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OTOLOGY

Evaluation of vestibular function following endolymphatic sac surgery

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Abstract

Purpose To evaluate objective vestibular function after endolymphatic sac surgery (ELSS) for Menière's disease (MD), using comparative vestibular function tests: videonystagmography (VNG), vestibular evoked myogenic potentials (VEMP) and video head-impulse test (VHIT)

Methods Patients with definite MD using the American Academy of Otolaryngology—Head and Neck Surgery (AAO-HNS) of 1995 criteria modified in 2015 and treated with ELSS (sac decompression or sac opening) were included. The primary outcome was the preservation of vestibular function, comparing pre- and postoperative vestibular function tests: VNG, VEMP, VHIT. Secondary outcomes were control of episodes of vertigo, hearing outcome using AAO-HNS criteria, and QoL using the Menière's disease outcome questionnaire.

Results 73 patients were included in the study. We found a significant preservation of vestibular function as measured by VNG and VHIT. There was no statistical difference in the presence or absence of cervical and ocular (P13/N23 and N1/P1) waves on VEMP pre- and postoperatively. 67% of patients had good control of episodes of vertigo post-operatively, with significantly better results in the sac opening group (75%). There was no significant change in hearing postoperatively, and QoL scores were significantly improved after surgery ($p < 0.0001$).

Conclusion Endolymphatic sac surgery (ELSS) is a conservative surgical treatment, which does not negatively impact vestibular function. It was associated with improved control of episodes of vertigo, preservation of hearing, and a clear improvement in QoL scores. Despite its pathophysiology not being fully understood, it remains a first-line procedure preserving vestibular function, for MD refractory to medical management.

Keywords Menière's disease · Vertigo · Endolymphatic sac surgery · Vestibular function tests · Caloric test · Vestibular evoked myogenic potentials

Objective

Endolymphatic sac surgery (ELSS) is recognized as third-line treatment for Menière's disease (MD) for patients who do not respond to medical treatment [1]. The rationale for ELSS is based on the pathophysiology of MD relating to endolymphatic hydrops.

The effects of this surgery have long been criticized after two Danish comparative studies were published [2, 3]. More recently, a Cochrane meta-analysis and an International Consensus (ICON) have given a grade B recommendation in favor of ELSS. They concluded that it should be considered as the next option after failure of conservative medical treatment, especially if hearing is preserved [1, 4]. In contrast to chemical labyrinthectomy and vestibular neurotomy, ELSS is considered a conservative surgical treatment.

The main objective of this study was to demonstrate the non-destructive nature of ELSS on vestibular function, using objective vestibular function tests: videonystagmography (VNG), vestibular evoked myogenic potentials (VEMP) and video head impulse test (VHIT). Secondary outcomes were episodes of vertigo, auditory outcome and quality of life (QoL) using the Menière's disease outcome questionnaire (MDOQ) [5].

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Materials and methods

Cases from a tertiary referral center were retrospectively reviewed.

Inclusion criteria were as follows:

- patients with a definite MD, according to guidelines from the American Academy of Otolaryngology—Head & Neck Surgery (AAO-HNS) of 1995, modified in 2015 [6–8
- debilitating vertigo spells despite medical treatment,
- treated with ELSS using two techniques: "sac decompression" or "sac opening with mastoid shunt" [9].

Exclusion criteria were as follows:

- lost to follow-up (follow-up of less than 2 months after surgery),
- lack of patient consent.

This study was approved by the local ethics committee (GNEDS).

Patients' characteristics and symptoms were evaluated. We reviewed radiological investigations and previous medical treatments. We also reviewed any prior conservative treatments such as grommet insertion, intratympanic injection of steroids (ITS).

Vestibular function was assessed before and after surgery using vestibular function tests: VNG, VEMP, VHIT.

In VNG, caloric testing was performed, and several measures were evaluated: canal paresis (negative if paresis on the operated side, positive if on the contralateral side), vestibular excitability and directional preponderance.

Cervical and ocular VEMP (cVEMP and oVEMP) were performed. Presence or absence of P13/N23 waves for cVEMP was recorded, as well as their latency, amplitude, and asymmetry ratio (AR) with the following formula:

(peak to peak amplitude of P13/N23 of the operated side – non-operated side),
(peak to peak amplitude of P13/N23 of the operated side + non-operated side).

The same measurements were calculated for oVEMP with N1/P1.

VHIT gain was measured on the superior, lateral and posterior semi-circular canals.

