long standing dizzy symptoms over all there are few rehabilitation programs described. In order to further develop rehabilitation programs we wanted to explore weather this postural behavior could be understood as a response to a constant fear of losing postural control.
Methods: We evaluated the effect of information of forthcoming vibratory stimulation to the calf muscles to the postural control of 24 healthy subjects and 37 patients with phobic postural vertigo. Posturography recordings of thirty seconds of quiet stance without following stability threat of vibratory stimulation were compared with 30 seconds of quiet stance preceding a postural threat.
Results: As previously described patients with Phobic Postural Vertigo exhibited a postural sway of significantly higher frequency in quiet stance as compared to healthy subjects. Those differences between groups disappeared except for sagittal high frequency sway during anticipation of vibratory stimulation.
Conclusions: It seems as if patients with phobic postural vertigo have, during a wider range of circumstances, a postural strategy that healthy subjects adopt only when under postural threat. This postural behavior might be understood as a negatively reinforced response in standing due to a constant fear of losing postural control. Identification of negatively reinforced behaviors is crucial to the treatment of anxiety disorders why those results indicate that postural strategies among phobic postural vertigo patients should be addressed in rehabilitation programs. The absence of effect of anticipation of postural threat within the Phobic Postural Vertigo population might be understood as a consequence of already maximized adaptation.



		Sagital total		Sagital ≤0.1 hz		Sagital ≥0.1 hz		Lateral total		Lateral ≤0.1 hz		Lateral ≥0.1 hz	
PPV	Mean	1.079	0.819	0.565	0.396	0.478	0.397	0.457	0.271	0.117	0.091	0.317	0.177
	S.e.m	0.196	0.143	0.156	0.100	0.099	0.064	0.194	0.051	0.022	0.015	0.166	0.043
Healthy	Mean	0.402	0.432	0.220	0.235	0.175	0.203	0.172	0.261	0.070	0.120	0.095	0.138
	S.e.m	0.082	0.047	0.063	0.039	0.024	0.020	0.040	0.038	0.013	0.022	0.026	0.029
P (wilc)		0.001	0.220	0.023	0.718	0.000	0.042	0.032	0.479	0.488	0.268	0.003	0.894

Figure 1. Antero-posterior sway (normalised torque variance [Nm/(Kg·m)]2) for PPV patients and healthy subjects during quiet stance and anticipatory stimulation. Mean and standard error of the mean are shown and P values refers to wilcoxon test for paired comparisons .

D6-5

The effect of vibrotactile feedback on vestibular-deficient postural performance during visual perturbations

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Objectives: Visual, vestibular, and somatosensory information are continuously sampled by the central nervous system and used to generate corrective motor torques to maintain upright balance. Individuals with vestibular deficits rely most heavily on visual and somatosensory information. However, visual and somatosensory information can be misleading or incomplete (i.e. uneven ground or poor lighting conditions) potentially contributing to instability and falls. Previous research has shown that oscillatory virtual reality visual perturbations induce instability in healthy subjects by increasing center of pressure (COP) variability. Other studies have shown that vibrotactile feedback can be effective in decreasing trunk root-mean-square (RMS) sway. This study investigates the effect of visual perturbations on the postural stability of individuals with vestibular deficits and determines whether concurrent vibrotactile feedback can counteract the destabilizing effects of these visual perturbations.
Methods: A virtual reality display was created using a large curved rear projection screen that presented a visual field resembling a virtual dark hallway tiled with randomly placed white rectangles. Subjects were presented with semi-random perturbations of the visual

field in the form of translations in either the medial-lateral (M/L) or anterior-posterior (A/P) direction. Additionally, there was a control condition with no perturbations. For trials that included vibrotactile feedback, subjects were instrumented with a system composed of: a belt with four tactors (i.e. pager motors) positioned on the right and left external obliques, navel, and spine; an off-the-shelf inertial measurement unit; and a laptop. Vibrotactile feedback was provided when trunk tilt exceeded a one-degree activation threshold. Subjects were instructed to move away from the vibration toward a neutral upright position and to "keep the tactors quiet". The six pilot subjects ($49.2 + 10.5$ yrs) had unilateral vestibular involvement. Subjects were asked to perform 30 second trials in Tandem Romberg (heel-to-toe) stance with eyes open on a force treadmill either with or without vibrotactile feedback during one of three visual conditions (no visual perturbations, M/L perturbations, or A/P perturbations). Metrics used for quantifying performance included the mean absolute trunk tilt and standard deviation (referred to as variability) of trunk tilt and COP. Statistical significance was defined as $p < 0.05$.

