Auris Nasus Larynx xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Auris Nasus Larynx

journal homepage: www.elsevier.com/locate/anl

Comparison of VEMPS, VHIT and caloric test outcomes after vestibular neurectomy in Menière's disease

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ARTICLE INFO

Article history:
Received 29 December 2017
Accepted 20 April 2018
Available online xxx

Keywords:
Vestibular neurectomy
Menière's disease
Neural anastomosis
Vestibular neurectomy outcomes
Recurrent vertigo

ABSTRACT

Objective: Selective unilateral vestibular neurectomy (VN) is considered a reliable surgical treatment in case of recurrent vertigo in Menière's disease (MD) because of hearing preservation and a minimally invasive posterior fossa retrosigmoid approach. The present study aimed to assess the quality of life and the long-term vestibular function in patients submitted to yearly follow-up after VN because of intractable MD.

Methods: Retrospective series of 15 MD patients undergoing retrosigmoid VN for recurrent vertigo. Outcome measures included cVEMPs and oVEMPs (cervical and ocular vestibular evoked myogenic potentials), VHIT (Video Head Impulse Test) and caloric test, besides to DHI (Dizziness Handicap Inventory) and PTA (Pure Tone Audiometry).

Results: Mean DHI score resulted within normal values in 74% of patients, significantly correlated to the duration of the follow-up. In the operated side, cVEMPs and oVEMPs have not been elicited respectively in 11 patients (73%) and 13 patients (87%), whereas it was not possible to evoke any response at bithermal caloric test in 4 cases. The gain of VOR from VHIT resulted always below normal values after VN except in one patient, who has also undergone an episode of posterior BBPV. The difference between average PTA threshold before and after VN resulted not significant.

Conclusion: The vestibular outcomes prove VN to be an effective and safe surgery in MD; furthermore, the unexpected occurrence of BPPV after VN can justify the presence of neural anastomosis between the inferior vestibular nerve and the cochlear nerve, allowing to still perceive vestibular symptomatology despite of a proper neurectomy.

1. Introduction

Menière's disease (MD) is an idiopathic disorder of the inner ear due to endolymphatic hydrops whose diagnosis is principally based on the evaluation of symptoms, recurrent vertigo lasting more than 20 min with rapid resolution, and Pure Tone Audiometry, characterized by typical sensorineural low frequencies fluctuating hearing loss [1]. MD is one of the most frequent causes of recurrent vertigo, with an estimated prevalence of about 50–500 cases per 100,000 people [2], and it significantly affects the patient's quality of life and work performance.

Although there is not actually any defined cure, it is possible to obtain good results, at least as regards the control of vertigo,

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https://doi.org/10.1016/j.anl.2018.04.006
0385-8146/

in the larger part of patients simply through changes in lifestyle and medical therapies such as salt and water restriction, diuretics or vasodilators. However some patients do not respond to medical management, requiring a different and more effective surgical treatment. The typical first approach is a minimally invasive chemical labyrinthectomy through intratympanic gentamicin [3]. Nevertheless, about 5% of MD patients do not respond also to this approach and are subjected to a further serious worsening in their quality of life [4]. In these cases, selective unilateral vestibular neurectomy (VN) has become widely accepted as the reference surgical treatment for patients with MD due to the hearing preservation and a minimal invasive posterior fossa retrosigmoid approach [3–6]. This kind of approach induce a unilateral vestibular deafferentation which is briefly compensated centrally; furthermore, considering bilateral MD with bilateral hearing loss is described in 5–20% of patients [7], a surgical neurectomy which provide hearing preservation is preferred [8,9].

The medium to long-term results for the retrosigmoid VN demonstrate the disappearance of vertiginous crisis in 78% of cases and a significant general improvement of symptoms in 14% of cases. The quality of life of patients with MD after surgery also results significantly improved compared to medical therapy alone; although, a low number of patients keep reporting episodes of vertigo, despite of a lower frequency and severity [4,10–15].