Our hypothesis was that there would be no deterioration in vestibular function postoperatively. Consequently, a non-inferiority study was performed and non-inferiority margins had to be determined (delta).

The non-inferiority margins were chosen based on clinical judgment using normal standard values and pathological limits [10, 11]. The margins were as follows:

- VNG canal paresis: − 20%
- VNG vestibular excitability: − 10°/s
- VNG directional preponderance: + 2°/s
- VEMP latency: + 2 ms
- VEMP amplitude: − 50 µV (saccular)/− 5 µV (utricular)
- VEMP asymmetry ratio: + 35%
- VHIT gain: − 0.25

Secondary outcomes were control of episodes of vertigo, auditory outcome (both using AAO-HNS guidelines) and QoL after surgery.

To assess episodes of vertigo we calculated $VN = (X/Y)/100$ (X = average number of episodes of vertigo per month evaluated 18–24 months after surgery, and Y = average number of defined episodes of vertigo per month during the 6 months before surgery). There were six levels of vertigo control ranging from A; complete resolution of episodes of vertigo, to F; intractable episodes of vertigo requiring further operative treatment.

The worst audiograms obtained before and after surgery were evaluated using pure tone average (PTA) defined as the mean of hearing thresholds at 500, 1000, 2000, 3000 Hz. The patient's hearing was then classified: stage 1 (PTA < 26 dB), stage 2 (PTA 26–40 dB), stage 3 (PTA 41–70 dB) or stage 4 (PTA > 70 dB). Hearing was considered to have deteriorated if PTA decreased by a minimum of 10 dB.

QoL was assessed postoperatively using the Retrospective-MDOQ questionnaire (Table 1). It uses 19 paired multiple-choice questions assessing pre and postoperative health, each with values ranging from 0 (poorest QoL) to 4 [5, 12].

The procedures were performed by a single experienced surgeon, using either the technique of simple sac decompression or by opening the endolymphatic sac. The technique was chosen by the surgeon based on preoperative audiometry. The main steps of ELSS included canal wall-up mastoidectomy with identification of the sigmoid sinus and 3rd portion of the facial nerve, thinning of the bone covering the dura mater of the posterior fossa between the posterior semicircular canal and the sigmoid sinus, finishing with deep infralabyrinthine drilling to expose the body of the endolymphatic sac and the endolymphatic duct [13]. Endolymphatic sac opening could be performed with rigid ear endoscope.

In terms of data analysis, a two-tailed Student's t test was used to compare means of the primary and secondary outcomes. McNemar's Chi-square test was used to compare paired nominal data. A p value ≤ 0.05 was assigned for significance.

Table 1 Retrospective-Menière's disease outcome questionnaire from Kato et al. [5]

Meniere's Disease Outcomes Questionnaire – Retrospective (MDOQ-R)

1. Overall, how much did your Meniere's Disease affect your life before your surgery?
0. Completely 1. Quite a lot 2. Moderately 3. Just a little 4. Not at all

2. After your surgery, how much does your Meniere's Disease affect your life, overall?
0. Completely 1. Quite a lot 2. Moderately 3. Just a little 4. Not at all

3. Before your ear surgery, how much did your Meniere's Disease prevent you from traveling, either for recreational or business purposes? (i.e. going on trips, taking vacation, going to the movies, etc.)
0. Always 1. Quite a lot 2. Moderately 3. Just a little 4. Never

4. After your ear surgery, how much does your Meniere's Disease prevent you from traveling, either for recreational or business purposes? (i.e. going on trips, going on vacation, going to the movies, etc.)
0. Always 1. Quite a lot 2. Moderately 3. Just a little 4. Never

5. Before your ear surgery, how much were you bothered by a loss of hearing?
0. Completely 1. Quite a lot 2. Moderately 3. Just a little 4. Not at all

6. After your ear surgery, how much are you bothered by a loss of hearing?
0. Completely 1. Quite a lot 2. Moderately 3. Just a little 4. Not at all

7. Before your ear surgery, how often were you either at the doctors office or on the phone with the doctors office?
0. Far too often 1. More than most 2. Routine visits
3. Hardly ever 4. Never

8. After your ear surgery, how often are you either at the doctors office or on the phone with the doctors office?
0. Far too often 1. More than most 2. Routine visits
3. Hardly ever 4. Never

