European Annals of Otorhinolaryngology, Head and Neck diseases xxx (xxxx) xxx–xxx

Available online at ScienceDirect www.sciencedirect.com

Elsevier Masson France EM|consulte www.em-consulte.com/en

Technical note

How to do and why perform the skull vibration-induced nystagmus test

G. Dumas [a,b], R. Quatre [a], S. Schmerber [a,c,*]

[a] Department of oto-rhino-laryngology, Head and Neck Surgery, University Hospital, Grenoble Alpes, France
[b] EA 3450 DevAH, Development, Adaptation and Handicap, Faculty of Medicine, University of Lorraine, Vandoeuvre-lès-Nancy, France
[c] INSERM S 1039 Laboratoire Radiopharmaceutiques Biocliniques, University of Grenoble Alpes, Grenoble Alpes, France

A R T I C L E I N F O

Keywords:
Skull vibration-induced nystagmus test
Vestibular Weber test

A B S T R A C T

The skull vibration-induced nystagmus test (SVINT) is a global vestibular test stimulating otoliths and semicircular canals at a frequency of 100 Hz, not modified by vestibular compensation, which may reveal vibration-induced nystagmus (VIN). Bone-conducted vibration applied to the mastoid processes and the vertex instantaneously induces predominantly low-velocity (~10°/s) horizontal nystagmus, with rapid phases beating away from the affected side in patients with unilateral vestibular loss (UVL). VIN starts and stops immediately with stimulation, is continuous, reproducible, beats in the same direction irrespective of which mastoid process is stimulated, with no or little habituation. The SVINT acts like a vestibular Weber test. In peripheral UVL, the SVINT is a good marker of vestibular asymmetry and demonstrates pathological nystagmus beating towards the healthy side in 90% of cases of vestibular neuritis, 71% of cases of Menière's diseases and 44 to 78% of vestibular schwannomas. In superior semicircular canal dehiscence, VIN usually beats towards the affected side due to facilitation of bone conduction related to the presence of a third window. Stimulation of the vertex is more effective than in UVL patients, with sensitivity extending to higher frequencies, up to 700 Hz. Observation of vibration-induced nystagmus then reveals equally represented vertical, torsional, and horizontal components beating towards the affected ear, suggesting dominant, but not exclusive, stimulation of the dehiscent superior semicircular canal.

1. Introduction

Clinicians managing patients with vertigo need to complete their clinical examination by first-line examinations in order to refine the otoneurological diagnosis towards a central or peripheral lesion, identify the affected side and guide subsequent vestibular explorations, or imaging. The skull vibration-induced nystagmus test (SVINT), described incidentally and anecdotally by Lücke in 1973 [1], has been used in clinical practice since 1999 and has been developed by the Grenoble group [2–4] as a robust, rapid, non-invasive test, that can be performed as a bedside examination. This test explores the vestibulo-ocular reflex (VOR) at high frequencies (100 Hz) not studied by the usual vestibular tests [4]. Vibration-induced nystagmus (VIN) is not modified by vestibular compensation at these high frequencies. The physiological basis of this test has been recently clarified by the work of Curthoys et al. [5] in a healthy animal model with no labyrinthine bone lesion, demonstrating that 100 Hz stimulation of otoliths and semicircular canals (SCC) was effective, while only otoliths were stimulated at 500 Hz.

This work completes a previous review published in 2016 [6] by specifying the positivity criteria, the origin of vibration-induced nystagmus, its optimal frequency, and the possible use of this test in paediatric ENT.

2. Technique

The SVINT is performed on a sitting patient and the induced nystagmus is observed with Frenzel goggles or under videonystagmoscopy/videonystagmography. The subject must maintain a

Abbreviations: SCC, semicircular canal; SSCD, superior semicircular canal dehiscence; HST, Head Shaking Test; UVL, unilateral vestibular loss; PUVL, partial unilateral vestibular loss; TUVL, total unilateral vestibular loss; VIN, vibration-induced nystagmus; VOR, vestibulo-ocular reflex; SVINT, skull vibration-induced nystagmus test; SPV, slow-phase velocity.