These failures could be consequent to the presence of neural anastomosis in the VIII cranial nerve between the inferior vestibular nerve and the cochlear nerve [15].

Currently the functional evaluation of vestibular end-organ allows a precise monitoring of the activity of the posterior labyrinth. Caloric stimuli allows to explore the functionality of the horizontal semicircular canal; by means of Video Head Impulse Test (VHIT) it is possible to separately evaluate the function of the three semicircular canals from both sides; finally myogenic evoked potentials such as cervical evoked myogenic potentials (cVEMPs) and ocular evoked myogenic potentials (oVEMPs) respectively allow to detect the saccular and the utricular function [15–18].

The aim of the present study was to investigate the quality of life and the long-term vestibular function of patients who presented the resolution of acute vertiginous crisis after been submitted to VN due to unilateral intractable definite MD.

2. Materials and methods

This is a retrospective study based on a cohort of patients submitted to yearly follow-up after VN due to intractable MD.

The group under examination consisted of patients affected by unilateral definite MD according to AAO-HNS diagnostic criteria [1] refractory both to medical therapy and to intratympanic gentamicin injections. In particular, all the samples had been previously submitted to a gentamicin titration scheme, consisting of an intratympanic injection (40 mg/ml suspension) once a week, up to a maximum of 4 doses, suspending the treatment in case of onset of unsteadiness. Once completed the 4 administrations, the treatment was considered unsuccessful and the patients were included in the protocol of study. Moreover, at the time of surgery all the patients were unable to work or had severe limitations to their daily activities.

In relation to the above-mentioned admission criteria, 15 patients suffering from MD have been considered: 8 subjects (54%) were females and 7 (46%) were males. The average age was 50.8 years (range 24–65 years). In 8 cases (54%) the disease affected the right ear whereas in 7 cases (46%) it affected the left ear.

Each of these patients were submitted to retrosigmoid VN and the operating technique, performed under facial nerve function monitoring, is briefly described below. A 4- to 5-cm retroauricolar skin incision was carried out, lateral to the greater occipital nerve, and then a craniectomy 2 cm in diameter was performed with the opening of the dura. The posterior fossa was completely decompressed and the CSF was allowed to drain from the cisterna, allowing a good exposure of the cerebellopontine angle (CPA) through a gently medialization of the cerebellar hemisphere. The VIIIth cranial nerve complex was identified with the use of the operating microscope: from a retrosigmoid approach the VIIIth nerve lays lateral to the facial nerve, allowing a safe approach to it and furthermore it was always identifiable the cleavage plane between the vestibular (superiorly) and the cochlear (inferiorly) part of it by a slightly greyer color of the first one.

By means of a microdissector, the vestibular nerve was separated and sharply sectioned; moreover, to avoid any possible reinnervation, a little portion of it was always removed (vestibular neurectomy).

After facial nerve function confirmation by its stimulation, the dura was closed, a cranioplasty was made and finally a suture of muscles, fascia and skin by layers was performed.

All the patients under consideration have been followed for at least 3 years after VN and only those without further evidence of acute crisis of vertigo compatible with MD were admitted in the study.

Every clinical examination and test was performed before surgery and again yearly after VN by our ENT department; in particular, all the patients have been submitted to:

- neurological evaluation (pupils status, corneal reflex, extrinsic ocular motility, VII, IX, X, and XI cranial nerve function, superficial tactile sensitivity, presence of headache, cerebellar tests, Pull test and Mingazzini test);
- ear examination (otoscopy);
- subjective status: investigated by the Dizziness Handicap Inventory (DHI), a questionnaire designed to identify difficulties that the patients may be experiencing because of the dizziness, specifically considering their condition during the last month; it comprises 25 different questions and it is structured to incorporate functional (F), physical (P), and emotional (E) impacts on disability; to each item, the following scores can be assigned: No = 0, sometimes = 2, always = 4; total scores inferior to 34 points are considered normal or mild handicap, values between 36 and 52 are representatives of moderate handicap whereas values greater than 54 are referred to severe impairment due to chronic unsteadiness [19], the original American version of DHI has been translated into several languages and among them it has been validated also for the Italian language [20].

