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Original article

Postoperative compensation after neurotomy in Meniere's disease: Retrospective study of 15 cases

L. Lemnos [a], K. Aubry [b], J.-J. Moreau [a], F. Caire [a], H. Salle [a,*]

[a] Service de neurochirurgie, CHU de Limoges, 87000 Limoges, France
[b] Service d'ORL, CHU de Limoges, 87000 Limoges, France

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ABSTRACT

Introduction. – Vestibular neurotomy is a functional surgery for Meniere's disease in the event of medical treatment failure. The aim of the study was to assess the efficacy and complications of vestibular neurotomy, and to address the question of postoperative compensation.
Material and method. – All patients included in this retrospective study underwent a vestibular neurotomy at our center between 2009 and 2016. A preoperative evaluation was performed including MRI, audiometry, and videonystagmography. The functional level of disability was evaluated by the Dizziness Handicap Inventory (DHI) score. In all patients suboccipital retrosigmoid approach was performed. All patients underwent early postoperative vestibular rehabilitation. One month and two years after surgery, we assessed the effectiveness of treatment on dizziness, disability and imbalance. At the time of this study (2 to 8 years), DHI and patients' satisfaction by patient's global impression of change (PGIC) scale were evaluated.
Results. – Fifteen patients aged between 42 and 74 years of age were included in our study. Postoperative complications occurred in two patients (meningitis and a wound infection). At one month, all patients had a dramatic clinical improvement with decreased vertigo. Two years after surgery, 85% of the patients were cured and had no dizziness or balance disorder. Only one patient experienced bilateralization and only one had a persistent poor compensation.
Conclusion. – Vestibular neurotomy is a very effective treatment in the case of Meniere's disease resistant to medical treatment, with very good functional results and an extremely low failure rate.

1. Introduction

Meniere's disease (MD) is characterized by the occurrence of episodes of vertigo associated with cochlear symptoms: tinnitus, aural fullness and low-frequency sensorineural hearing loss. These sudden onset crises can last from 20 minutes to several hours without exceeding more than 24 hours. In less than 10% of cases, these crises can cause a fall without loss of consciousness called Tamarkin's crisis [1]. The frequency of these attacks differs from one person to the other. Some patients may have several attacks per week. Other patients may have one attack per month. The clinical diagnosis is most often made between 40 and 60 years of age. The symptoms are believed to occur from the development of an endolymphatic hydrops or increased pressure and volume within the endolymphatic space.

The prevalence of MD is approximately 34–190 per 100,000. The age of onset ranges from the third to the seventh decade of life with a slight female predominance [2–4].

A spontaneously favorable evolution is accomplished in 57% of patients in 2 years and in 71% of patients in 8.3 years [5]. In some cases, the disease is characterized by a high frequency episodes of vertigo responsible for repetitive discontinuation of the work, social isolation and loss of autonomy. First-line medical treatment recommends a salt restriction combined with a histamine analogue (betahistine) and diuretics. A psychological support can also be recommended [1].

If medical treatment fails, several therapeutic options are available including intermittent micropressure treatments, intratympanic gentamicin injections and surgical procedures [6].

Vestibular neurotomy is usually preferred in our center. Nevertheless, one of the major issues with vestibular nerve section is postoperative compensation and instability, which can be quite

Abbreviations: MD, Meniere's disease; AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery; ABR, Auditory Brainstem Response; DHI, Dizziness Handicap Inventory; CSF, Cerebro Spinal Fluid; PGIC, Patients' Global Impression of Change.

* Corresponding author.
E-mail address: henrisalle1@gmail.com (H. Salle).

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prolonged in some patients, and this important aspect remains poorly evaluated in the literature. In this short series, our aim was:

- to assess the efficacy and complications of vestibular neurotomy;
- to address the question of postoperative compensation.

2. Material and methods

2.1. Patients' selection

This study was retrospective including all patients with unilateral Meniere's disease (MD) resistant to medical treatment who underwent vestibular neurotomy in a tertiary care center (University Hospital Center of Limoges, France) between 2009 and 2016. All patients were selected by the same neuro-otologist because they experienced incapaciting vertigo, dizziness, or drop attacks that had not responded to other therapies. All the patients enrolled in the study had been diagnosed as intractable MD according to the 1995 American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) criteria. This study was approved by the local ethics committee.