Results: Visual perturbations did not induce changes in mean A/P or M/L trunk tilt. M/L visual perturbations induced significant increases in A/P and M/L COP and trunk tilt variability. A/P visual perturbations were less compelling and induced significant increases only in A/P COP variability and M/L trunk tilt variability. With vibrotactile feedback, subjects significantly decreased M/L trunk variability for the M/L and A/P visual perturbation conditions, with similar trends observed in A/P trunk variability. However, vibrotactile feedback tended to increase A/P and M/L COP variability. Vibrotactile feedback significantly decreased mean A/P trunk tilt for all visual perturbation conditions.

Conclusion: Overall, visual perturbations induced increases in trunk tilt and COP variability in individuals with vestibular deficits while performing the Tandem Romberg balance exercise. Visual perturbations in the M/L plane affected balance more than those in the A/P plane, which can be attributed to increased M/L instability when standing in the Tandem Romberg position. Further, subjects were able to use the vibrotactile feedback to counteract the increases in trunk tilt variability induced by the visual perturbation, but at the cost of increases in COP variability. Vibrotactile feedback also significantly reduced mean A/P trunk tilt.

D6-6

The application of vibrotactile neurofeedback training in patients with a semicircular dysfunction

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Introduction: The best way to improve choric dizziness due to either unilateral or bilateral canal dysfuction is vestibular rehabilitation. The vibrotactile neurofeedback is powerfull tool to obtain vestibular compensation.

Methods: 15 Patients with an uncompensated unilateral semicircular function loss underwent an individualized vestibular rehab program with the vibrotactile neurofeedback device Vertiguard®-RT. The individualization of the rehab program started with a body sway analysis during 15 different every day life stance and walking conditions. The results were compared with inbuilt age and gender related normative values. Six tasks, which showed the most pathological results, were included in the training program and individual feedback thresholds were stored in the device. The training was performed daily over 2 weeks (10 sessions, weekend was excluded). A training session consisted on 5 repetitions of the selected training tasks (each repetition lasted 20 seconds). The patient received a vibrotactile feedback signal during the training in that direction which showed a higher body sway than the preset threshold. The results of the free field body sway analysis, the sensory organization test (SOT) and the vertigo symptom scale (VSS) were compared before and after the rehab program.

Results: In total, patients significantly decreased their body sway in 75 out of 90 training conditions. The mean reduction of sway in all successful conditions was 31.4% in pitch and 34.2% in roll direction, $p < 0.000$). The results of the VSS were reduced significantly ($p < 0.05$) and those of the SOT were increased significantly ($p < 0.05$).

Conclusions: Free field vibrotactile neurofeedback training with the Vertiguard®-RT device seems to improve the balance in everyday life conditions with minimal efforts for the patients. Further studies should investigate the long term follow-up.

Oral Session D7 – Meniere's & SSCD

D7-1

A novel inner ear monitoring system for evaluating ototoxicity of gentamicin eardrops in guinea pigs

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Objective: While most studies have identified damage in the cochlea and semicircular canals as the primary sites of aminoglycoside toxicity, little attention has been devoted to the toxic effects on the otolithic organs. This study aimed to assess the toxic effect of gentamicin eardrops on the inner ear endorgans via a novel inner ear monitoring system combined with morphological examination.

