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Association of posterior semicircular canal hypofunction on video-head-impulse testing with other vestibulo-cochlear deficits

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HIGHLIGHTS

- Isolated loss of the posterior canal on video-head-impulse testing is infrequent (<2%).
- Loss of the posterior canal is usually associated with additional vestibulo-cochlear impairment.
- The pattern of vestibulo-cochlear impairment depends on the underlying disease.

ABSTRACT

Objectives: The video-head-impulse test (vHIT) provides a functional assessment of all six semicircular canals (SCC). Occasionally isolated loss of the posterior canal(s) (ILPC) is diagnosed, though this finding is poorly characterized. Here we assessed how accurate that diagnosis is by measuring the co-occurrence of abnormalities on caloric irrigation, vestibular-evoked myogenic-potentials and audiometry.
Methods: We identified 52 patients with ILPC (unilateral = 40, bilateral = 12). We determined vHIT-gains and saccade-amplitudes and correlated vHIT-findings with other vestibulo-cochlear tests.
Results: The most frequent diagnoses were history of vestibular neuritis (13/52), Menière's disease (12/52) and vertigo/dizziness of unclear origin (13/52). Unilateral ILPC on vHIT was accompanied by a deficient horizontal canal on calorics, saccular and/or utricular deficits ipsilesionally in 33/40 (83%), while ipsilesional hearing-loss was noted in 24/40 (60%). Involvement of other sensors was highest for vestibular schwannoma (100%) and history of vestibular neuritis (92%). Bilateral deficits in ≥1 vestibulo-cochlear sensor(s) were noted in 2/12 cases with bilateral ILPC.
Conclusions: >80% of patients with unilateral ILPC had additional deficits of other parts of the vestibular organ, while this rate was ≤20% for patients with bilateral ILPC.
Significance: Dizzy patients should receive testing of the posterior canals and if abnormalities are observed, additional vestibulo-cochlear testing should be obtained.

1. Introduction

With the introduction of the video-head-impulse test (vHIT) a fast, non-invasive and quantitative assessment of all six semicircular canals (SCCs) of the vestibular organ became readily available to the clinician (Macdougall et al., 2013). In specialized dizziness clinics, the vHIT is now a routine test for patients with dizziness, vertigo or gait imbalance. Together with caloric irrigation and otolith testing (ocular vestibular-evoked myogenic potentials (oVEMPs), cervical vestibular-evoked myogenic potentials (cVEMPs) (Curthoys, 2010; Weber and Rosengren, 2015)), the vHIT allows comprehensive mapping of peripheral-vestibular function. As a screening test for dizzy patients, the vHIT now often provides the first evidence for peripheral-vestibular deficits. Sometimes a vHIT pattern of hypofunction restricted to one or both posterior SCCs can be observed, called isolated loss of the posterior canal

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(ILPC). In isolation, the clinical relevance of this finding is difficult to determine. Due to the anatomical proximity and based on clinical experience, rather a continuum between isolated involvement of a single SCC and the whole labyrinth (i.e., all 3 SCCs, both macular organs and the cochlea) is expected. These observations raise the question, to which extent other parts of the labyrinth may be involved as well in patients with seemingly isolated posterior SCC hypofunction on vHIT and what the distribution of the underlying diagnoses is. Such a closer characterization may help for the diagnostic approach to these patients. From the clinician's perspective, symptoms linked to isolated failure of the posterior SCC are often vague (typical clinical signs of unilateral peripheral-vestibular loss as spontaneous nystagmus or abnormalities on clinical head-impulse testing are frequently lacking (Chihara et al., 2012)). Cases with isolated involvement of the posterior SCC may therefore be missed or misinterpreted as of central (e.g. stroke-related) origin (Kattah et al., 2009).

In combination with impaired cVEMPs, unilateral hypofunction of the posterior SCC is characteristic for damage to the inferior branch of the vestibular nerve (inferior vestibulopathy, IVN) (Aw et al., 2001; Halmagyi et al., 2002; Chihara et al., 2012; Kim and Kim, 2012). ILPC may potentially be caused by various other peripheral-vestibular disorders including Menière's disease, labyrinthitis and labyrinthine concussion. Noteworthy, in most previous studies, a diagnosis of IVN was established based on caloric irrigation (bilaterally normal responses) and cVEMPs (being reduced on the affected side) (Monstad et al., 2006; Zhang et al., 2010; Chihara et al., 2012; Kim and Kim, 2012), while involvement of the posterior SCC was not addressed.

Here we aimed to analyze the pattern of peripheral-vestibular deficits in patients with either unilateral or bilateral ILPC on video-head-impulse testing and to correlate with underlying diagnoses. We therefore compared results from vHIT with those from other routine vestibulo-cochlear tests (caloric irrigation, ocular/cervical VEMPs, pure-tone audiogram). Potentially, this may provide patterns in vestibular hypofunction helpful in narrowing down the differential diagnosis in patients.