2.2. Preoperative evaluation

The functional level of disability was evaluated by Dizziness Handicap Inventory (DHI) [7] score (Table 1). Dizziness, disability and/or imbalance were evaluated, as well as working ability and presence of severe limitations in terms of daily routine activities.

Vestibular evaluation was performed by the same neuro-otologist, specialized in vestibular disorders, independent of the surgical team. A cochleovestibular examination including tonal and speech audiometry, auditory brainstem response (ABR), bithermal caloric test, glycerol test, videonystagmography and MRI which focused on cerebellopontine angle were performed.

2.3. Surgical procedure

Surgery was performed by a twin team of a neurosurgeon and ENT surgeon. The patient was installed in the supine position under general anesthesia, with the patient's head turned to the opposite side and maintained by a Mayfield headrest. Electrophysiological monitoring of the facial nerve NIM 2 (Medtronic, Min.) was installed. An antibiotic prophylaxis by injection of 2 g first generation cephalosporins (Cefazoline) was administered. A curvilinear retroauricular incision was made after minimal shaving (Fig. 1a). The ENT surgeon performed retrosigmoid approach by suboccipital drilling (Fig. 1b). The dura was opened along the sinus elbow using surgical shears. Then, the microscope and the Yasargil retractor were positioned. The cisterna with mixed nerves was opened to allow relaxation of the cerebellar hemisphere. The acoustico-facial nerve bundle was visualized (Fig. 2a). The cleavage plane between the cochlear nerve and the vestibular nerve was identified by a groove situated between the vestibular verve (in superior position) and the cochlear nerve (in inferior position) (Fig. 2b). The anterior inferior cerebellar artery was identified after the opening of the arachnoid. The vestibular nerve section was performed (Fig. 2c) followed by careful hemostasis. The dura was closed with sutures and patch of scalp glued with biological glue. The muscle fascia was closed by suturing and skin by stapling.

2.4. Postoperative evaluation

One month after surgery, patients underwent a clinical evaluation of dizziness, disability and/or imbalance. A cochleovestibular examination including tonal and speech audiometry was also performed.

Two years after surgery, patients underwent a clinical evaluation of dizziness, disability and/or imbalance. Working ability or the presence of severe limitations in terms of daily routine activities was also assessed.

At the time of this study, all patients underwent a clinical evaluation of dizziness, disability and/or imbalance. DHI score was

Table 1
Dizziness Handicap Inventory.

Questions	Always	Sometimes	No
P1. Does looking up increase your problem?			
E2. Because of your problem, do you feel frustrated?			
F3. Because of your problem, do you restrict your travel for business or recreation?			
P4. Does walking down the aisle of a supermarket increase your problems?			
F5. Because of your problem, do you have difficulty getting into or out of bed?			
F6. Does your problem significantly restrict your participation in social activities, such as going out to dinner, going to the movies, dancing, or going to parties?			
F7. Because of your problem, do you have difficulty reading?			
P8. Does performing more ambitious activities such as sports, dancing, household chores (sweeping or putting dishes away) increase your problems?			
E9. Because of your problem, are you afraid to leave your home without having someone accompany you?			
E10. Because of your problem have you been embarrassed in front of others?			
P11. Do quick movements of your head increase your problem?			
F12. Because of your problem, do you avoid heights?			
P13. Does turning over in bed increase your problem?			
F14. Because of your problem, is it difficult for you to do strenuous homework or yard work?			
E15. Because of your problem, are you afraid people may think you are intoxicated?			
F16. Because of your problem, is it difficult for you to go for a walk by yourself?			
P17. Does walking down a sidewalk increase your problem?			
E18. Because of your problem, is it difficult for you to concentrate?			
F19. Because of your problem, is it difficult for you to walk around your house in the dark?			
E20. Because of your problem, are you afraid to stay home alone?			
E21. Because of your problem, do you feel handicapped?			
E22. Has the problem placed stress on your relationships with members of your family or friends?			
E23. Because of your problem, are you depressed?			
F24. Does your problem interfere with your job or household responsibilities?			
P25. Does bending over increase your problem?			

To each item, the following scores can be assigned: No = 0; Sometimes = 2; Always = 4. Total score: 16–34 points = mild handicap; 36–52 points = moderate handicap; > 54 points = severe handicap.

