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Original Article

The Need for Vestibular Implants in a Tertiary Referral Ear, Nose, and Throat Center and Its Relation to Hearing Status

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BACKGROUND: Patients with bilateral vestibulopathy (BVP) are at increased risk of falling and have poor quality of life. Several research groups are currently developing and investigating vestibular implants to treat BVP. The goal was to identify how many patients can be considered eligible for vestibular implantation.

METHODS: The objective vestibular implantation criteria for research were applied to the results of the caloric irrigation test, the sinusoidal harmonic acceleration test, the video head impulse test, and the cervical and ocular vestibular evoked myogenic potential tests.

RESULTS: Vestibular implant eligibility was situated between 3.6% and 15.7% (semicircular canal implant: 3.6%; otolith implant: 15.7%; combined implant: 4.8%). Only 16 out of the 29 patients (55%) eligible for a vestibular implant had bilateral severe-to-profound hearing loss. The remaining 45% (13/29) thus have better hearing in at least 1 ear.

CONCLUSION: Vestibular implant eligibility in an ear, nose, and throat department was situated between 3.6% and 15.7%, depending on the type of implant that was considered. In addition, the data showed that 45% of the eligible patients had normal-to-moderate hearing in at least 1 ear. In other words, only recruiting patients with (bilateral) severe-to-profound hearing loss for vestibular implantation leads to the systematic exclusion of about half of the candidates. Structure-preserving surgical techniques are thus a major future challenge in the field of vestibular implantation.

KEYWORDS: Vestibular implants, bilateral vestibulopathy, eligibility, hearing preservation

INTRODUCTION

The classification committee of the Bárány Society describes bilateral vestibulopathy (BVP) as "a chronic vestibular syndrome which is characterized by postural imbalance and/or unsteadiness of gait, which worsen in darkness and/or on uneven ground, as well as, in a minority of patients, by head or body movement-induced blurred vision or oscillopsia."[1] The prevalence of BVP was estimated at 4.0% by Zingler et al[2] and at 4.3% by Tarnutzer et al.[3] In 2013, Ward et al[4] reported a much lower prevalence of 28 per 100 000 US adults (i.e., 0.028%). The same year, Agrawal et al[5] evaluated the coexistence of saccular and/or utricular loss in patients diagnosed with BVP. Sixty-one percent (20/34) had a coexisting saccular dysfunction, and 64% (21/34) had a coexisting utricular dysfunction. Tarnutzer et al[3] similarly concluded that comorbid bilateral saccular loss was prevalent in 50% (50/101) of the patients with BVP and bilateral utricular loss in 56% (57/101).Patients with vestibular dysfunctions are at increased risk of falling and suffer from increased cognitive load and reduced quality of life.[6-8] As the classic treatment options for BVP (e.g., vestibular rehabilitation) only moderately improve a patient's balance, new therapeutic options are being investigated,[9,10] the vestibular implant (VI) being one of them.[10] A VI is an implantable device designed for improving a patient's balance by electrically

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stimulating the vestibular nerve. The electrode array(s) of the VI can be inserted in the semicircular canals (SCCs) and/or in the vicinity of the utricle and/or saccule. Sometimes an intracochlear electrode array is provided as well for restoring the hearing.[10] One research group attempted to implant an isolated SCC implant in patients with substantial amounts of residual hearing but unfortunately, the hearing dropped within the first year after implantation.[11] The recruitment of VI candidates is usually based on the presence of BVP and profound sensorineural hearing loss or deafness, as the surgery carries the risk of damaging residual hearing and vestibular functions.[12-16] The diagnosis "BVP" requires the patients to meet the diagnostic criteria (DC).[1] The DC for BVP include objective cutoff values for the results of the caloric test, the sinusoidal harmonic acceleration test (SHAT), and the horizontal video head impulse test (vHIT). The patients must meet at least 1 of the objective DC and must report a combination of specific symptoms without being diagnosed with any other known pathology that may explain their symptoms. However, by applying the DC for BVP, the interpretation of saccular, utricular, anterior SCC, and posterior SCC function is omitted.