9. Before my ear surgery, I felt that my self-confidence was:
0. Terrible 1. Poor 2.Average 3. Above average 4.Great

10. After my ear surgery, I feel that my self-confidence is:
0. Terrible 1. Poor 2.Average 3. Above average 4.Great

11. Before my ear surgery, my physical health was:
0. Terrible 1. Poor 2. Average 3. Good 4. Ideal

12. After my ear surgery, my physical health is:
0. Terrible 1. Poor 2. Average 3. Good 4. Ideal

13. Before your surgery, how much trouble did you have doing day-to-day tasks (bathing, doing household chores, etc.)?
0. Maximal 1. A lot 2. Some 3.A little 4. None

14. After your surgery, how much trouble do you have doing day-to-day tasks?
0. Maximal 1. A lot 2. Some 3.A little 4. None

15. Before your surgery, did you have spinning episodes (vertigo)? If so, how disabling were they?
0. Yes, totally incapacitating 1. Yes, they interfered with my life
2. Yes, but I could manage 3. Yes, but they hardly affected me
4. No, never

16. After your surgery, do you have spinning episodes (vertigo)?
0. Yes, totally incapacitating 1. Yes, they interfered with my life
2. Yes, but I could manage 3. Yes, but they hardly affected me
4. No, never

17. Before your surgery, did you have bothersome noise or tinnitus in the ear?
0. Yes, it drove me crazy 1. Often 2. Sometimes
3. Rarely 4. No, never

18. After your surgery, do you have bothersome noise or tinnitus in the ear?
0. Yes, it drove me crazy 1. Often 2. Sometimes
3. Rarely 4. No, never

19. Before your surgery, did you have a problem remembering things?
0. All the time 1. Often 2. Sometimes 3. Rarely 4. Never

20. After your surgery, do you a problem remembering things?
0. All the time 1. Often 2. Sometimes 3. Rarely 4. Never

21. Before your surgery, did you have difficulty walking in a straight line?
0. All the time 1. Often 2. Sometimes 3. Rarely 4. Never

22. After your surgery, do you have difficulty walking in a straight line?
0. All the time 1. Often 2. Sometimes 3. Rarely 4. Never

23. Before your surgery, did you have a problem with your concentration? (e.g. reading, working on a computer, etc.)
0. All the time 1. Often 2. Sometimes 3. Rarely 4. Never

24. After your surgery, do you have a problem with your concentration? (e.g. reading, working on a computer, etc.)
0. All the time 1. Often 2. Sometimes 3. Rarely 4. Never

25. Before your surgery, did you feel depressed?
0. All the time 1. Often 2. Sometimes 3. Rarely 4. Never

26. After your surgery, do you feel depressed?
0. All the time 1. Often 2. Sometimes 3. Rarely 4. Never

27. Before your surgery, how much unsteadiness (imbalance) did you have in-between Meniere s attacks?
0. Extremely poor balance 1. Quite a lot 2. A moderate amount
3. A little bit 4. None

28. After your surgery, how much unsteadiness (imbalance) do you have in-between Meniere s attacks?
0. Extremely poor balance 1. Quite a lot 2. A moderate amount
3. A little bit 4. None

29. Before your surgery, how often were your activities (shopping, socializing, going to restaurants, exercising, etc.) impaired?
0. I could not do anything 1. More often than not
2. A moderate amount 3. A little bit 4. Never

30. After your surgery, how often are your activities (shopping, socializing, going to restaurants, exercising, etc.) impaired?
0. I could not do anything 1. More often than not
2. A moderate amount 3. A little bit 4. Never

31. Before your surgery, how much unsteadiness did you have when you were having a Meniere's attack?
0. Extremely poor balance 1. Quite a lot 2. A moderate amount
3. A little bit 4. None

32. After your surgery, how much unsteadiness do you have when you are having a Meniere's attack?
0. Extremely poor balance 1. Quite a lot 2. A moderate amount
3. A little bit 4. None/I don't have attacks.

33. Before your surgery, did your Meniere's Disease affect your work (job performance, sick days, time off, job termination, etc.)?
0. I was fired or had to quit 1. Often 2. Occasionally
3. Rarely 4. Never, or I do not work

34. After your surgery, does your Meniere's Disease affect your work?
0. I was fired or had to quit 1. Often 2. Occasionally
3. Rarely 4. Never, or I do not work

35. Before your surgery, approximately how often would you have a Meniere's attack?
0. Daily 1. Weekly 2. Monthly 3. Rarely 4. Never

36. After your surgery, approximately how often do you have a Meniere's attack?
0. Daily 1. Weekly 2. Monthly 3. Rarely 4. Never

37. Before your surgery, how severe were your worst Meniere's attacks?
0. Totally incapacitating 1. Severe 2. Bothersome
3. Not bad 4. Barely noticeable/no attacks

38. After your surgery, how severe are your worst Meniere's attacks?
0. Totally incapacitating 1. Severe 2. Bothersome
3. Not bad 4. Barely noticeable/no attacks

39. (OPTIONAL) You may use the space that follows to describe (in words, drawing, photograph, etc.) how you felt about your Meniere's Disease before surgery:

40. (OPTIONAL) You may use the space that follows to describe how you feel about your Meniere's Disease after having had surgery.