Please cite this article in press as: Canale A, et al. Comparison of VEMPS, VHIT and caloric test outcomes after vestibular neurectomy in Menière's disease. Auris Nasus Larynx (2018), https://doi.org/10.1016/j.anl.2018.04.006

The auditory function was assessed by pure-tone audiometry (PTA): the hearing threshold was detected at 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz and, in accordance with the AAO-NHS guidelines [1], the mean hearing threshold at 500, 1000, 2000 and 4000 Hz was also evaluated.

The vestibular function was tested by means of spontaneous nystagmus (Ny) research through bedside examination with Frenzel's goggles and videonystagmography, cervical and ocular vestibular evoked myogenic potentials (cVEMPs and oVEMPs), Video Head Impulse Test (vHIT) and caloric test.

VEMPs were evoked through pulses stimulating separately both the pathological and the contralateral ear by means of an Amplaid MK22 polygraph (Amplifon, Milan, Italy) and the electrodes were positioned as indicated by Colebatch and Halmagy [21].

CVEMPs were evoked by "log-on" tone bursts presented through headphones at 500 Hz frequency and 120 dB HL intensity, with a stimulation rate of 4/s; the outcome was evaluated on the basis of the threshold, normally set at 120 dB ± 10 dB, analyzing the first positive–negative peak (P13 and N23) latency. Absence of a meaningful wave form with P13 and N23, as well as abnormalities of it, were strictly defined as a cVEMP pattern of "no response".

Similarly oVEMPs were evoked with pulses at 250 Hz frequency and 40 dB intensity and the outcome was evaluated measuring N10 wave latency. All VEMP tests were repeated 3 times on each subject to ensure reliability and reproducibility of responses.

VHIT was evaluated following a standard procedure [22], which requires 20 valid head impulses with peak velocity ranges 100–300°/s for each semicircular canal according to the planes of stimulation (horizontal plane, right-anterior-left-posterior (RALP) plane, left-anterior–right-posterior (LARP) plane). Participants wore a lightweight goggle frame with a built-in infrared camera to record right eye movements and an accelerometer to record head movements at a sampling frequency of 250 Hz (ICS Impulse, GN Otometrics, Taastrup, Denmark). Vestibular hypofunction was defined as a reduction in the angular vestibulo-ocular reflex (aVOR) gain, which was calculated using Otosuite 2.0 (GN Otometrics). For gains, cut-off values of 0.8 (horizontal canals) and 0.7 (vertical canals) have been proposed in order to distinguish normal from reduced aVOR-function [23].

Bithermal caloric test was carried out by means of the Fitzgerald–Hallpike technique (250 ml of water at 30 °C and 44 °C in 40 s); the evaluation was conducted on the basis of the slow phase velocity of the Ny measured at culmination. The symmetry of the functionality was evaluated by means of the Jongkees's formula and a difference lower than 20% between the two sides was considered normal.

All the vestibular exams were performed in May 2017 and the mean follow-up after surgery at that moment resulted 6.7 years (range 3–12 years).

Written informed consent to be routinely submitted to the tests was obtained by each of the enrolled subjects and the protocol study, carried out according to the 1964 Helsinki Declaration and its later amendments or comparable ethical standards, has been approved by the Institutional Review Board of the University of Turin. Statistical analysis of the data was performed using SPSS software 21 (Chicago, IL, USA). A level of 0.05 of significance was set for all the tests.

3. Results

Among all the 15 patients enrolled in the present study, the outcome of the neurological examination after VN to a follow-up of 3–12 years resulted within normal limits for all the subjects involved, as well as otoscopy resulted negative for all them. In relation to the above-mentioned admission criteria, none of the patients reported episodes of vertigo due to MD after surgery.