Therefore, a group of experts wrote a consensus document on vestibular implantation criteria in a research setting (VIC).[17] Depending on the type of VI to be implanted, the VIC describe objective criteria for each vestibular end organ. Major and minor criteria were published; the minor criteria are less strict than the major ones but for each vestibular function test at least 1 (minor or major) criterion must be met. For the SCC implant, the focus is on the 3 SCC function tests (caloric, SHAT, and vHIT). For the otolith implant, it is described that the patient should meet the VIC for SCC implantation and that he/she should have bilaterally absent cervical and ocular vestibular evoked myogenic potentials (c- and oVEMP, respectively) as well. According to this definition, such a patient can actually be considered eligible for a combined implant (SCC + otolith). Van Stiphout et al[18] applied the VIC to 45 BVP patients and reported that 34 of them were eligible for SCC implantation.

To our knowledge, no research has been done regarding the eligibility for otolith or combined (SCC + otolith) implantation separately. Neither has this been done in a heterogeneous ear, nose, and throat (ENT) patient population, while considering all potentially eligible candidates with different degrees of hearing loss.

MATERIAL AND METHODS

The goal was to identify how many patients in a tertiary referral ENT center (European Institute for Otorhinolaryngology, Sint-Augustinus Hospital, GZA, Wilrijk, Belgium) are eligible for SCC implantation, otolith implantation, and combined (SCC + otolith) implantation while considering all potentially eligible patients with different degrees of hearing loss.

MAIN POINTS

- Vestibular implant eligibility was situated between 3.6% and 15.7% depending on the type of vestibular implant that was considered.
- Analysis of the hearing status showed that about half of the eligible candidates (45%) were systematically excluded because they had normal-to-moderate hearing thresholds in at least one ear (instead of (bilateral) severe-to-profound hearing loss).
- Therefore, the development and investigation of structure-preserving surgical techniques with a focus on hearing preservation is thus an important future challenge.

All patients with balance symptoms who consulted an ENT specialist and who underwent vestibular function testing between January 1, 2017, and December 31, 2021, were evaluated.

Patients

The mean age of 480 patients was 57.4 years with a standard deviation of 15.3 years (age range: 18-92 years). Fifty-nine percent (282/480) was female, and 41% (198/480) was male. The diagnoses are captured in Table 1. In total, 351 out of 480 patients underwent caloric testing, 444 SHAT, 284 vHIT, and 172 c- and oVEMPs.

Audiovestibular Assessment

The hearing was evaluated by means of pure-tone audiometry. The hearing thresholds (expressed in decibel hearing level, dB HL) obtained at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz were averaged so that the grade of hearing (loss) could be defined: normal hearing (−20 to +20 dB HL), mild HL (21 to 40 dB HL), moderate HL (41 to 70 dB HL), severe HL (71 to 90 dB HL), and profound HL (>90 dB HL).[19] If the patient could not detect the stimulus, "120 dB HL" was entered in the database.

The vestibular function was assessed by means of the standard 5 tests, of which the methodology is described briefly below. The parameters and cutoff values for interpreting the results are mentioned in Table 2.

The standard caloric irrigations with cold (30°C) and warm (44°C) water were performed (Aquastar, DIFRA, Eupen, Belgium) for 30 seconds each.

The SHAT was performed at 0.05 Hz with a maximum velocity of 52°/s (MiniTorque, DIFRA, Eupen, Belgium). In the VIC consensus document,[17] it is clearly stated that the SHAT should be performed at 0.10 Hz. In this retrospective study, such data were not available (typically measured at 0.05 Hz), and therefore the prescribed cutoff values for a SHAT performed at 0.10 Hz were applied (Table 2), which may have led to a higher number of patients meeting this criterion as a lower rotation frequency typically results in lower gains.[20,21] The parameters phase (°) and time constant (s) were not used as these are often incalculable in BVP patients due to too low gains.

The vHIT was performed with the Headstar system (DIFRA, Eupen, Belgium). Only head impulses with a velocity of approximately 180 to 220°/s were accepted. The gain was defined by the regression slope of the eye velocity (°/s) in relation to the head velocity (°/s) (Table 2).