Results

We analysed a total of 73 patients between 2011 and 2018; 39 males (53%) and 34 females (47%), with a mean age of 54 ± 12.6 years. Apart from episodes of vertigo, the main presenting symptoms were hearing loss (79%) and tinnitus (67%). The mean duration of disease before surgery was 6.8 ± 4.76 years. Most patients had a CT scan (52%) and an MRI (82%) performed before the operation.

A 3-T MRI (with IV Gadolinium and late FLAIR sequence at + 4 h) was performed in 19 patients with signs of endolymphatic hydrops seen in 58%.

All patients had failed long-term medical treatment, defined by persistent debilitating vertigo spells. 21% had a history of grommet insertion and 8% received ITS before surgery.

Two types of surgical procedures were performed: sac decompression in 30% and opening of the sac in 70%. The mean operative time was 90.5 ± 29 min, with no statistical difference between the two procedures ($p = 0.92$). The surgeon used endoscopy in 85% of the cases. There were no postoperative complications (i.e. facial paralysis, cerebrospinal fluid leak or meningitis).

The mean follow-up time was 20.5 months.

Primary outcome

Descriptive results of pre- and postoperative vestibular function tests are shown in Table 2.

25 VNG were compared. Results of the non-inferiority statistical analysis are shown in Fig. 1. Canal paresis was reduced to an average of − 3.65 (CI 90% − 15.95 to 8.65). There was no statistically significant change in canal paresis (CP) as the lower end of the confidence interval was superior to the non-inferiority margin (− 20%). Vestibular excitability (VE) was raised in an average of + 7.57°/s (CI 90%; 0.52–14.61) and directional preponderance (DP) was reduced in an average of − 1.47°/s (CI 90%; − 3.01 to 0.01). There was no statistically significant change in VE or DP as the lower and the upper ends of the confidence interval were superior and inferior to the delta, respectively.

16 cervical and ocular VEMP were analysed. Results of the non-inferiority statistical analysis are shown in Fig. 2a (cVEMP) and 2b (oVEMP).

There was no statistical difference in the presence or absence of P13/N23 waves pre- and postoperatively ($p = 0.71$).

Mean variations for cervical VEMP were.

- P13 latency: + 4.10 ms (CI 90% − 0.79 to 8.99),
- N23 latency: + 4.82 ms (CI 90% − 1.62 to 11.25),
- P13N23 amplitude: − 40.78 μV (CI 90% − 87.78 to 6.23),
- Asymmetry ratio: + 0.056 (CI 90% − 0.312 to 0.424).

Deltas were included in the confidence interval for the above values; thus, we could not determine non-inferiority for changes in latencies, amplitude and AR.

For oVEMP, there was no statistical difference in the presence or absence of N1/P1 waves pre- and postoperatively ($p = 0.18$).

Mean variations for ocular VEMP were.

- N1 latency: + 1.32 ms (CI 90% − 4.26 to 6.90),
- P1 latency: + 1.28 ms (CI 90% − 6.47 to 9.03),
- N1P1 amplitude: − 3.27 μV (CI 90% − 13.05 to 6.51),
- Asymmetry ratio: + 0.22 (CI 90% − 0.35 to 0.79).

Deltas were included in the confidence interval for the above values; thus, we could not determine non-inferiority for changes in latencies, amplitude and AR.

7 VHIT were compared. Results of the non-inferiority statistical analysis are shown in Fig. 3. Mean variations of VHIT gain were.

- Superior canal: + 0.12 (CI 90% − 0.18 to 0.42),
- Posterior canal: + 0.14 (CI 90% − 0.23 to 0.51),
- Lateral canal: + 0.043 (CI 90% − 0.005 to 0.090).