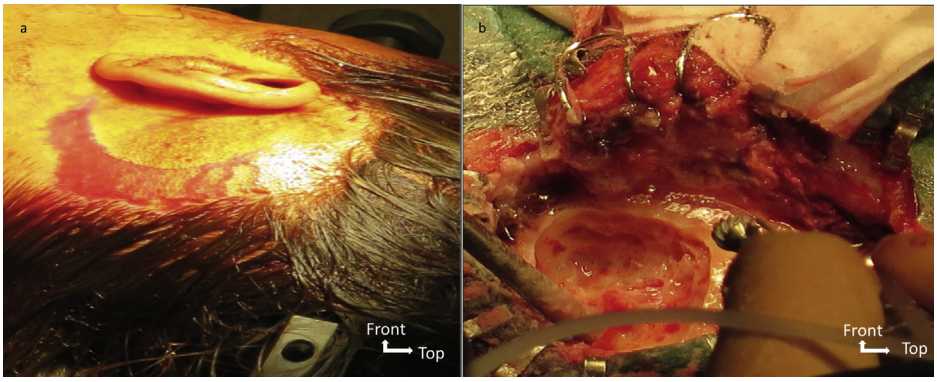

Fig. 1. a: curvilinear retroauricular incision, the patient placed in supine position; b: infraoccipital retrosigmoid approach to the cerebellar pontine angle.

Fig. 2. a: identification of the cochlear-vestibular bundle (arrow), and facial nerve (*) deeper; b: identification of the cochlear and vestibular nerves, separated by a groove located between the vestibular portion in superior position and the cochlear nerve in inferior position; c: complete section of the vestibular nerve.

Table 2
Patients' Global Impression of Change.

No change (or condition has got worse)	1
Almost the same, hardly any change at all	2
A little better, but no noticeable change	3
Somewhat better, but the change has not made any real difference	4
Moderately better, and a slight but noticeable change	5
Better, and a definite improvement that has made a real and worthwhile difference	6
A great deal better, and a considerable improvement that has made all the difference	7

Patients have to answer the following question: "Since beginning treatment at this clinic, how would you describe the change in activity limitations, symptoms, emotions and overall quality of life related to your painful condition?" Their response is reported on a 7-steps scale.

estimated. Patients' satisfaction was measured using PGIC [8] score (Table 2).

3. Results

Results are summarized in Table 3.

3.1. Patients

A total of 15 patients from 42 to 74 years of age were operated between 2009 and 2016. Mean age was 57 years. 10 patients were active working people and 5 patients were retired. All patients were diagnosed with Meniere's disease with unilateral symptomatic triad of tinnitus, vertigo and hearing loss lasting for several months resistant to medical treatment. One patient had a Meniere's disease with Tumarkin's crises. The cochleovestibular examination demonstrated sensorineural hearing loss in all patients with hearing levels between 60 dB and 70 dB, and an ipsilateral vestibular hyporeflexia in the caloric test. The mean duration of symptoms was 6 years.

3.2. Surgical procedure

All patients underwent vestibular neurotomy by suboccipital retrosigmoid approach performed by same surgeons. Total vestibular nerve section was performed in all patients. The average duration of the surgery was 1 h 44 minutes. The average hospital stay lasted 10 days (6–34 days).

3.3. Postoperative evaluation

In the immediate postoperative period, patients experienced an acute vestibular syndrome with instability, imbalance and a spontaneous nystagmus contralateral to the side of neurotomy. All patients underwent early postoperative vestibular rehabilitation.

One patient experienced bacterial meningitis 12 days after the surgery. It was treated for 3 weeks by administering double antibiotic therapy, with a favorable outcome. A minor local wound infection was observed in a second patient, that did not require any antibiotherapy. No facial paralysis and no CSF leak occurred in any patients.

At one-month follow-up, all 15 patients experienced a dramatic improvement of dizziness. None of them reported vertigo crisis since surgery. Nevertheless, they all reported balance disorders. Audiogram showed no hearing loss, except for one patient with serous otitis.

At two years follow-up, 2 patients were lost to follow-up. Among the remaining 13 patients, 11 had no significant dizziness and had a complete recovery of imbalance. No patients complained of any gait problems. Patient 2 (woman, 52-years-old) experienced bilateralization of the disease 20 months after the surgery. Patient 14 (woman, 63-years-old) developed a poor compensation of vestibular nerve section, with persistent long-term balance disorders [5].

Last follow-up occurred at the time of this study, i.e. 61 months on average after the surgery (range 24–95 months). Two patients were still lost to follow-up. The status of the remaining 13 patients

Table 3
Pre- and postoperative data.