The cVEMP test was performed with air-conducted 500 Hz tone bursts (alternating polarity; 2 ms rise/fall and plateau time; repetition rate = 5.1 Hz). The air-conduction stimuli were presented through insert earphones (E-A-RTone 3A Insert Earphones®, E-A-R Auditory Systems, Indianapolis, Ind, USA) at maximally 130 dB SPL (Neuro-Audio, Neurosoft®, Ivanovo, Russia). Only traces with an averaged muscle tension higher than 100 μV were accepted[22] and cases

Table 1. Diagnoses for the 480 Patients Who Underwent Vestibular Function Tests

Diagnosis	n	%
Category: Vestibular	196	40.6
Acute unilateral vestibulopathy (unspecified)	2	0.4
Acute unilateral vestibulopathy (unknown cause) + benign paroxysmal positional vertigo	1	0.2
Acute unilateral vestibulopathy (vestibular neuritis)	8	1.7
Acute unilateral vestibulopathy (vestibular neuritis) + benign paroxysmal positional vertigo	1	0.2
Acute unilateral vestibulopathy (labyrinthitis)	5	1.0
Uncompensated unilateral vestibulopathy	3	0.6
Benign paroxysmal positional vertigo	15	3.1
Benign paroxysmal positional vertigo + chronic hyperventilation	1	0.2
Benign paroxysmal positional vertigo + vestibular paroxysmia	1	0.2
Meniere's disease	43	9.0
Meniere's disease + chronic middle ear disorders	1	0.2
Meniere's disease + vestibular neurectomy	1	0.2
Meniere's disease + benign paroxysmal positional vertigo	2	0.4
Meniere's disease + cholesteatoma	1	0.2
Meniere's disease + vestibular migraine	5	1.0
Vestibular migraine	45	9.4
Vestibular migraine + benign paroxysmal positional vertigo	3	0.6
Vestibular migraine + chronic hyperventilation	1	0.2
Vestibular migraine + vestibular neuritis	1	0.2
Vestibular migraine + vestibular paroxysmia	2	0.4
Vestibular schwannoma	32	6.7
Vestibular schwannoma + benign paroxysmal positional vertigo	1	0.2
Mal de Debarquement Syndrome	4	0.8
Mal de Debarquement Syndrome + vestibular migraine	1	0.2
Superior semicircular canal dehiscence	2	0.4
Presbyvestibulopathy + benign paroxysmal positional vertigo	2	0.4
Presbyvestibulopathy + chronic middle ear	1	0.2
Presbyvestibulopathy + orthostatic intolerance	1	0.2
Persistent positional perceptual dizziness	8	1.7
Cerebellar ataxia, neuropathy, vestibular areflexia syndrome	2	0.4
Category: otology	40	8.2
Auditory neuropathy	3	0.6
Cholesteatoma	4	0.8
Cholesteatoma + superior semicircular canal dehiscence	1	0.2
Cholesteatoma + vestibular schwannoma	1	0.2
Otosclerosis	11	2.3
Otosclerosis + barotrauma + skull fracture	1	0.2
Otosclerosis + secondary hydrops	4	0.8
Otosclerosis + vestibular paroxysmia	1	0.2
Chronic middle ear disorders	13	2.7
Chronic middle ear disorders + superior semicircular canal dehiscence	1	0.2
Category: Trauma	21	4.3
Barotrauma (plane, diving, etc.)	1	0.2
Iatrogenic	7	1.5
Iatrogenic (cholesteatoma)	1	0.2
Sudden noise exposure (e.g., explosion)	1	0.2
Systematic noise exposure	4	0.8
Temporal bone fracture	2	0.4
Skull fracture	2	0.4
Traumatic SNHL but no fractures/middle ear damage	2	0.4
Unspecified	1	0.2
Category: Syndromes	9	1.8
Alport's syndrome	1	0.2
Branchiootorenal syndrome	1	0.2
Usher's syndrome	1	0.2
Congenital rubella	1	0.2
Maternally inherited diabetes and deafness	1	0.2
Large vestibular aqueduct syndrome	4	0.8
Category: Genetic/hereditary	28	5.8
Genetic (undefined)	2	0.4
COCH gene mutation (Deafness Autosomal Dominant, type 9, DFNA9)	20	4.2
KCNQ4 gene mutation	1	0.2
MYO7A gene mutation	1	0.2
Connexin 26 mutation (progressive form)	1	0.2
TMPRSS3 gene mutation	2	0.4
TMPRSS3 gene mutation + encephalitis	1	0.2
Category: Other	48	10.0
Wallenberg's syndrome	1	0.2
Parkinson's disease	1	0.2
Stickler's syndrome	1	0.2
Oxygen deprivation during birth	1	0.2
Oto- and/or vestibulotoxicity (gentamicin, streptomycin, etc.)	6	1.3
Multifactorial	6	1.3
Multiple sclerosis	2	0.4
Nonvestibular (no diagnosis yet, neurological, etc.)	25	5.2
Chronic hyperventilation	4	0.8
Meningitis	1	0.2
Category: Idiopathic	107	22.2
Idiopathic	101	21.0
Idiopathic + superior semicircular canal dehiscence	1	0.2
Idiopathic + vestibular schwannoma	1	0.2
Idiopathic + benign paroxysmal positional vertigo	2	0.4
Idiopathic congenital deafness	1	0.2
Idiopathic sensorineural hearing loss + hemodynamic orthostatic dizziness/vertigo	1	0.2
Category: No diagnosis yet	31	6.5
No diagnosis yet	31	6.5