* Corresponding author at: Otologie, neuro-otologie, implants auditifs, clinique universitaire oto-rhino-laryngologie, université de Grenoble Alpes, INSERM UMR 1205, CHU A. Michallon, BP 217 38043 Grenoble cedex 09, France.
E-mail address: SSchmerber@chu-grenoble.fr (S. Schmerber).

https://doi.org/10.1016/j.anorl.2020.11.014
1879-7296/

Fig. 1. Stimulation protocol. The examiner stands in front of or behind the subject in order to use his dominant hand. Mastoid stimulation is applied behind the auricle, over the EAC (Vibrator 3F Synapsys 30, 60, 100 Hz). Each mastoid process is stimulated successively, followed by the vertex. The duration of stimulation is 5 to 10s on each site. The test is repeated 2 to 3 times to confirm its reproducibility.

Table 1
Vibration amplitudes and accelerations depending on the frequency of the pacemaker.

Frequency	Amplitude (mm)	Acceleration (m/s^2)
50 Hz	0.21	10.3
60 Hz	0.16	11.7
100 Hz	0.06	11.5
150 Hz	0.03	14.8
200 Hz	0.02	18.8

Values given for the most used frequencies in the clinic. Bruel and Kjäer manufacturer data (Naerum; Denmark). The Bruel and Kjäer stimulator is likely to provide stimulations of 10 to 800 Hz.

midline gaze, looking straight ahead, with the eyes wide open and blinking as little as possible. Any visual fixation is suppressed by masking the other eye to avoid inhibition of the VOR. This test is well tolerated in both adults [7] and children [8].

2.1. Stimulation

The examiner performs the test by standing either in front of or behind the patient, firmly holding the vibrator, preferably with his dominant hand to ensure greater reproducibility (Fig. 1) [9].

Several vibrators are available on the market and have been used by our group:

- VVIB 3F (30–60–100 Hz), VVIB 100 Hz Synapsys, France;
- ISV 1 or IP 500 Amplifon, France;
- VVSED 500 Euroclinic, Italy;
- NC 70209, North Coast Medical Inc., USA.

Vibrators should preferably have a cylindrical contact surface, 2 cm in diameter, covered with a layer of felt or thin rubber, to ensure sufficient comfort and efficiency. To be effective, the vibrator must have a vibration amplitude > 0.02 mm and a sufficient mass (Table 1) [7]. The vibrator must be applied perpendicular to the mastoid process or at the vertex. The examination requires a total of 3 stimulation sequences, each lasting 5 to 10 seconds: the two mastoid processes and the vertex are stimulated successively. At the mastoid process, the vibrator is applied behind the auricle, at the level of the external auditory canal (Fig. 1). The examiner must avoid stimulating the tip of the mastoid process, which can trigger proprioceptive stimulation of the trapezius and sternocleidomastoid muscles. A force of about 10 N or 1 kg is exerted. The examiner uses his free hand to keep the patient's head in the correct position. For very high-frequency stimulation, a Bruel and Kjäer type 2718 amplifier (Naerum, Denmark) drives a hand-held Mini-Shaker type 4810 (Bruel and Kjäer, Naerum Denmark) weighing about 1 kg. Vibration amplitudes and accelerations depend on the frequency: vibration amplitudes range from 0.02 to 0.2 mm and accelerations range from 10 to 20 m/s^2 (Table 1). These values are presented only as a guide to the choice of equipment.

2.2. Positivity criteria

Three strict criteria are required [2–4,7]:

- VIN starts and stops with stimulation, does not present any secondary reversal, is constant on both mastoid processes, and beats in the same direction. For example, VIN beating towards the right on the right mastoid process and towards the left on the left mastoid process is not significant: The test is negative;
- the slow-phase velocity (SPV) of the VIN must be > 2.5°/s;
- it is reproducible and must be identical or similar on two successive tests.

2.3. Doubtful cases

When only 2 of the 3 criteria are met, the test is considered to be doubtful:

- criterion 1 is not met: For example, VIN is obtained on only one mastoid process or only at the vertex, while criteria 2 and 3 are positive;
- criterion 2 is not met: Slow-phase velocity (SPV) ≤ 2.5°/s, while criteria 2 and 3 are positive;
- criterion 3 is not met: This situation is highly unlikely when criteria 1 and 2 are met, and tends to suggest that the test was not performed correctly.