Patient No.	Preoperative status						Postoperative status								
	Age (y)	Sex	Side	Duration of symptom (y)	Audiogram	DHI	1 month			2 years			Last follow-up		
							Dizziness	Balance disorders	Audiogram	Dizziness	Balance disorders	Work	Time from surgery (months)	DHI	PGIC
1	74	Female	Left	5	−70 dB	72 Severe	No	Yes	−70 dB	No	No	NA	95	12 Normal	7
2	52	Female	Left	15	−65 dB	80 Severe	No	Yes	−65 dB	Yes	Yes	No	92	68[a] Severe[a]	5
3	74	Female	Right	7	−70 dB	88 Severe	No	Yes	−70 dB	Lost to follow-up					
4	65	Female	Left	2	−75 dB	68 Severe	No	Yes	−75 dB	No	No	NA	85	4 Normal	7
5	46	Male	Left	2	−70 dB	78 Severe	No	Yes	−90 dB[c]	No	No	Yes	80	0 Normal	7
6	51	Male	Left	3	−55 dB	72 Severe	No	Yes	−55 dB	No	No	Yes	75	0 Normal	7
7	57	Male	Right	4	−70 dB	82 Severe	No	Yes	−70 dB	No	No	No	70	10 Normal	7
8	42	Male	Right	10	−30 dB	92 Severe	No	Yes	−30 dB	No	No	Yes	68	6 Normal	7
9	66	Female	Right	1	−60 dB	92 Severe	No	Yes	−60 dB	No	No	NA	66	6 Normal	7
10	55	Male	Right	2	−70 dB	72 Severe	No	Yes	−70 dB	No	No	Yes	55	0 Normal	7
11	57	Male	Left	2	−65 dB	88 Severe	No	Yes	−65 dB	No	No	Yes	35	24 Mild	5
12	60	Male	Right	3	−70 dB	70 Severe	No	Yes	−70 dB	No	No	NA	26	20 Mild	7
13	50	Female	Left	3	−60 dB	96 Severe	No	Yes	−60 dB	No	No	Yes	24	4 Normal	7
14	63	Female	Right	20	−70 dB	90 Severe	No	Yes	−70 dB	No	Yes	NA	24	70[b] Severe[b]	2
15	43	Male	Right	15	−40 dB	82 Severe	No	Yes	−50 dB	Lost to follow-up					

[a] Patient No. 2 experienced bilateralization of her disease 20 months after the surgery.
[b] Patient No. 14 developed a poor compensation of vestibular nerve section, with persistent disability.
[c] Temporary hearing loss due to serous otitis at the time of evaluation.

was similar to the 2 years follow-up: DHI score was normal or mild for 11 patients (Fig. 3). Symptoms were unchanged for patients 2 and 14. DHI score was 68 (severe) for patient 2, still suffering from contralateral Meniere's disease. For patients DHI score was nevertheless significantly improved compared with the preoperative one (70 versus 90). Patients' Global Impression of Change score was 7 (considerable improvement) for 12 patients, 5 (noticeable change) for 2 patients including the one with secondary bilateralization, and 2 for patient No. 14 with poor compensation.

4. Discussion

4.1. Preoperative evaluation

Meniere's disease is a clinical diagnosis based on a history of typical disease with vertigo, tinnitus and hearing loss during recurrent crises. The underlying pathophysiologic change responsible of the disease is an endolymphatic hydrops.

In our preoperative procedure, we not only performed a cochleovestibular evaluation but also an MRI in order to eliminate a differential diagnosis such as schwannoma. It could be interesting to perform an MRI with delayed contrast imaging in order to visualize an anatomic resolution to image the intracochlear fluid spaces of the inner ear and identify an endolymphatic hydrops. The cochlea of the inner ear contains both perilymphatic and endolymphatic fluid filled spaces. Perilymph enhances greater than endolymph after contrast administration of gadolinium. In the ear affected by Meniere's disease, a loss of definition of the cochlear fluid spaces was shown [9,10].

4.2. Alternative surgical treatments

Endolymphatic sac decompression is a non-destructive procedure to remove endolymphatic hydrops. This surgery allows hearing preservation. However, its long-term efficacy is debatable the risk of gap closure by surgical fibrosis. Its interest is often controversial in the literature [11,12].