Methods: Guinea pigs were treated with 50 μl saline ($n = 10$) and 50 μl gentamicin (40 mg/ml, $n = 10$) on the right and left round window membranes, respectively. An inner ear monitoring system including auditory brainstem response (ABR), caloric, ocular vestibular-evoked myogenic potential (oVEMP) and cervical VEMP (cVEMP) tests was used to assess ototoxicity in guinea pigs at two weeks after treatment. Then, animals were sacrificed for morphological study via confocal microscopy.

Results: Normal results in ABR, caloric, cVEMP and oVEMP tests were shown in all saline-treated ears, while elevated ABR threshold and absent responses in caloric, oVEMP and cVEMP tests were noted in all gentamicin-treated ears. The cochlear and vestibular explants harvested from the gentamicin-treated ears revealed substantial loss of hair cells.

Conclusion: The inner ear monitoring system including ABR, caloric, oVEMP and cVEMP tests may help to evaluate toxicity information of the topical eardrops or agents on the inner ear endorgans including cochlea, semicircular canals, utricle and saccule.

D7-2

Using different protocols of intratympanic gentamycin for the treatment of meniere disease, according to the condition of the patient

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Introduction: At the moment there is not a clear consensus about which is the best protocol using intratympanic gentamycin to treat Meniere's Disease (MD). In this paper we compare the results of three different protocols performed in three centers of Argentina in a 6 years follow up (average).

Material and Methods: We studied 89 patients without significant differences in age between the 3 groups (average 54)

- Single dose protocol: 19 patients
- Multiple dose protocol, means multiple applications with the end-point of lack of response in the caloric tests: 59 patients
- Titration protocol, means multiple applications until reaching the clinical control of the symptoms: 11 patients

Results: With all the modalities of the treatment control Class A of vertigo(according to Committee on Hearing and Equilibrium Guidelines for Diagnoses and Evaluation of Therapy in Meniere's Disease, AAOHNS Board of Directors) was reached in all the cases except one, with this differences:

- Single dose protocol: the average (in months) between the injection and the diagnosis of MD was 53,21
- Multiple dose protocol: the average of applications was 5, the average (in months) between the injection and the diagnosis of MD was 22
- Titration protocol: the average of control of the symptoms in this group was 61 months (5 years)

Conclusions: We did not find significant differences between those groups in terms of vertigo control but with single dose protocol the time between diagnosis of MD and the injection was quite longer. With titration, even when the control of the symptoms is eventually reached it takes a long period which impacts on the quality of life of these patients.

D7-3

The effect of intratympanic injection of gentamicin in low concentration for Meniere's disease on hearing level (3 years follow up)

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Objective: To define the effect of low concentration intratympanic gentamicin injection on hearing level.

Study Design and Methods: Between 1–2 ml of low concentration (16–20 mg/ml) of gentamicin solution was injected into the middle ear of 19 patients suffering from intractable attacks of vertigo. Three injections, in one week interval were performed. Hearing test was monitored before each injection and 1month after the treatment. A full vestibular assessment was performed prior, and 12 months after the treatment. Pre and post injection hearing level is presented for 15 out of 19 injected patients. A post-injection one year and 3 years follow-up data is presented in 8 patients.

Results: Remission of the Vertigo attacks was noticed in all patients during 6 months following the injections. In two patients (13.5%), however, a second course of injections was required after 6–12 months of the initial treatment, and in another two (13.5%) between 12–24 months after injection due to recurrence of the vertigo spells. Hearing improvement was noticed comparing the initial hearing test prior to the injections, and the one performed one month after the last injection. The hearing improvement was about 9dB on 500 Hz, 12 dB on 1000 Hz, 6dB on 2000 Hz, 0dB on 4000 Hz and a decrease of 1 2dB was noticed on 8000 Hz. After one year hearing improvement of 4 dB on 500 Hz, 6 dB on 1000 Hz, 1 dB on 2000 Hz, 2dB on 4000 Hz and 5 dB on 8000 Hz. A 3 year follow-up on 8 patients demonstrated a mild deterioration of 4 dB on 500 Hz, 4 dB on 1000 Hz, 1 dB on 2000 Hz and 4000 Hz, and a borderline improvement of 1 dB on 8000 Hz.