Table 2 Pre- and postoperative values of vestibular function tests

	Preoperative	Postoperative
VNG		
Canal paresis	− 18% ± 26	− 21% ± 42
Vestibular excitability	16°/s ± 10	23°/s ± 23
Directional preponderance	2.9°/s ± 4.6	0.99°/s ± 2.2
cVEMP		
Positivity of P13/N23 peaks	65%	65%
P13 peak latency	11 ms ± 5.4	14 ms ± 5.1
N23 peak latency	18 ms ± 8.7	20 ms ± 7.4
P13/N23 amplitude	59 μV ± 65	20 μV ± 20
Interaural asymmetry ratio	0.24 ± 0.23	0.26 ± 0.19
oVEMP		
Positivity of N1/P1 peaks	65%	60%
N1 peak latency	8.7 ms ± 3.8	10 ms ± 4.4
P1 peak latency	13 ms ± 5.2	14 ms ± 5.6
N1/P1 amplitude	3.5 μV ± 4.5	0.91 μV ± 0.63
Interaural asymmetry ratio	0.19 ± 0.18	0.23 ± 0.19
VHIT		
VOR gain—anterior canal	0.9 ± 0.2	0.9 ± 0.3
VOR gain—posterior canal	0.8 ± 0.2	0.7 ± 0.4
VOR gain—lateral canal	1 ± 0.09	0.9 ± 0.02

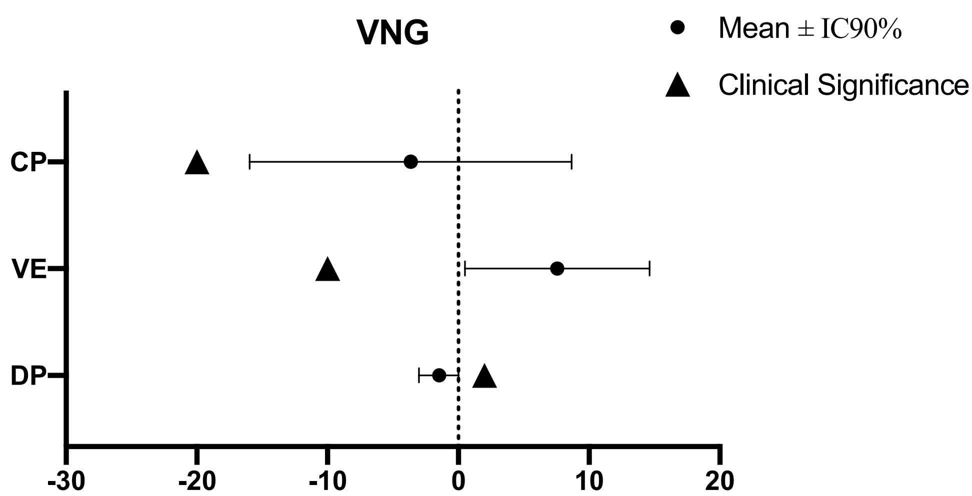

Fig. 1 Non-inferiority testing of VNG pre-/postoperatively. There was no statistically significant change in canal paresis (CP),vestibular excitability (VE) or directional preponderance (DP) as the Delta (non-inferiority margin) was not included in the confidence interval