Surgical labyrinthectomy destroys the labyrinth, leading to complete deafness. This technique is very effective and allows a regression of almost 95% of clinical symptoms but should be reserved for patients with a profound ipsilateral hearing loss [13]. This treatment should not be proposed as initial treatment due to risk of bilateralization in Meniere's disease. This surgery permanently disables the possibilities of cochlear implantation in the operated side. Fish et al. obtained in a series of 100 patients good results without loss of hearing and demonstrated that it is a safe surgical approach even in older patients [14].

Transtemporal supralabyrinthine vestibular neurotomy can be use in Meniere disease. This is a middle cranial fossa surgical approach below the temporal lobe. We access the vestibular nerve through the internal auditory canal by drilling the petrous bone. The real advantage of this surgical approach over posterior fossa approach is the ability to take advantage of the natural division between the cochlear and vestibular nerves in the distal part of the internal auditory canal [14]. Some authors even published a complication rate lower than reported for posterior fossa neurotomy [15]. However, this surgical approach appears to be technically more difficult than the posterior fossa retrosigmoid approach [15].

For all reasons previously described, retrosigmoid vestibular neurotomy remains the reference surgical treatment of intractable vertigo accompanying Meniere disease. Compared to endolymphatic duct surgery [16] and intratympanic gentamycin injections [17], vestibular neurotomy proved to be the best treatment in terms of vertigo control and hearing 6 preservation [18]. A total control on vertigo crisis is obtained in 85–95% of reported cases [19–22]. Moreover, minimal invasive posterior fossa retrosigmoid approach [21] allows to preserve hearing with a very low rate of serious complication. A recent study including 118 patients underwent vestibular neurotomy by posterior fossa retrosigmoid approach shown that most patients returned to their professional activities with rather improved symptoms [23].

4.3. Efficacy: vertigo control

In our series, immediate efficacy was excellent, with a disappearance of severe vertigo in all patients. At two years, the benefit was maintained in all but two patients: one developed contralateral Meniere's disease, and one had insufficient compensation of

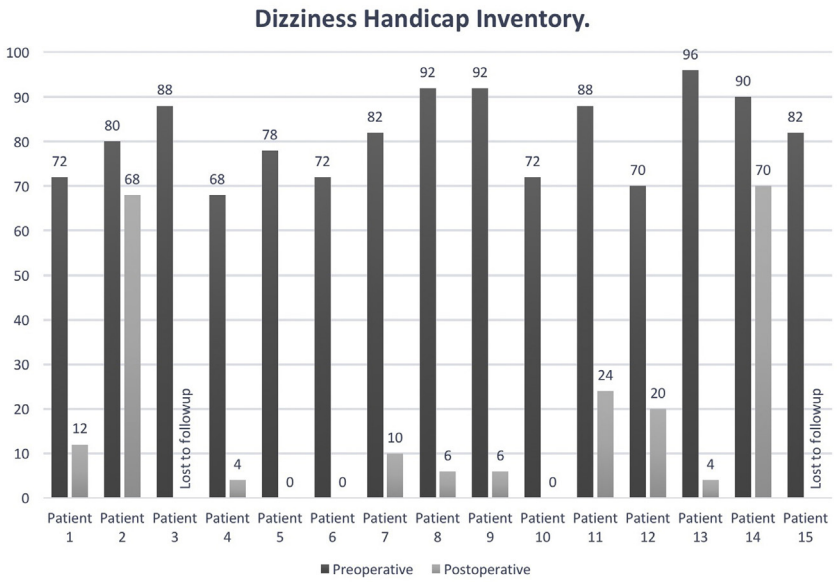

Fig. 3. Dizziness Handicap Inventory pre and postoperative.

vestibular nerve section. DHI score was normal or mild for 11 of 13 patients. Patients' Global Impression of Change (PGIC) ≥ 5 in 12 patients confirms the satisfaction of patients. In terms of vertigo treatment, large series of the literature report 94 to 100% of excellent and good efficacy [5,19,24]. Our own results are in line with these data and with the results of smaller series [22,25,26]. Several authors underlined the importance of complete nerve sectioning for the quality of clinical result [26,27].

The simplicity and the excellent efficacy of retrosigmoid vestibular neurotomy explain why this technique almost totally replaced previous techniques: middle fossa vestibular neurotomy, retrolabyrinthine vestibular neurotomy (RVN) [28], and combined retrolabyrinthine-retrosigmoid approach [29].