Conclusion: Low concentration intartympanic gentamicin injection is a useful treatment for controlling vertigo attacks in intractable Meniere's disease. It seems that such treatment not only does not damage hearing, but might also improve the hearing level up to one year afterwards. A return to the initial hearing and even a slight deterioration is seen 3 years after injection, most probably as a result of the disease itself and not the injections. A further investigation should be continued on a larger study group.

D7-4

Audiological status of intratympanic gentamicin and medication teatment for Meniere's disease

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Abstract: Introduction: Intratympanic gentamicin treatment is nowadays common procedure to cure vertigo for Meniere's disease (MD). The intratympanic treatment with gentamicin has a risk of profound sensorineural hearing loss that occurs in 5–10% of treated patients.

The purpose of present study is to investigate long term hearing outcome and the predictive value of inner ear electrical responses for hearing outcome among patients with Meniere's disease.

Subjects and Methods: Among 33 patients with Meniere's disease (mean age 54.5y, range 23–86y, male 14, female 19, diseased side rt 15, lt 17, bilateral 1 case) hearing after intratympanic gentamicin treatment was followed to for five years on average (mean history of MD 12.8y, mean follow up 5.3y). For comparison we had 159 MD patients (mean age 52.2y, range 22–84y, male 43, female 116 cases, diseased side rt 73, lt 84 and bilateral 3 cases).

Pure tone audiogram (RION AA-98A, Japan) and extratympanic electrocochleography (ECoG) were performed.(Nihonkohden, Neuropack μ, Japan), Silver ball electrode (type UL3010-3 Unique Medical Japan). For ECoG click stimulus was at 100dB SPL was delivered from speaker 8cm away from the tested ear. SP (Summating Potential), AP (Action Potential) amplitudes and SP/AP ratio were analyzed.

Results: Hearing level before and after gentamicin treatment at the frequency of 250 Hz and 500 Hz showed slight improved after treatment. In ECoG the mean SP value before and after treatment were 0.61 μV, 0.31 μV respectively. The respective values for AP were 1.29 μV and 0.87 μV and for SP/AP 0.48 and 0.34. The differences were statistically significant for SP, AP and SP/AP values.

In comparing hearing level gantamicin and control groups, hearing level at all frequencies for control groups was significantly better than in gentamicin group before treatment. After treatment the hearing level at the frequencies of 250 Hz and 500 Hz did not differ between gentamicin and control groups.

In ECoG the SP amplitude (mean SP, after gentamicin 0.31 μV and control group 0.36 μV) and SP/AP (in gentamicin 0.35 and in control 0.29) after treatment did not differ significantly. There was statistical significant difference ($p < 0.01$) between AP amplitude (gentamicin 0.86 nd control group 1.38) after treatment, the gentamicin group showing poorer AP intensity.

Conclusion: Normalized SP/AP resulted in hearing gain at the frequency of 250 Hz and 500 Hz. Hearing gain may reflect a reduction in endolymphatic hydrops. Intratympanic gentamicin did not affect statistically hearing threshold at the frequency of 1 kHz, 2 kHz and 4 kHz. Both SP and AP amplitudes after gentamicin treatment resulted in significantly lower than those before treatment indicating hearing loss.

At low frequencies gentamicin treatment may normalize SP/AP and amplitude of SP. Hearing after gentamicin treatment was different from control subjects with MD. It is suggested that gentamicin treatment is seemingly effective for controlling vertigo, however it will

cause deterioration of hearing that can be revealed in ECoG.

D7-5

Ventilation tubes in Meniere's disease and Meniere's syndrome – cochlear and vestibular effects

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Objectives: The static and dynamic pressure transfer from middle ear to the inner ear is objective of experimental and clinical studies in animals and men. Inner ear pressure dysregulation can be induced by idiopathic endolymphatic processes as well as pressure influences from intracranial and/or middle ear compartments. In case of attacks of cochlea-vestibular dysfunction ventilation tubes are used to modify the pressure transfer between middle ear and inner ear. There is no common consensus about the effectiveness of ventilation tubes in the case of cochlea-vestibular dysfunction.