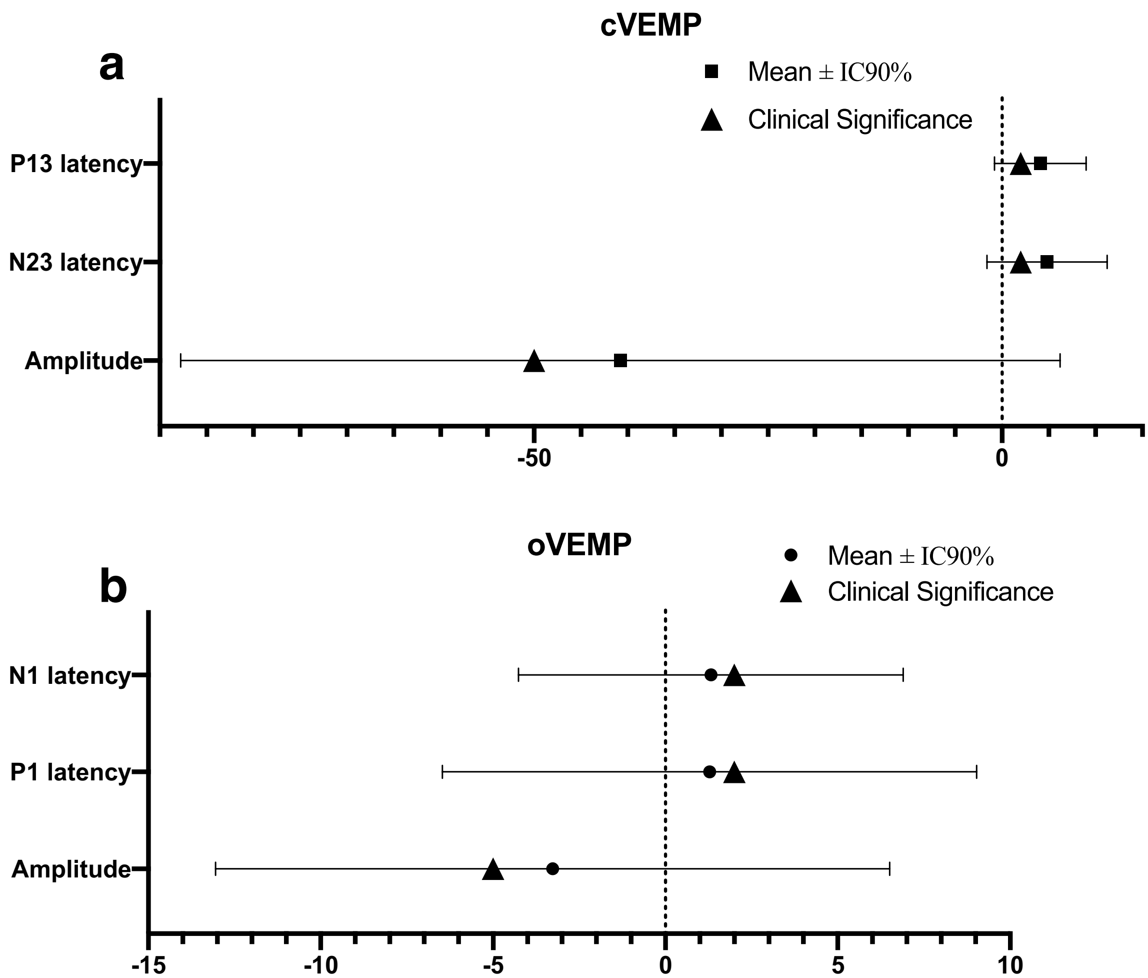

Fig. 2 **a** Non-inferiority testing of pre/postoperative cVEMP and **b** Non-inferiority testing of pre/postoperative oVEMP. Deltas were included in the confidence interval for the above values, thus we could not determine non-inferiority for changes in latencies, amplitude and asymmetry ratio

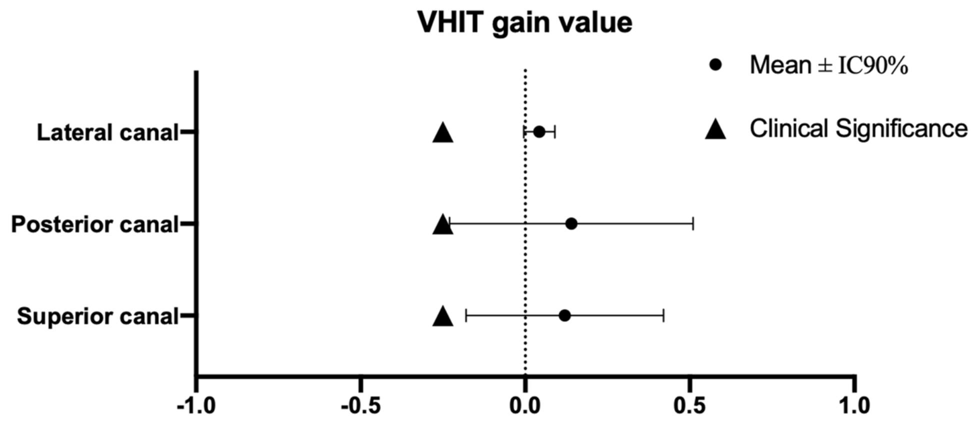

Fig. 3 Non-inferiority testing of VHIT gain. Non-inferiority was demonstrated for VHIT gain as all lower ends of the confidence intervals were higher than the delta

Non-inferiority was demonstrated for VHIT gain as all lower ends of the confidence intervals were higher than the delta.

Secondary outcomes

ELSS was associated with a reduction in the number of episodes of vertigo in 67% of the patients (51% and 16% in class A and class B, respectively). 13 patients required further surgical treatment due to persistent episodes of vertigo (class F 18%).

Improvement in vertigo was significantly better when sac opening was performed (75% of class A and B combined) compared with 50% in the simple decompression group (odds ratio 3.16; $p=0.04$).

A non-statistically significant decrease in postoperative mean PTA was noted, on average −4 dB ± 18 (−0.2 to 8.4) ($p=0.06$).