Mean DHI score resulted 35 (range 10–76), namely the lower limit of normality. Ten patients (67%) achieved a DHI value lower than 34 (mild handicap), 1 patient (7%) reported a score between 36 and 52 (moderate unsteadiness) and finally 4 patients (26%) obtained a total DHI score greater than 54 (severe handicap). DHI score after surgery resulted significantly correlated, at the Pearson's test ($p < 0.05$), with follow-up (months after VN) although it was not correlated with age ($p > 0.05$).

All the vestibular tests carried out before VN resulted within normal limits bilaterally, whereas the results of the same vestibular tests (cVEMPs, oVEMPs, VHIT, caloric test) administered after surgery on both sides are reported in Tables 1–4.

The research of spontaneous Ny in the post-neurectomy follow-up resulted negative for all the patients during the primary bedside examination. For that reason a videonystagmography has been later performed on all subjects, highlighting a slight first degree spontaneous Ny directed towards the unaffected side in only 2 different patients.

CVEMPs (Table 1) resulted always within the normal ranges in the unaffected side; on the contrary in the operated side cVEMPs have not been elicited in 11 patients (73%), whereas in the remaining 4 subjects (n. 4, 7, 10 and 14) the potentials were recorded with a nearly normal latency of P13 and N23. Among

Table 1
cVEMPs latency and threshold in the affected and unaffected ear.

Patient	Affected side			Unaffected side		
	Latency (ms)		Threshold (dB)	Latency (ms)		Threshold (dB)
	P13	N23		P13	N23	
1	/	/	/	14.40	27.00	110
2	/	/	/	18.00	26.40	110
3	/	/	/	17.60	26.80	120
4	11.20	21.20	130	18.00	24.00	110
5	/	/	/	17.60	28.40	110
6	/	/	/	14.00	22.40	120
7	12.00	22.00	130	12.40	24.80	90
8	/	/	/	20.40	27.20	120
9	/	/	/	17.60	25.20	100
10	19.20	25.60	110	20.00	27.20	110
11	/	/	/	15.60	21.60	120
12	/	/	/	14.80	22.80	130
13	/	/	/	19.60	34.00	130
14	17.60	28.00	110	21.60	25.20	110
15	/	/	/	20.00	28.40	130

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Table 2
oVEMPs latency in the affected and unaffected ear.

Patient	Latency (ms) in the affected side	Latency (ms) in the unaffected side
1	/	11.20
2	/	12.04
3	/	12.60
4	/	13.44
5	/	10.92
6	/	10.92
7	/	16.52
8	/	12.40
9	/	12.60
10	12.88	12.04
11	/	12.88
12	/	12.32
13	/	13.16
14	12.32	14.00
15	/	13.44

Table 3
Results of the caloric test in terms of side prevalence. Data are referred to the slow phase angular velocity of nystagmus at culmination.

Patient	Side prevalence (%)
1	100
2	66
3	100
4	43
5	100
6	75
7	92
8	0
9	100
10	36
11	54
12	57
13	60
14	83
15	95

these 4 patients, only 2 of them demonstrated an elevated threshold in comparison to the unaffected side (n. 4 and 7).

Concerning the oVEMPs (Table 2), they resulted all within normal limits in the unaffected side as well as it emerged from the cVEMPs. Contrariwise, oVEMPs in the side submitted to surgery have not been elicited in 13 patients (87%) and only in the remaining 2 subjects (n. 10 and 14) was possible to evoke the myogenic vestibular potentials with a nearly normal latency.

Bithermal caloric test demonstrated the predominance of the healthy ear in all cases except in patient n. 8 (93%), in which both sides showed a reduced response to the stimuli (Table 3). Regarding the operated side, in four different cases, namely patients n. 1, 3, 5 and 9 (27%), it was not possible to demonstrate any response to stimuli after the caloric test.