Methods: Therefore an analysis of cochlear and vestibular function parameters in 150 patients with definite Meniere's disease according to the criteria of the AAO-HNS before and after the insertion of ventilation tubes was performed. The indication for the ventilation tube was dependent from the findings of impedance audiometry. Key factor for the indication was the 24 hours impedance audiometry. Values of the impedance optimums were documented during 24 hours in 1 hour intervals. Cut-off normal values of $\pm$ 50 daP were defined during a previous study. The complaints of the patients were recorded by use of the DHI (german translation with statistic recertification). Pure-tone threshold, spontaneous nystagmus, head impulse tests of the three semicircular ducts, caloric reaction and cVEMP responses were evaluated.

Results: The results were examined with statistic evaluation. Patients with pathological impedance values were included after informed consent and according to the procedure of good clinical practice. Postoperative intervals were more than ten times longer than the interval between attacks of each patient. 68% of the patients were free of vestibular symptoms or fit for daily activities after ventilation tube insertion on the ipsilateral ear. Their DHIf and DHIp had pre/post differences > 12. 12% of the patients had a significant improvement of hearing (3 frequencies > 10 dB). No significant changes of vestibular function tests were recorded. In 4% chronic otitis media had to be treatetd by means of tympanoplasty and attico-antrotomy. No cholesteatoma were observed. In 15% of the patients otitis media with secretion was treated with antihistamine and montelucast administration.

Conclusions: It is concluded, that temporary Eustachian tube dysfunction can provoke spells of cochleo-vestibular dysfunction with progressive deterioration of the inner ear function. The progress can be stopped by early insertion of ventilation tube. While cochlear function can be improved in 12% of the patients with impaired Eustachian tube function and middle ear pathology, labyrinth function cannot be reestablished. The 24 hours impedance audiometry recording is the most important tool to select patients with the criteria of definite Meniere's disease, who can benefit from the ventilation tube treatment. The treatment with ventilation tube is effective in 68% of these patients with Meniere's syndrome.

D7-6

Middle ear pressure treatment of Meniere's disease by the trans-tympanic membrane stimulation

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In the treatment of Meniere's disease by the Meniett device, pressure to the external auditory canal transmits to the round window by way of the inserted tympanic ventilation tube. In this study, we treated the patients with Meniere's disease by a new pressure device, which directly stress the oval window by way of the tympanic membrane and auditory ossicle without insertion of the ventilation tube.

The new device is a tympanic pressure equipment used for treatment of otitis media with effusion in Japan, and is able to produce pressure stimulation similar to the Meniett device. Without insertion of the tympanic ventilation tube, pressure is directly applied through the earplug inserted into the external auditory canal to the tympanic membrane, and transmits to the inner ear by way of both the oval and round window. Pressure treatment is three minutes per one cycle, two or three cycles per day.

By this method, we treated 13 patients with Memiere's disease or delayed endolymphatic hydrops suffering from intractable vertiginous attacks, which could not be controlled by the conventional treatments including osmotic diuretics. The medications taking before the pressure treatment were used together. Average vertiginous attacks before the pressure treatment were from 1.5 attacks per months to 14 attacks per months.

In all 13 patients treated by this devise, we could observe useful effects. In five patients, we finished the pressure treatment because their vertiginous attacks disappeared. In eight patients, their vertiginous attacks improved, the numerical values of which were below 40. In all patients, the vertigo control occurred within one month, which is shorter than that of the Meniett device in our hospital. We did not observe any harmful complications.

The characteristics of this pressure treatment by the new device are summarized as follows:

1. The effect of the treatment by this device was equal or higher than that of the Meniett device.
2. Vertigo control briefly occurred within one month after the treatment.
3. As insertion of the tympanic ventilation tube is not necessary, we could easily start the tympanic pressure treatment immediately in case of need.

Based on our result, we could expect that our tympanic pressure treatment by the new device might come into wide use in the future. Therefore, we would continue the treatment for a larger number of the Meniere's disease or delayed endolynphatic hydrops patients.