Preoperative PTA was higher in the sac decompression group 30 dB ± 19 (5–61), versus 56 dB ± 14 (19–78) in the sac opening group. Postoperative decrease in PTA was higher in the sac opening group (−6 dB ± 23.4) versus (−2.29 dB ± 6.09) in the decompression group but this difference was not statistically significant ($p=0.62$).

We collected 38 MDOQ QoL questionnaires (52% response rate), with an average time between surgery and evaluation of 56 months ± 28. Mean response to MDOQ was 22 ± 9.9 (7–56) preoperatively. Mean postoperative response was 43 ± 16 (11–69).

There was a statistically significant improvement in QoL after surgery ($p<0.0001$), with a mean improvement of + 21 ± 15 (−6 to 57).

Discussion

ELSS was first described by Portmann in 1927 [13] and has since been widely used for intractable Menière's disease. Despite experimental and animal studies, the role of the endolymphatic sac in hydrops remains unclear. Numerous hypotheses have been proposed including accumulation of osmotically active proteins in the sac, insufficient reabsorption of endolymphatic fluid [14, 15].

Population

The population of our study was largely representative of the MD population found in the literature [16], with a similar proportion of male and female, and most patients in their 5th or 6th decades. Not many patients previously underwent ITS, as this procedure was not performed routinely in the center at the time of this study. It is now recommended by the ICON consensus as the second line in case of failure of medical treatment [1]. This was not felt to compromise the result as several studies show that ITS only offers short-term benefit [17, 18].

Controversy on ELSS

ELSS has been criticized since the publication of two Danish studies in 1981 and 1998 which contested the effectiveness of the procedure. Thomsen et al. conducted a prospective study comparing a group of patients who underwent ELSS with another group who underwent simple mastoidectomy [2]. Functional results were compared, and the authors did not find any statistical differences between the two groups and consequently referred to ELSS as "placebo surgery". This study has been heavily criticised from an ethical perspective by several other authors, not only for controversially performing an alleged "placebo surgery" on patients for the purpose of the study, but also from a methodological point of view. In that regard, Welling et al. reanalyzed Thomsen's results and found a statistically significant improvement in episodes of vertigo and tinnitus in the group ELSS vs the mastoidectomy group [19].

Thomsen et al. published another comparative study in 1998, this time comparing ELSS with grommet insertion [3]. There was an improvement in episodes of vertigo in both groups with no statistical difference. Several biases in this study were outlined in a Cochrane analysis [4]; there was no description of the randomization protocol, there were no precise numerical results, follow-up was less than a year, double-blinding was not possible.

A more recent meta-analysis by Lim et al. in 2015 found 8 studies with level 3 evidence showing short- and long-term efficacy in terms of vertigo control for more than 80% who underwent ELSS. None of these studies included an analysis of vestibular function.

Primary outcome

Previous studies had demonstrated the beneficial effect of surgery on endolymphatic hydrops measured by electrocochleography, but did not include other vestibular function tests [20, 21].

Our study demonstrates the conservation of vestibular function as measured by the caloric test of VNG. Therefore, we demonstrate that functional improvement associated with ELSS is not related to the destruction of the vestibular apparatus, in contrast to other non-conservative interventions such as chemical labyrinthectomy (CL) or vestibular neurotomy (VN). Vestibular excitability on the operated side seemed to increase postoperatively which can be a sign of a better vestibular function.

This result supports the use of ELSS especially in patients with bilateral disease, as the preservation of vestibular function could be useful to avoid postural instability after surgery. ELSS could also be considered in the elderly, who may be more prone to vestibular instability related to presbyvestibulia, where a destructive procedure could have negative consequences in terms of postural stability [22]. In comparison, the residual instability rate is reported to be as high as 30% following VN [23].

Regarding VEMP, there was no significant change in the presence or absence of P13/N23 or N1/P1 waves. Conversely, we did not succeed in demonstrating non-inferiority for other VEMP criteria. This result could be explained by a lack of power due to the relatively small sample size for VEMP. Also, we intentionally chose small non-inferiority margins to obtain a clinically significant result for the primary outcome. A great variability in normal VEMP norms is found in the literature which can also explain that our predetermined delta was included in the confidence interval.

VEMP abnormalities in MD are quite inconsistent as VEMP variations are found in 30–69% of patients in the majority of studies [16].

There was in our study no significant deterioration of VHIT gain. This result was predictable. Gain changes are rarely seen in MD [24, 25]. In a study by Jerin et al., VHIT gains were always normal in MD and not correlated with canal paresis on caloric response or with VEMP asymmetry ratio [24]. We demonstrated that ELSS did not alter the high-frequency vestibulo-ocular reflex.