n, number of cases; SNHL, sensorineural hearing loss.

Table 2. Overview of the Objective Research Criteria for Vestibular Implantation As Described by van de Berg et al[17]

Major Criteria for Vestibular Implantation: At Least One of the Following "Major" Criteria Should Be Met in the Case of a Semicircular Canal Implant (+ Bilaterally Absent c- and oVEMPs in the Case of an Otolith Implant)			
vHIT	Caloric test	SHAT†	c/oVEMPs
Bilateral horizontal aVOR gain ≤ 0.6 and at least bilaterally 1 vertical aVOR gain < 0.7	Sum of bithermal maximum peak SPV on each side ≤ 6°/s for 30-second water stimulation (or < 10°/s for 60-second air stimulation)	Gain ≤ 0.1 and a phase lead ≥ 15° (time constant ≤ 6seconds)	Bilaterally absent (in the case of an otolith implant)
Minor Matched Criteria for Vestibular Implantation: The Major Criteria That Are Not Met Should Be Matched with the Respective "Minor" Criteria in the Case of a Semicircular Canal Implant (+ Bilaterally Absent c- and oVEMPs in the Case of an Otolith Implant)			
vHIT	Caloric test	SHAT†	c/oVEMPs
Bilaterally pathological VOR gains of at least 2 semicircular canals < 0.7	Sum of bithermal maximum peak SPV on each side < 10°/s for water and air stimulation of ≥30 seconds	Gain < 0.2	Bilaterally absent (in the case of an otolith implant)

aVOR, angular vestibulo-ocular reflex; c/oVEMPs, cervical and ocular vestibular evoked myogenic potentials; oVEMP, ocular vestibular evoked myogenic potentials; SHAT, sinusoidal harmonic acceleration test; SPV, slow phase velocity (°/s); vHIT, video head impulse test.
†The described gain and phase cutoff values had to be obtained at a 0.10 Hz rotation frequency. As mentioned earlier, the SHAT was typically performed at 0.05 Hz in our clinic.

requiring bone-conduction cVEMPs (due to conductive hearing loss) were excluded. Patients with a superior SCC dehiscence (n = 5) or large vestibular aqueduct syndrome (n = 4) were excluded from the analysis of the cervical and ocular vestibular evoked myogenic potentials (oVEMP).

The oVEMP test was conducted with a handheld bone-conduction vibrator (Mini Shaker type 4810®, amplifier model 2718, Brüel & Kjaer®, Nærum, Denmark) that was placed at the midline of the forehead near the hairline (Fz). The stimuli were 500 Hz tone bursts (2 ms rise/fall time, no plateau; alternating polarity; repetition rate = 5 Hz) at an intensity of 121 decibel Force Level (Neuro-Audio, Neurosoft®, Ivanovo, Russia).

Criteria for Vestibular Implantation

The VIC for research were written for research projects (Table 2).[17] To be eligible for SCC implantation, the results of all 3 SCC function tests should be below the described cutoff values (Table 2) (n = 169). If otolith implantation is considered, bilaterally absent c- and oVEMPs should be observed as well. In other words, those patients are not only eligible for otolith implantation but also for a combined (SCC + otolith) implantation (n = 84). Therefore, the authors decided to define otolith implant eligibility separately, by calculating the frequency of bilaterally hard-to-evoke or absent c- and oVEMPs (regardless of SCC function) (n = 172). The sample size thus differed depending on which type of VI was considered, and this sample size was based on the number of criteria that had to be met.