D7-7

Vestibulo-ocular reflex evoked by bone-conducted tone in superior and posterior canal dehiscence

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Background: Vestibular and cochlear hypersensitivity to loud sound suggestive of a third labyrinthine window maybe caused by superior canal dehiscence (SCD) or posterior canal dehiscence (PCD).

Objective: We sought to characterize the bone-conducted tone (BC-tone) evoked vestibulo-ocular reflex (VOR) in SCD and PCD to determine its usefulness in conductive hearing loss.

Methods: Binocular, three-dimensional eye rotations evoked by BC-tone at 110 dB NHL, 500 Hz and 7ms duration were measured with dual-search coils in 17 SCD and one PCD patients confirmed by CT imaging. Their results were compared to eight normal subjects. Eye rotation axes of their BC-tone VORs computed by vector analysis were referenced to known semicircular canal planes.

Results: Normal BC-tone VOR comprised miniscule downward eye rotations of amplitude < 0.01 deg and magnitude < 3 deg/s. BC-tone VOR from unilateral SCDs comprised enlarged upward, contraversive-torsional eye rotations of magnitude up to 27 deg/s and onset latency of about 10 ms from either ipsilateral or contralateral mastoid bone stimulation. Eye rotation axes from SCDs aligned with superior canal axis suggesting activation of superior canal receptors. BC-tone VOR from unilateral PCD comprised enlarged downward, contraversive-torsional eye rotations with similar latency; its eye rotation axis aligned with posterior canal axis. In bilateral SCDs, BC-tone VOR comprised components from ipsilateral superior canal stimulation with some torsional cancellation and vertical summation from concomitant contralateral superior canal stimulation. Unlike air-conducted clicks, BC-tone VOR was induced in the presence of conductive hearing loss.

Conclusion: BC-tone VOR is a useful diagnostic measurement to identify unilateral SCD and PCD or bilateral SCDs, especially in conductive hearing loss.

D7-8

Autophony and pulsatile tinnitus in patients with superior canal dehiscence syndrome (SCDS): insights into mechanisms from tympanic membrane displacement measurement

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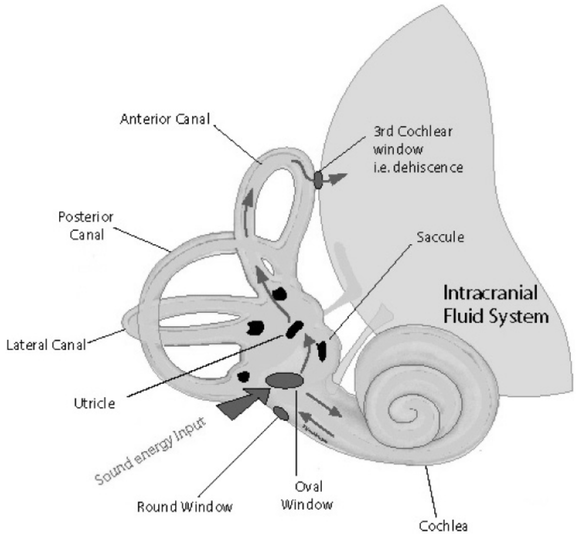
Objectives: Patients with superior canal dehiscence syndrome (SCDS) have been reported to complain of autophony and pulsatile tinnitus as well as sound-induced vestibular symptoms. To further investigate the patho-mechanism of these auditory phenomena, the tympanic membrane displacement measurement (TMD) technique (Marchbanks1) was used to test for evidence consistent with a) a third labyrinthine window and b) transmission of intracranial pressure waves intraurally.