Secondary outcomes

Reduction in episodes of vertigo in our study was approximately 70%, which is close to the rate reported in similar studies [26, 27]. We found that the sac opening technique was associated with a higher rate of improvement in control of vertigo. This result is not found in other studies that demonstrated no particular advantage in using one technique over another. The rate of improvement in episodes of vertigo is usually greater than 90% for VN and between 85 and 90% for CL [28, 29]. These success rates are slightly better than the one in ours (75% for the sac opening technique). However, the adverse effects and potential complications of such destructive procedures should be taken into consideration. For example, VN is associated with a significant rate of postoperative complications. In their study of 58 patients treated with VN, Schmerber et al. described complications including infection or delayed healing (12%), CSF leak (7%), and also a risk of meningitis and other neurological complications [30]. There were no such adverse effects or postoperative complications reported in our ELSS patient cohort.

Regarding hearing outcomes, rates of preservation of hearing function (improved or deteriorated by no more than 10 dB) are usually around 70% [31]. A similar rate was found in our study, with a non-statistically significant decrease in PTA of −4 dB. Hearing decreased slightly more in the sac opening group, but that difference was not statistically significant. This finding is consistent with most studies [31]. This trend probably influenced the surgeon as he generally chose a simple decompression in the group of patients with a normal preoperative PTA. In comparison, the hearing preservation rate is usually approximately 85% with VN [32]. With CL, hearing deteriorates in as many as 25 to 45% of patients, with great variability depending on the treatment protocol used [33]. In summary, ELSS is associated with a high rate of hearing preservation.

The QoL questionnaire we used was presented by Kato et al. to assess the impact of ELSS on the physical, emotional and social aspects of health [5]. Convert et al. used the same questionnaire to evaluate ELSS, demonstrating an 81.4% increase in the QoL score with a mean follow-up time of 57 months [12]. We found very similar results with an 87% improvement in QoL scores after surgery, with a mean follow-up of 56 months. Compared with other interventions, a meta-analysis by Ballard et al. reported a mean improvement of + 25 to + 42 points in the MDOQ score for ELSS [34]. With CL, the improvement was on average between + 7 and + 33. There were no studies using the MDOQ score to evaluate VN. The more heterogenous results in QoL in CL could be related to residual postural instability which is often described as a complication of this destructive method. This highlights the advantage of using conservative techniques such as ELSS whenever possible [23].

Future scope for research

The pathophysiology of ELSS and its relationship to symptom improvement still have to be clarified. Although they had a small number of patients, Liu et al. demonstrated that endolymphatic fluid volume measured on 3 T MRI had decreased after ELSS.

A better understanding of the role of the endolymphatic sac is needed. Some authors recently described a new technique of endolymphatic duct blockage, showing promising results [35]. The hypothesis is that the sac plays a role in both endolymphatic fluid absorption and secretion and that hydrops actually occurs due to excess secretion within the sac. As such, blocking the duct would help limit the accumulation of fluid. These results do not contradict the techniques described in our study as many hypotheses have been formulated to explain the effect of surgery on the endolymphatic sac: altering osmotic pressures, altering blood supply, and modifying immune factors [36].

Although ethical issues would need to be addressed, further studies are needed including a controlled comparative group.

Conclusion

We have demonstrated preservation of vestibular function with ELSS, as measured with the main vestibular function tests (VNG, VHIT), which had not been demonstrated in previous studies. There was no modification of the presence of P13/N23 or N1/P1 waves postoperatively in cervical and ocular VEMP. This result highlights the main advantage of this conservative technique over destructive procedures, as preserved vestibular function will cause less postural instability and will not impede vestibular rehabilitation.

We have also shown the beneficial effects of the surgery in reducing episodes of vertigo with 70% reporting improved control, and with no significant reduction in hearing. The sac opening technique was associated with a better improvement in vertigo. The vast majority of patients had a significantly improved QoL after surgery.

The pathophysiology of MD and the role of the endolymphatic sac has yet to be clearly established. New imaging techniques including 3-T-FLAIR MRI will be useful in the future to diagnose and quantify endolymphatic hydrops. Despite more widely used techniques like ITS, ELSS remains an effective and low-risk surgical option in the treatment of MD.

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Declarations

Conflict of interest The author declares that they have no competing interest.

Ethics approval This study was approved by the local ethics committee (GNEDS—Groupe Nantais d'Ethique dans le Domaine de la Santé).

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