2. Material and methods

In this retrospective study we identified 52 patients with ILPC. The protocol was approved by the Cantonal ethics commission Zurich (KEK-ZH-2013-0468). It was in accordance with the ethical standards laid down in the Declaration of Helsinki for research involving human subjects from 1964/2013 (7th revision). Since this was a retrospective database analysis, written informed consent from the participants could not be retrieved. This approach was in accordance with the approval from the ethics committee. Prior to analysis, patient records/information was anonymized and de-identified.

2.1. Vestibular testing procedure

'Standard vHIT procedure at the University Hospital Zurich (UHZ) requires 20 valid head-impulses for each canal (Macdougall et al., 2013). SCCs are tested in pairs according to the planes of stimulation (horizontal plane, right-anterior-left-posterior (RALP) plane, left-anterior-right-posterior (LARP) plane). For video-oculography, we used commercially available video-head-impulse testing goggles (GN Otometrics, Taastrup, Denmark) with an infrared camera recording the right eye. Horizontal and vertical eye position was measured (250 Hz frame rate) and head velocity was determined by three orthogonal gyroscopes. For further analysis, eye and head velocity values were calculated', as previously described (Tarnutzer et al., 2016).

We reviewed saccular and utricular otolith function as assessed by air- or bone-conducted cVEMPs (saccular testing) and bone-conducted oVEMPs (utricular testing). VEMPs were acquired according to the standards published elsewhere (Rosengren et al., 2010; Weber and Rosengren, 2015). Differences in response amplitude (left vs. right) of >30% or absent responses were considered abnormal, i.e., indicating unilateral/bilateral hypofunction. This was based on normative values obtained with the same setup and derived cut-off values (defined as mean + 2SD). Whenever air-conducted cVEMPs were inconclusive or negative, we obtained bone-conducted cVEMPs and judgment was based on the findings from the latter one. In cases with air-conducted cVEMP stimulation with different sound intensities, only results from the highest intensity were used.

Bithermal (i.e., warm (44 °C) and cold (30 °C) water) caloric irrigation was obtained in all patients, providing slow-phase eye velocity during stimulation. 'Unilateral hypofunction was defined as a canal paresis factor of >25% with a preserved response on the healthy side (Halmagyi et al., 1997), while for bilateral hypofunction a nystagmus with a mean peak slow-phase velocity of <5°/s for cold- and warm-water irrigation on each side was required (Zingler et al., 2007)', as we used previously (Tarnutzer et al., 2016). In addition, results from pure-tone audiograms (PTA) were retrieved. We adhered to the Council on Physical Therapy – American Medical Association (CPT-AMA) guidelines for sensorineural hearing-loss (Council on Physical Therapy, 1942). Therefore, hearing loss at four frequencies (500 Hz, 1 kHz, 2 kHz, and 4 kHz) was determined and corresponding CPT-values (based on existing data taking into account the relative importance of different frequencies) were added. Total CPT values of 20% or larger were considered significant.

2.2. Patient identification and statistical analysis

All patients included here had sought medical attention because of vertigo/dizziness, gait ataxia, or hearing-loss. We searched the University Hospital Zurich vHIT database for patients with semicircular canal hypofunction that was restricted to one or both posterior canals (period: October 1st 2012 to March 21st 2016). Eighty-eight patients (out of 2904 patients) meeting these inclusion criteria were identified for evaluation.

OtosuiteV 3.0 (GN Otometrics) was used for re-analysis of the angular vestibulo-ocular reflex (aVOR)-gains of the vHIT recordings. 'The gain of the aVOR was calculated as the ratio of cumulative slow-phase eye velocity over cumulative head velocity from the onset of the head impulse to the moment when head velocity returned to zero (Macdougall et al., 2013). For the quantification of corrective saccades we used custom-written MATLAB (The MathWorks, Natick, MA, USA) routines, providing cumulative overt saccade amplitudes (see (Weber et al., 2009) for details)', as previously described (Tarnutzer et al., 2016). Either a reduction in the gain of the aVOR or the occurrence of compensatory saccades was required to rate a given SCC as hypofunctional have been proposed by The manufacturer of the video-goggles used (GN Otometrics) proposed cut-off values in aVOR-gain for the horizontal (0.8) and the vertical (0.7) canals. These values were in agreement with normative values for a wide range of ages reported (McGarvie et al., 2015b). Recently proposed cut-off values suggest that saccade amplitudes above 0.7 to 0.8°/trial indicate loss of function of the canal tested (MacDougall et al., 2016; Tarnutzer et al., 2016). Here we adhered to the cut-off value (0.73°/trial) proposed by (Tarnutzer et al., 2016) as the same statistical approach was used.

All vHIT traces were independently reviewed by two neuro-otologists with extensive experience (AAT, KPW). Inter-rater agreement for individual canal function (normal vs. pathological) was