Methods: 11 patients complaining of sound-induced vertigo (Tullio phenomenon) with a superior canal dehiscence (SCD) on CT scanning of the ipsilateral petrous temporal bone, were assessed using dynamic

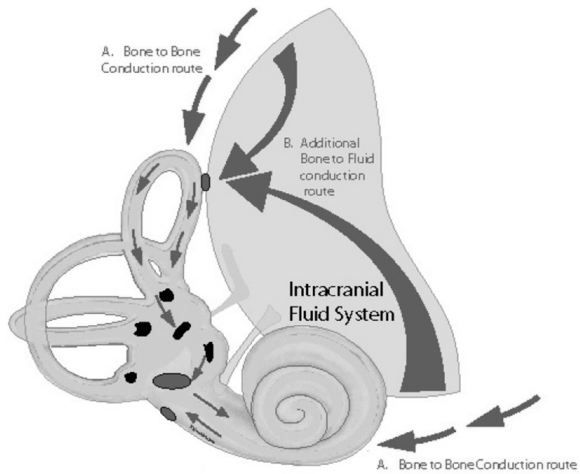
and spontaneous TMD measurements, pure tone air and bone conduction audiometry as well as with VEMPs, and VOG during monaural sound pressure stimulation. Results: All 11 patients (3F, 8M; average age 44 (28–63)) identified both external and internally-generated sound triggers to their Tullio phenomenon e.g. mobile ring tone, humming. 10/11 reported autophony i.e internal noises and vibrations heard unusually loudly in the affected ear. 10/11 patients reported pulsatile tinnitus, 4 of whom only with exercise. Audio-vestibular abnormalities consistent with SCDS were obtained: 11/11 had an air-bone gap at 0.5 and 1kHz ipsilaterally (average bone conduction threshold: -7dBHL) and all had normal stapedius reflex thresholds (85–110 dBHL). 7/11 had an ipsilaterally raised air conduction threshold (ACT) at 250 Hz (average 30 dBHL). VEMP threshold was low in 11/11 Tullio ears, and VOG recordings documented contralateral torsional nystagmus in response to low frequency monaural sound ipsilaterally.
Evoked TMD results showed transmission of intracranial pressure changes with sitting and lying to the ipsilateral cochlea in all 11 cases. In 3/6 patients who reported continuous pulsatile tinnitus, the spontaneous TMD documented abnormally large (747, 1187 and 1804 nl peak-to-peak) pulse-synchronous intraural pressure waves in the ipsilateral ear (amplitude normal upper limit: 500 nl, 95%). The patient with the largest bilateral dehiscences ($>$ 3 mm) had abnormal cardiovascular pressure waves in both ears (2055 and 1187nl). Furthermore, in 5/6 of the patients with continuous pulsatile tinnitus, abnormally large intraural swallowing waves were identified in the dehiscent ear as well as in 3/4 further patients experiencing pulse-synchronous tinnitus only with exercise.
Conclusions: Dynamic TMD findings in all 11 patients are in accordance with the concept of the "3rd labyrinthine window". The combined findings, including the documentation of abnormally large intraural pressure waves, allow the following hypotheses to be made: 1) the raised ACT at 250 Hz is caused by acoustic energy being "shunted" away from the cochlea towards the SCD and dissipating into the intracranial fluid space; 2) autophony with "supra-normal" bone conduction thresholds results from transmission of low frequency vibrations through a fluid/ bone route into cochlea via the SCD; 3) pulsatile tinnitus results from transmission of intracranial pressure waves through the SCD into the cochlea; and 4) torsional nystagmus directed away from the Tullio ear is explained by sound pressure following the line of least resistance through the superior semicircular canal towards the dehiscence, depolarising superior canal afferents en route.