VIN can be recorded by 2D or 3D videonystagmography (VNG). As with any VNG recording, complete absence of make-up facilitates pupil detection. The main results of the test according to the partial or total nature of the deficit are summarized in Table 2. Total unilateral vestibular loss (TUVL) occurs in a context of vestibular neurotomy, operated cerebellopontine angle tumours or petrous temporal bone fractures with rupture of the bony labyrinth wall; partial unilateral vestibular loss (PUVL) occurs in a context

Table 2
Results of the vestibular bone vibration test based on pathology.

Disease	Optimal stimulus frequency	Lateralisation	VIN direction	VIN features	SPV	Structures predominantly stimulated
TUVL	100 Hz	98% cases +	Healthy side 100%	Predominantly horizontal component	10.83°/s (SD 6.81)	Lateral SCC
PUVL	100 Hz	75% cases +	Healthy side 91%	Predominantly horizontal component	7.5°/s (SD 7.49)	Canals and utricle
SSCD	60 to 800 Hz Optimal at 400 Hz	88% cases+	Pathological side 95%	Torsional and especially vertical component	2.5 to 6°/s	Superior SCC

TUVL: total unilateral vestibular loss; PUVL: partial unilateral vestibular loss; SSCD: superior semicircular canal dehiscence; SPV: slow-phase velocity.

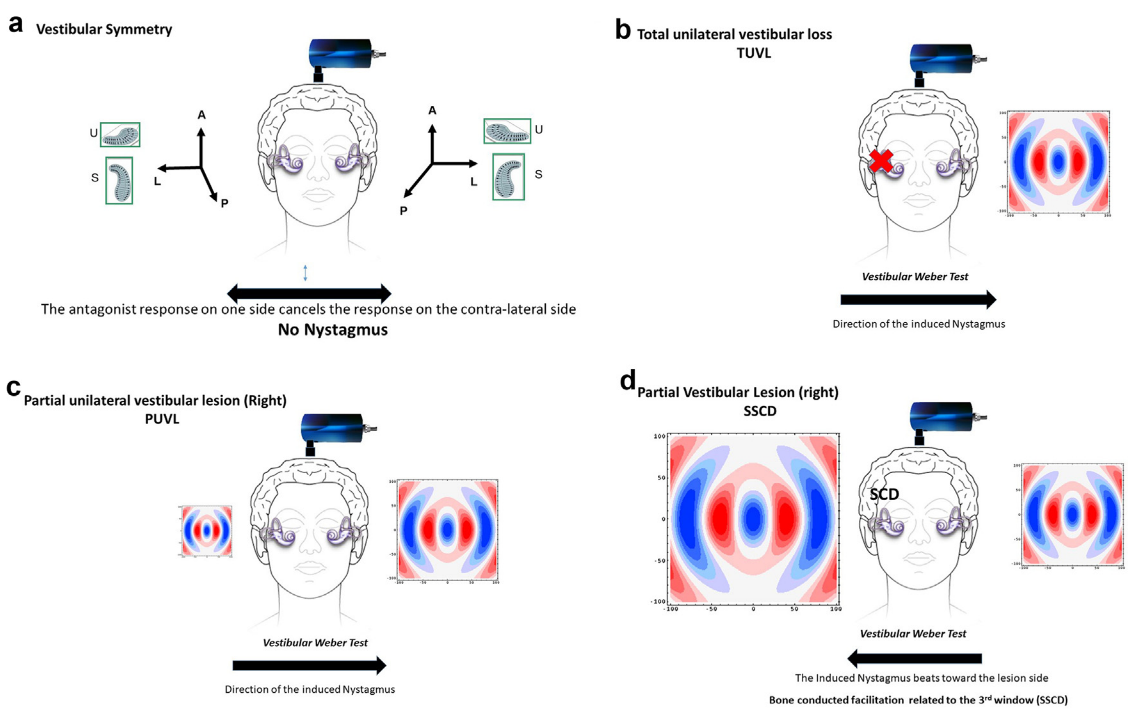

Fig. 2. Interpretation of the results. The SVINT acts as a vestibular Weber test. Unilateral vestibular loss (TUVL and PUVL) associated with impaired caloric function: a lesional type of VIN is induced, beating towards the healthy side. Irritative syndrome or facilitation of bone conduction toward the pathological side, as in superior semicircular canal dehiscence: the VIN beats towards the affected side.