It must be mentioned that the objective VIC are not limited to numeric data. Other criteria were clearly described.[1,17] Briefly, the patient should suffer from a chronic vestibular syndrome, characterized by at least 3 of the following symptoms: postural imbalance, unsteadiness of gait, movement-induced blurred vision or oscillopsia during walking or quick head/body movements, and/or worsening of the postural imbalance or unsteadiness of gait in darkness and/or on uneven ground. In addition, the patient should not experience any symptoms when in static conditions (e.g., while sitting or lying down). Furthermore, the patient should not have been diagnosed with any other known pathology that can explain the reported symptoms.

Statistical Analysis

Descriptive statistics were performed with Statistical Package for Social Sciences (SPSS) version 28.0 (IBM SPSS Corp.; Armonk, NY, USA).

This retrospective study was approved by the institutional review board of Sint-Augustinus, GZA Hospital, (Approval number: 220401RETRO). The acquisition of informed consent was not required as there were no research-related risks and as the institutional review board decided that, in this case, informed consent was not required. The data were analyzed in accordance with the Declaration of Helsinki.

RESULTS

Semicircular Canal Implantation

In total, 169 patients underwent all 3 required SCC function tests (SHAT and VHIT and caloric) for defining whether they met the SCC implantation criteria. Six patients (3.6%) met all 3 criteria.

Otolith Implantation

Twenty-seven patients out of 172 (15.7%) who underwent c- and oVEMP testing had bilaterally absent c- and oVEMPs.

Combined Implantation

Eighty-four cases underwent all 5 required tests (SHAT, vHIT, caloric, cVEMP, oVEMP) for assessing whether the patient met the implantation criteria for a combined (SCC + otolith) implant . In total, 4 patients (4.8%, 4/84) thus met the criteria for such a combined implant.

Hearing Status

As not all tests had to be performed in each patient for assessing how many patients met the SCC or otolith implantation criteria, a combination of the abovementioned subgroups was made, leading to a sample size of 234 cases, in whom the hearing status could be evaluated (Figure 1). Cases who underwent all (SCC + otolith) tests were only counted once and those who did not undergo pure-tone audiometry were excluded from this sample size.

The 6 patients eligible for SCC implantation all suffered from bilateral moderate to profound SNHL (Figure 1: red circles and triangles)