Reference

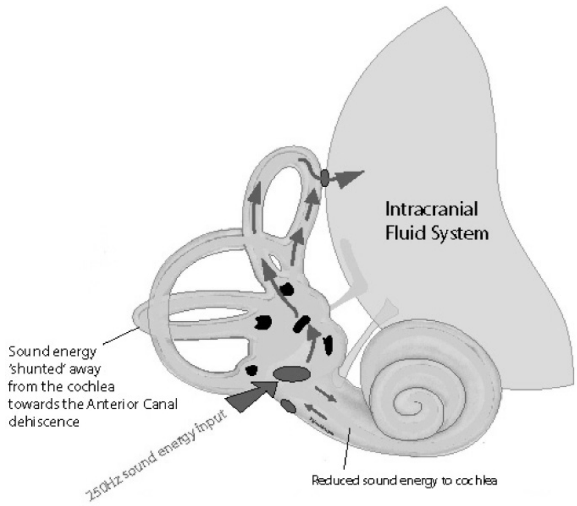
[1] R.J. Marchbanks, 'Measurement of inner ear fluid pressure and clinical applications', In: *Textbook of Audiological Medicine: Clinical Aspects of Hearing and Balance*, (Chapter 17), L. Luxon, ed., Martin Dunitz Ltd. 2003, ISBN 1-90186-534-7, 2003, pp. 289–307.



Raised air conduction threshold at 250 Hz: sound energy "shunted" away from the cochlea towards the superior canal dehiscence.



Autophony, supra-normal bone conduction thresholds and pulsatile tinnitus: resulting from additional fluid to bone conduction of low frequency sound/vibration through the superior canal dehiscence



Mechanism of torsional nystagmus: sound pressure following line of least resistance through superior semicircular canal towards dehiscence activating hair cells of crista

D7-9

Superior canal dehiscence in Iceland

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For the last six years 26 persons in Iceland have been diagnosed as having SCD (superior canal dehiscence) or high suspicion of SCD on high resolution CT scans of the temporal bones, i.e. prevalence of 7.8 per 100.000. They were all examined at the same x-ray center where most of the temporal bones CT scans have been performed in later years because of specialization in that field.
The aim of this study was to find out how many of them had symptoms of SCD and/or clinical signs of SCD. Three persons declined to participate so 23 of these 26 were enrolled in the study, that comprised of history taking, neuro-otological examination with videonystagmography, provocation tests to look for pressure or sound induced signs or symptoms, tuning fork tests, audio logical workup, VEMP's, balance platform examination and electronystagmography.
Ten of those 23 (43%) had clinical SCD (prevalence 3 per 100.000), presenting a vivid clinical picture with significant disturbances in several of the tests performed. Out of these 10 patients 4 have been operated successfully.

D7-10

The subarcuate canal and its artery as a surgical landmark in transmastoid repair of superior semicircular canal dehiscence syndrome

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Objectives: In superior semicircular canal (SCC) dehiscence syndrome, a dehiscence of the otic capsule bone overlying the superior SCC creates a mobile third window to the inner ear. This allows abnormal volume displacements within the membranous labyrinth and results in vestibular and audiological symptoms. In medical study books, the subarcuate artery is usually portrayed right in the middle of the superior SCC. However, when you want to use the subarcuate artery as a landmark to give you an idea of where to expect the arch of the superior SCC above the common crus, it is important to know the distance between the subarcuate artery and the arch of the superior SCC above the common crus. The aim of the study was to evaluate the reliability of the subarcuate canal and its artery as a surgical landmark in plugging of the superior SCC using a transmastoid approach.
Methods: High-resolution CT scans of temporal bones of 10 consecutive patients performed for chronic middle ear disease and of 10 patients with superior SCC dehiscence syndrome were reviewed with special emphasis on the course of the subarcuate canal through the superior SCC. In the plane of the superior SCC, a circle was drawn over the canal of which the radius was measured and the distance to the subarcuate canal. Two researchers performed independently the measurements, with good agreement in the results. The circle was then divided in quadrants in which the presence of the subarcuate canal was noted.
Results: The ratio between the radius of the circle and the distance to the subarcuate canal was 3 to 1. The subarcuate canal courses nearer to the non-ampullary (posterior) arm than the ampullary (anterior) arm of the superior SCC. In 20 out of 38 ears the subarcuate canal was located in the supero-posterior quadrant.
Conclusions: When plugging the superior SCC via a transmastoid approach and when using the arteria sub-

arcuata as a landmark, one should bear in mind that this artery is often localized closer to the posterior arch of the superior SCC. Pre-operative evaluation of the CT scan can provide detailed information on the course of the subarcuate artery, except in some cases of severe deformities.