of vestibular neuritis, acute peripheral vestibular nerve deficits, chemical labyrinthectomy (intratympanic gentamicin injections), and vestibular schwannomas managed by simple observation. Fig. 2 shows the basic elements that help to guide interpretation of the observed VIN. When posturographic analysis is decided to determine the absence of a possible influence of vestibular compensation on the SVINT in relation to posture, a portable vibrator attached to the patient's skull by means of an elastic band should be preferred to a vibrator held in the examiner's hand in order to avoid pressure forces that can alter lateralisation (parameter X) of the posturographic recording. The vibrator designed by Magnusson [10] delivering an 85 Hz stimulation frequency or the Vibrasens 80 Hz system (Techno Concept, France) is recommended in this situation.

3. Discussion

The skull vibration-induced nystagmus test is a recently developed (1999), robust, simple and non-invasive, screening test used in routine clinical practice that acts as a vestibular Weber test. The tolerability of the SVINT has been studied in 18,500 patients [9]. This rapid, non-invasive, first-line examination instantly reveals any vestibular asymmetry, even in patients with very longstanding and compensated unilateral vestibular loss. It is not modified by vestibular compensation, which makes it a useful test in occupational and forensic medicine. The simple test technique must be rigorously applied and vibration-induced nystagmus positivity and acceptability criteria must satisfy strict characteristics of reproducibility, consistency on the 2 mastoid processes and a minimum SPV (> 2.5°/s). This test is very useful in the presence of a perforated eardrum, which contraindicates the water caloric test or in the presence of external auditory canal agenesis or malformation. In older subjects with atherosclerosis or osteoarthritis of the neck, it is less invasive than the head shaking test (HST) or the video head impulse test (VHIT). The SVINT is well tolerated in children and easier to perform than caloric testing or VHIT [8]. The test is useful for monitoring the course of a disease, objectively and simply confirming the efficacy of treatment, for example: chemical labyrinthectomy by intratympanic gentamicin in debilitating Meniere's disease. It is a reliable marker of vestibular deafferentation, not modified by vestibular compensation. Recent extension of the applications of this test includes its use in the pre-cochlear implantation vestibular assessment. It is also used to guide the choice of implantation side in the case of unilateral cochlear implantation, especially in children [8]. In cases of conductive hearing loss with a normal eardrum, observation of torsional and horizontal components of VIN beating towards the affected side, with extended sensitivity to very high frequencies (500–700 Hz) is highly suggestive of superior semicircular canal dehiscence (SSCD) [11,12]. In this condition, the presence of VIN ipsilateral to the lesion can be explained by facilitation of bone conduction and decreased labyrinthine impedance on the side of the dehiscent canal related to the presence of a third window. The dehiscent canal is therefore more intensely stimulated and 3D recordings show a high proportion of torsional and vertical components mainly corresponding to stimulation of the superior semicircular canal concerned. In most other forms of unilateral vestibular loss (UVL), VIN usually beats towards the healthy side due to preferential stimulation of the intact side [13] (Fig. 2). The SVINT is complementary to other vestibular tests in multi-frequency analysis of the vestibule. It is a global test because vibrations stimulate the SCCs and the otolith organ at 100 Hz, but with a predominant semicircular canal contribution. In UVL, the SCC and otoliths (mainly utricle) on the intact side are stimulated to equivalent degrees at a stimulation frequency of 100 Hz. However, as the horizontal semicircular canal, due to its structure, responds primarily to unidirectional stimulation, this canal will demonstrate this asymmetry by predominantly contributing to vibration-induced nystagmus, whereas the only remaining utricular otolith is able to respond to bidirectional stimulation, due to the different orientation of the kinocilia on either side of the striola (line of polarity reversal) and their distribution for a 180° response azimuth, thus revealing less marked asymmetry [13]. Consequently, a predominantly horizontal VIN is observed at 100 Hz, but is absent at 500 Hz, which corresponds to the characteristics of the frequency spectrum of semicircular canal responses. This test does not provide any accurate information about the site of the lesion in the vestibulo-ocular reflex arc, but is more sensitive to demonstrate a peripheral rather than a central lesion [7].