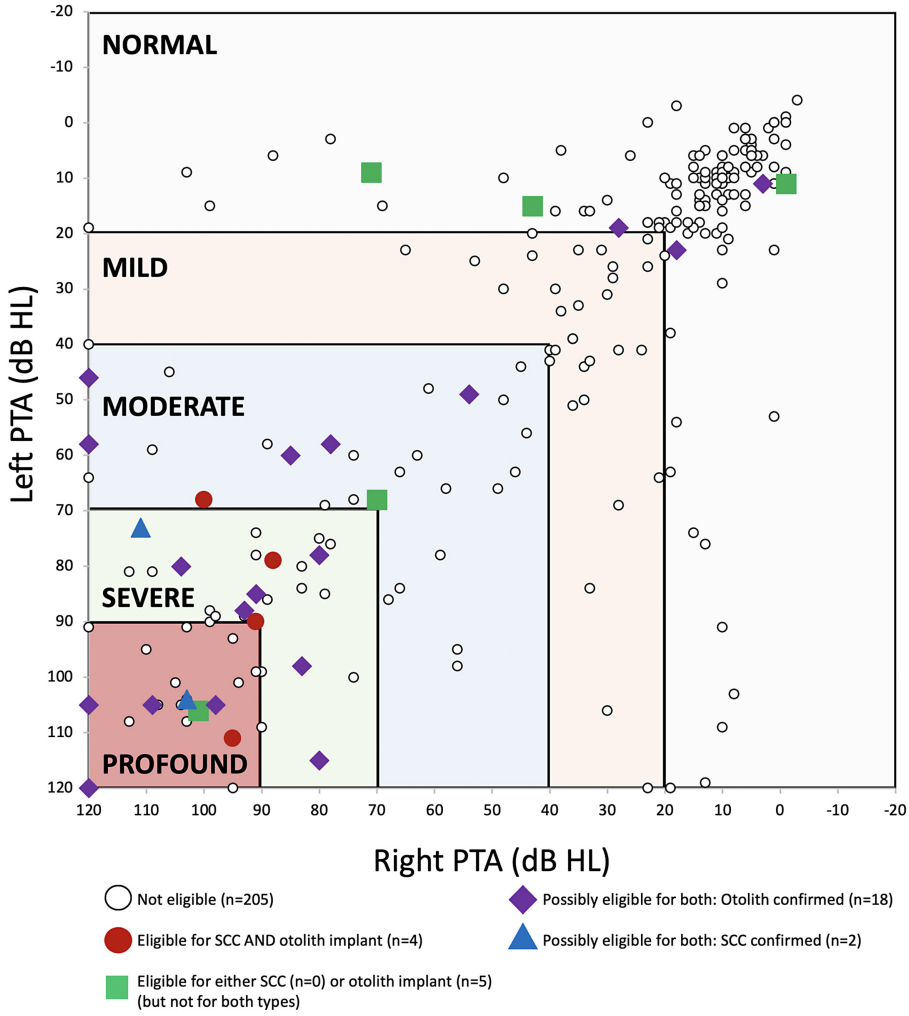

Figure 1. Hearing status and vestibular implant eligibility (n = 234). The average hearing (obtained at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz) of the left and right ear is depicted in this scatter plot. The 5 different grades of hearing (normal hearing, mild hearing loss (HL), moderate HL, severe HL, and profound HL) were indicated by the 5 zones that were named accordingly. The white circles represent the cases who were not eligible for vestibular implantation based on the vestibular implantation criteria for research (n = 205). The red circles indicate patients who were eligible for both SCC and otolith implantation. The squares represent the patients who were eligible for either an otolith (n = 5) or semicircular canal (SCC) implant (n = 0) but not for both. The triangles and rhombi represent the cases who might be eligible for SCC and otolith implantation but for whom eligibility for only 1 of the 2 could be confirmed, at the time of analysis, due to incomplete test data. Thus, the rhombi represent the cases for whom eligibility for the otolith implant was confirmed but not yet for the SCC implant.The triangles represent those for whom eligibility for the SCC implant was confirmed (but not yet for the otolith implant). n, number of cases; PTA, pure-tone audiometry (average of the hearing thresholds obtained at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz); *normal/mild/moderate/severe/profound* hearing loss grades.

(moderate-to-severe HL: n = 1; bilateral severe HL: n = 1; severe-to-profound HL: n = 2; bilateral profound HL: n = 2). For 2 patients, otolith implant eligibility could not be evaluated due to incomplete data. They were categorized under "Possibly eligible for both: SCC confirmed."

The 27 cases who were eligible for otolith implantation were divided into 3 groups: "eligible for otolith implant" (n = 5), "eligible for SCC and otolith implant" (n = 4), and "possibly eligible for both: otolith confirmed" (n = 18). The 5 cases who were only eligible for the otolith implant had the following hearing grades: bilateral normal hearing (n = 1), unilateral moderate HL (n = 1), unilateral severe HL (n = 1), bilateral moderate HL (n = 1), bilateral profound HL (n = 1) (Figure 1, triangles). Those eligible for SCC and otolith implantation had moderate to profound HL (n = 1), bilateral severe SNHL (n = 1), bilateral severe-to-profound HL (n = 1), or bilateral profound HL (n = 1) (Figure 1, red circles). The remaining 18 cases were eligible for otolith implantation and possibly also for SCC implantation (but this could not be confirmed due to missing data) (Figure 1, rhombi). The following hearing grades were observed: bilateral normal hearing (n = 1), unilateral mild HL (n = 2), bilateral moderate HL (n = 1), bilateral moderate-to-severe HL (n = 2), bilateral moderate-to-profound HL (n = 2), bilateral severe SNHL (n = 1), bilateral severe-to-profound HL (n = 5), or bilateral profound HL (n = 4).

Combining this data showed that 16 of the 29 patients (55%) who were eligible for a VI, had bilateral severe-to-profound hearing loss (hearing thresholds $\geq$ 70 dB HL), and thus met the Belgian reimbursement criteria for cochlear implantation.[23] The remaining 13 cases (45%), however, had better hearing thresholds in at least in 1 ear.