With regard to the results of the VHIT, all the patients achieved a normal gain in the three semicircular canals (gain of VOR > 0.8) in the healthy side after head impulses. On the contrary, in the operated ear the gain resulted always below the above-mentioned normal value, except for the posterior canal of the patient n. 7, whose gain resulted within normal limits (Table 4).

The average preoperative PTA threshold at 0.5-1-2-3 kHz in the affected ear of all 15 patients was 74 ± 27 dB. After surgery the same average PTA threshold resulted 76 ± 25 dB, with a mean variation of 2 dB; the difference obtained between the audiometric threshold before and after VN resulted not significant at the Student's T test for paired data ($p > 0.05$).

One patient (n. 7) presented a typical paroxysmal positional vertigo as a result of canalolithiasis of the posterior semicircular canal at the same side of VN. The patient was successfully treated with a liberatory Semont's manoeuvre.

The results of the tests obtained for each of the patients who have taken part to the present study are summarized in Table 5, in which only data referred to the affected side are reported.

Table 4
Gain of vestibulo-ocular reflex (VOR) in MD patients submitted to Video Head Impulse Test (VHIT) in order to evaluate the function of the three semicircular canals in the affected and unaffected ear.

Patient	Affected side			Unaffected side		
	Lateral	Anterior	Posterior	Lateral	Anterior	Posterior
1	0.43	0.47	0.43	0.92	0.77	0.76
2	0.44	0.43	0.39	1.00	0.91	0.78
3	0.55	0.63	0.65	0.93	1.06	0.92
4	0.13	0.45	0.52	1.01	1.05	0.80
5	0.31	0.32	0.56	0.83	1.05	0.84
6	0.35	0.48	0.22	0.89	0.83	0.80
7	0.66	0.44	0.86	0.99	0.85	0.85
8	0.61	0.39	0.42	0.92	0.84	0.78
9	0.57	0.62	0.60	0.86	0.84	0.84
10	0.27	0.40	0.31	0.72	0.78	0.84
11	0.39	0.37	0.47	0.95	0.83	0.78
12	0.51	0.51	0.56	0.90	0.89	0.78
13	0.44	0.40	0.46	1.07	0.77	0.79
14	0.51	0.55	0.54	1.00	0.78	0.87
15	0.47	0.53	0.62	0.98	0.97	0.78
Mean value	0.44 ± 0.1	0.47 ± 0.1	0.51 ± 0.1	0.93 ± 0.1	0.89 ± 0.1	0.81 ± 0.4

Normal gain value is set at 0.8

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Table 5
Outcome of the parameters evaluated after VN at last control during follow-up (3–12 years).

Patient	Sex	Age (years)	Follow-up (years)	DHI	PTA before surgery	PTA after surgery	cVEMPs	oVEMPs	Caloric test	VHIT
1	M	40	8	10	112	112	/	/	P	P
2	M	44	12	14	79	76	/	/	P	P
3	F	64	9	24	92	92	/	/	P	P
4	M	65	7	24	15	19	N	/	P	P
5	F	58	9	14	50	57	/	/	P	P
6	F	53	8	60	60	67	/	/	P	P
7	F	24	5	74	60	60	N	/	P	N post BPPV
8	F	55	9	26	75	81	/	/	P	P
9	F	47	5	32	85	82	/	/	P	P
10	M	57	8	20	70	71	N	N	P	P
11	M	65	3	72	120	120	/	/	P	P
12	M	50	3	24	75	74	/	/	P	P
13	F	41	3	76	70	71	/	/	P	P
14	M	55	7	35	75	85	N	N	P	P
15	F	44	4	29	82	80	/	/	P	P

Dizziness Handicap Inventory (DHI) maximum score is 100. Total DHI scores inferior to 34 are considered normal or mild handicap.
Pure Tone Audiometry (PTA) mean values are expressed in dB.
N: normal; P: pathological.

4. Discussion

Selective vestibular neurectomy is considered an excellent surgical procedure in controlling recurrent acute episodes of vertigo [3,5,11–14].