The skull vibration-induced nystagmus test is a good marker of a high-frequency vestibular asymmetry, and the nystagmus observed is more relevant from a canal than an otolith contribution. This easy-to-perform and clinically useful test should be performed in all patients undergoing vestibulometry assessment.

Disclosure of interest

The authors declare that they have no competing interest.

References

[1] Lucke K. A vibratory stimulus of 100 Hz for provoking pathological nystagmus (author's transl). Z Laryngol Rhinol Otol 1973;52:716–20.
[2] Dumas G, De Waele C, Hamann KF, Cohen B, Negrevergne M, Ulmer E, et al. Skull vibration induced nystagmus test. Ann Otolaryngol Chir Cervicofac 2007;124:173–83.
[3] Dumas G, Michel J, Lavieille JP, Ouedraogo E. Semiologic value and optimum stimuli trial during the vibratory test: results of a 3D analysis of nystagmus. Ann Otolaryngol Chir Cervicofac 2000;117:299–312.
[4] Dumas G, Schmerber S, Lavieille JP. Nystagmus and vibratory test: evidence for mechanism. Material conditions and methods in the fast detection of unilateral vestibular lesions. Ann Otolaryngol Chir Cervicofac 2003;120:286–95.
[5] Curthoys IS, Vulovic V, Burgess AM, Manzari L, Sokolic L, Pogson J, et al. Neural basis of new clinical vestibular tests: otolithic neural responses to sound and vibration. Clin Exp Pharmacol Physiol 2014;41:371–80.
[6] Dumas G, Perrin P, Ouedraogo E, Schmerber S. How to perform the skull vibration-induced nystagmus test (SVINT). Eur Ann Otorhinolaryngol Head Neck Dis 2016;133:343–8.
[7] Dumas G, Curthoys IS, Lion A, Perrin P, Schmerber S. The skull vibration-induced Nystagmus test of vestibular function – a review. Front Neurol 2017;8:41.
[8] Sinno S, Perrin P, Smith Abouchacra K, Dumas G. The skull vibration-induced nystagmus test: a useful vestibular screening test in children with hearing loss. Eur Ann Otorhinolaryngol Head Neck Dis 2020, http://dx.doi.org/10.1016/j.anorl.2020.03.013.
[9] Dumas G. Influence of vibratory stimulations applied to skull and cervical muscles on equilibrium function. Physiological interpretation and applications in pathology. Development and validation of a new vestibular test: the skull vibration induced Nystagmus test or Dumas test. PhD Thesis. France: University of Lorraine; 2014 [https://hal.univ-lorraine.fr/tel-01750871].
[10] Magnusson M, Andersson G, Gomez S, Johansson R, Martensson A, Karlberg M, et al. Cervical muscle afferents play a dominant role over vestibular afferents during bilateral vibration of neck muscles. J Vestib Res 2006;16:127–36.
[11] Dumas G, Tan H, Dumas L, Perrin P, Lion A, Schmerber S. Skull vibration induced Nystagmus in patients with superior canal dehiscence. Eur Ann Otorhinolaryngol Head Neck Dis 2019;16:263–72, http://dx.doi.org/10.1016/j.annorl.2019.04.008.
[12] Dluglaiczyk J, Burgess AM, Goonetilleke S, Sokolic L, Curthoys IS. Superior canal dehiscence: relating clinical findings with vestibular neural responses from a guinea pig model. Otol Neurotol 2019;40:e406–14.
[13] Dlugaiczyk J, Burgess AM, Curthoys IS. Activation of guinea pig irregular semicircular 1 canal afferents by 100 Hz vibration: clinical implications for vibration-induced nystagmus and vestibular evoked myogenic potentials. Otol Neurotol 2020;41:e961–70.