DISCUSSION

Almost 4% (6/169) of the patients in our ENT department were considered eligible for SCC implantation, while 15,7% was eligible for

otolith implantation, and 4.8% for combined (SCC+ otolith) implantation. To our knowledge, no previous reports have been made in a similar cohort of patients. Van Stiphout et al[18] examined a different cohort of patients with BVP and concluded that 76% of them, met the criteria for SCC implantation (34/45). Comparing this data with the current is not preferred as 2 different cohorts were studied.

As was mentioned in the methodological section, otolith implantation was approached differently in the current study. Instead of assessing both SCC and otolith function, as suggested by the consensus document,[17] only otolith function was considered. This approach led to an increase in numbers from 4.8% to 15.7%. In other words, systematically only recruiting patients with complete loss of all vestibular functions, would lead to the exclusion of 10.9% of those who might serve to gain from an otolith implant. Nonetheless, regardless the type of VI that is considered for implantation, the entire inner ear should be examined to define the risk of iatrogenic loss of residual functions and to define the best end organ and side for implantation.

Moreover, in this early stage of VI research, the risk of iatrogenic loss of vestibular residual function still remains and should be taken into account when deciding whether to include a specific patient in a VI study.

It could be hypothesized that in the future, the decision of which type of VI should be implanted, could depend on the residual function in the vestibular system and/or on the most disturbing symptom as reported by the patient (e.g., oscillopsia or imbalance) However, as previous research has shown, the correlation between reported symptoms and residual function is typically weak to absent,[24] thus suggesting that the reported symptoms may not be the best indicator for defining which type of VI should be considered.

The auditory data showed that both patients with and without hearing loss may benefit from vestibular implantation. Only 55% (16/29) had bilateral severe-to-profound hearing loss, which implies that almost half of the patients (45%;13/29) had better hearing in at least 1 ear. Thus, by recruiting only patients with bilateral severe-to-profound hearing loss, about half of the eligible candidates are systematically excluded. This finding emphasizes the need for structure-preserving surgical techniques in this field.

There are some limitations to the present study. The SHAT was performed at 0.05 Hz, which conflicted with the 0.10 Hz rotation frequency which was prescribed in the VIC. Due to the retrospective study design, this could not be corrected. Gains obtained at 0.05 Hz are typically lower than those obtained at 0.10 Hz.[20,21] Consequently, the number of the patients eligible for SCC or combined implantation may be lower than what was reported.

An important remark to the retrospectively obtained data is that it was not possible to determine the functional and psychosocial impact of the chronic vestibular loss on the BVP patients or those eligible for a VI. For future prospective studies, this should be one of the research objectives.

In total, 4 patients were diagnosed with presbyvestibulopathy (PVP).[25] Patients with PVP suffer from imbalance due to bilaterally impaired vestibular function and are older than 60 years. The residual vestibular function is typically higher than the residual function in patients with BVP, and therefore, patients with PVP are currently not considered eligible for a VI. Similar to what was seen in cochlear implantation, loosening of the selection criteria through time might lead to the inclusion of patients with PVP as well.

Another limitation is that the use of vestibular suppressants was not controlled for. However, the audiovestibular testing was typically performed before any vestibular suppressants were described, as the test results were part of the decision making process.

The data were collected in a tertiary referral ENT center. The concentration of patients with vestibular problems was therefore inherently higher than in the general population. However, BVP is characterized by vague nonpathognomonic symptoms,[26] leading to an underestimation of the prevalence. National campaigns and patient organizations could play a crucial role in creating awareness about BVP (and PVP).

Vestibular implant eligibility was situated between 3.6% and 15.7% depending on the type of VI that was considered. In addition, the data showed that 45% of the eligible patients had normal-to-moderate hearing thresholds in at least 1 ear. Therefore, only recruiting patients with (bilateral) severe-to-profound hearing loss for vestibular implantation leads to the systematic exclusion of about half of the candidates. Structure-preserving surgical techniques are thus a major future challenge in the field of vestibular implantation.

Ethics Committee Approval: This study was approved by Ethics Committee of Sint-Augustinus, GZA Hospital (Approval No: 220401RETRO, Date: April 19, 2022).

Informed Consent: The acquisition of informed consent was not required as there were no research-related risks and as the institutional review board decided that, in this case, informed consent was not required.

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