Nevertheless, according to previous studies, some of the patients who underwent VN, obtaining the resolution of vertigo, still claimed sometimes few annoying symptoms: among these, unsteadiness, above all after high velocity head movements towards the operated side, and difficulty in walking in the darkness were the most frequently reported symptoms in almost all patients [4].

Since persisting unsteadiness because of incomplete vestibular compensation after a successfully vestibular nerve section could impair daily activities, in the present study we decided to evaluate the quality of life in a group of MD patients in which acute crisis of vertigo disappeared despite of a possible persistence of disability as a result of light unsteadiness.

The DHI is a questionnaire, translated and validated for the Italian language, which allows to evaluate functional, emotional and physical limitations of everyday life in subjects affected by vertigo [19]. A previously published paper demonstrated greater values in DHI score, and therefore a general improvement of the symptomatology, after labyrinthectomy related to VN, because of a larger amount of recurrences after this procedure; in particularly, the authors observed an enhancement of the DHI score in the emotional subscale [10].

The present results pointed out normal values of the DHI score in 74% of patients, demonstrating how, in absence of any acute episodes of vertigo, the own quality of life after VN is generally considered adequate, even in presence of an annoying slight and chronic unsteadiness. It was decided to not compare pre and post VN results because of the symptomatology, which is completely different considering pre-surgical problems are due to recurrent acute crisis of vertigo interspersed with periods of wellness, whereas after VN the only symptom reported from patients could be a slight instability.

The correlation between the results of the DHI score and the duration of follow-up demonstrates that probably the vestibular compensation may still keep improving for many years after VN. Conversely, the absence of a statistical correlation between quality of life and age at surgery could be explained by the relatively young age of all our patients; it is our habit, indeed, to discourage this kind of surgical operation in MD patients after 65 years old because vestibular compensation could be less effective and unsteadiness may be more relevant or even irreversible.

The second aim of the present study was to evaluate the outcome of vestibular assessments following a selective vestibular nerve section, through which is it possible to get the resolution of acute crisis of vertigo. This condition may be considered as probative of the complete and effective nerve section at the cerebellopontine angle.

Our results demonstrated that both caloric test and VHIT better described the loss of vestibular function after surgery, since through these tests a vestibular deficit has been shown in all 15 cases whereas cVEMPs and oVEMPs failed to reveal the same deficiency in 4 (27%) and in 2 cases (13%) respectively. Therefore, sensibility of the tests carried out in describing the vestibular loss of function resulted respectively 100% for caloric test and VHIT [24], 73% for oVEMPs and 47% for cVEMPs.

On the other hand VHIT results never showed a complete loss of the vestibular function after VN as well as the caloric test revealed it only in four cases (27%), while instead VEMPs resulted always absent when pathological. Consequently vestibular evoked myogenic potentials seem to be less sensitive but much more specific and indicative of a complete loss of vestibular function, whereas caloric test and VHIT resulted more sensitive although their outcome is not related to the extent of such deficit.

The results of such instrumental evaluations, as like as the long-term recurrent vertiginous episodes after retrosigmoid VN quoted in literature [10–15] and the BPPV episode experienced by a patient enrolled in the present study, allow us to speculate about the possible regenerative abilities of the VIII cranial nerve or to the presence of vestibulocochlear anastomosis.

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To the best of our knowledge, very few reports in literature discuss about the regeneration of the auditory nerve in humans, whereas there are some works about the VIII cranial nerve of the frog which is capable instead of regenerating and normally functioning after both preganglionic and postganglionic axotomy [25,26]. In humans, after transection of the eighth nerve in the inner meatus, 95% of the cochlear neurons along with practically all efferent fibres degenerate and only a moderate proliferation in the peripheral branches of the remaining afferent neurons can be demonstrated near the habenula perforata in the organ of Corti [27]. Furthermore Scheller et al. reported a series of 112 patients who had undergone vestibular schwannoma surgery via retrosigmoid approach revealing no differences between the cochlear nerve function in the early postoperative course and 1 year after surgery, pointing to a lack of regenerative potential of the cochlear nerve [28].

Therefore, since regeneration of auditory fibres in humans is unlikely the explanation of the occasional persistence of vertigo after vestibular neurectomy, such occurrence in some patients may be the consequence of the presence of connections between vestibular and cochlear nerve bundles [29,30].

Von Oort initially described the vestibulocochlear anastomosis in 1918 [31] as 2–3 mm long nerve fibres running from the saccular branch of the inferior vestibular nerve to the cochlear nerve, containing efferent fibres from the medial olivocochlear system [32,33]. The evidence that a vestibular nerve section could ablates the efferent influence upon the cochlear function, and therefore the related anastomosis, was confirmed by Giraud who evaluated the effects of contralateral acoustic stimulations on evoked otoacoustic emissions (OAE). Results in 10 patients who had undergone vestibular neurectomy demonstrated indeed that the inhibitory effect of contralateral noise on OAE amplitude was absent from the cochlea with severed efferent fibres [34]. As mentioned before, aware of the probable presence of such anastomosis and in order to avoid any possible reinnervation, we decided to always perform the removal of a little portion of vestibular nerve during surgery; nevertheless we observed in one patient the persistence of positional vertigo, probably due to the thin vestibulocochlear cleavage plane in regions named “ovelapping zones” [35] which allow Oort’s anastomosis to still conduct impulses and therefore elicit cVEMPs although a proper nerve section.

The explanation of a value of VOR, in the operated side, above the normal range in the patient n. 7 could furthermore be ascribed to other contamination reflexes induced by the neck rotation or different visual inputs. Studies by Black et al. [36] and Della Santina et al. [37] suggest that patients suffering from unilateral vestibular deafferentation have higher VOR gain during active head movements (those that are self-generated) than during passive ones (those induced manually). Moreover this central pre-programming, evoked by neck proprioceptive afferents which are predicted and possibly cancelled in the active condition, results to be visually dependent since these effects are only induced in the light and not in the darkness condition [38]. In consideration of the above, although we always accurately performed VHIT with unpredictable head impulses, we can not therefore exclude the ability of a young woman (subject n. 7 was the youngest patient of the study group — namely 24 years old) to behave in a different manner as compared to the other older patients, probably due to a better activation of muscle proprioreceptors, the light condition of the test and the presumed existence of vestibulocochlear anastomosis.

Concerning the detection of a slight spontaneous Ny only in two patients after surgery, we believe that such unexpected result could be ascribed to the occurrence of an incomplete vestibular compensation: both subjects indeed had the shortest follow-up of the study since they had been submitted to VN only 3 years before the present evaluation. In this regard Fisch reported that in humans, after vestibular neurectomies, Ny was maximal in the first post-operative week but decreased rapidly thereafter, being only 3 deg/s for the next three years [39].

Finally, the results of the audiometric tests demonstrated a not statistically significant increasing in PTA average thresholds after performing VN, proving, according to other authors [3,5,11], the safety of such kind of surgery regarding the hearing function preservation.

5. Conclusions

In conclusion our data regarding vestibular function demonstrated that selective unilateral VN has achieved the goal of obtaining a complete anatomical vestibular nerve section in all those patients, submitted to surgery, who got the resolution of vertigo besides the sparing of auditory function. Solely in one case we observed the manifestation of an episode of BPPV after VN: this rare occurrence, despite the confirmation of a correct and selective surgery, could be only justified by the persisting functionality of the inferior vestibular nerve, demonstrating the likely presence of neural anastomosis between the cochlear nerve and the inferior vestibular nerve which allow to still perceive vestibular symptomatology [14,40].

Acknowledgement

Not applicable.

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Please cite this article in press as: Canale A, et al. Comparison of VEMPS, VHIT and caloric test outcomes after vestibular neurectomy in Menière's disease. Auris Nasus Larynx (2018), https://doi.org/10.1016/j.anl.2018.04.006