4.4. Postoperative complications

In our series, the complication rate was 17% with 2 cases of infection: meningitis and wound infection. In the literature, the most common complication is, as expected, CSF leak. This complication is highly dependent on technical considerations, and therefore variable between surgical teams. The highest rate (10%) is reported by Mahattanaku et al. [20]. The risk of postoperative facial palsy is usually very low [19,22]. The highest rate (10%) is again reported by Mahattanaku et al. [20]. There was no case in our own series.

4.5. Hearing preservation

In this short study, all patients had a disabling Meniere's disease grade 3 or 4 according to AAO-HNS (American Academy Otolaryngologist-Head and Neck Surgery; Meniere's disease functional level scale) and all required constant adaptation of their professional activities according to their disease.

We proposed to these patients vestibular neurotomy as a first choice as:

- it allows preservation of ipsilateral hearing in contrast to surgical labyrinthectomy;
- it leaves the possibility of cochlear implantation in case of bilateral severe to profound hearing loss.

In our series, we observed preservation of a stable hearing postoperatively. This result is concordant with the data of the literature. Nevertheless, several authors observed impairment of earing function in a significant number of patients: 10 dB or more in 82% of patients for Perez et al. [22], 8% for Leveque et al. [27], 2% for Magnan et al. [24].

4.6. Bilateralization

We observed a case of contralateral Meniere's disease 20 months after the surgery. This situation is badly known, because in most series the follow-up is too short. Albera et al. [30] observed 2 cases in a series of 45 patients (36 had received intratympanic gentamycin injection, and 9 vestibular neurotomy), and Li et al. [19] 2 cases in a series of 73 patients within 2 years after vestibular neurotomy.

4.7. Compensation after vestibular nerve section

The neurologic phenomenon of vestibular compensation underlies the surgical treatment of MD by unilateral vestibular neurotomy. Vestibular neurotomy removes the dysfunctional afferents of the pathological ear so as to prevent rotational vertigo due to acute conflict between visual, proprioceptive and vestibular balance-related afferents. It induces deafferentation of the vestibular apparatus while sparing the cochlear pathways [31]. The vestibule or posterior labyrinth is a mechanoreceptor essential to balance. Visual and somesthetic sensory afferents converge from various peripheral receptors to the vestibular nuclei and the central vestibular pathways. Deafferentation of one vestibular nucleus induces asymmetry in the vestibular system, with unilateral static and dynamic vestibular deficit causing postural, perceptual and oculomotor disturbances.

According to Ris, vestibular nuclei are subdivided into two groups: the first, endogenous pacemakers (EP) neurons whose resting activity is little influenced by unilateral vestibular deafferentation, and the second, non-pacemaker (NP) neurons which become silent after unilateral vestibular deafferentation. In patients with vestibular normoreflexy, the activity of the vestibular nuclei should be based on both functional EP and NP neurons. After surgery, the deprived NP neurons become silent as opposed

to the EP neurons. Degradation of postural performances observed immediately after surgery could be related to the sudden unilateral suppression of vestibular information originating from NP neurons. In patients with vestibular areflexia, the activity of the vestibular nuclei before surgery is based on EP neurons and on NP neurons which were deafferented because of the disease and the resting activity of which had been restored even before unilateral vestibular deafferentation [32,33].

Vestibular compensation is based on central nervous system reorganization such as increased excitability or sensitivity to neuromediators or modifications in synaptic connections, leading to functional rehabilitation after a few weeks to months [34]. It is promoted by patient-specific sensorimotor rehabilitation [35]. Although neurotomy cures vertigo in 90% of cases [15,24], 10 to 15% of patients show disabling residual instability despite unilateral vestibular areflexia [36,37], due to poor vestibular compensation. Nevertheless, the existing data in the literature are rare, and should be considered with caution. Our own results, with 1 case of poor compensation in a series of 15 patients, confirm these data.

This compensation mechanism is also observed in vestibular schwannoma. In this case, Due to the slow growth of the lesion and progressive alteration of vestibular function, vestibular compensation minimizes the related symptoms [38]. The decompensation of this previously compensated situation is caused by the surgical removal of the tumor. It explains why patients report severe vertigo and imbalances immediately after surgery. Central adaptive mechanisms allow to a restoration and improvement of vestibular imbalances [39,40].

The presurgical degree of vestibular compensation, is caused by the progressive loss of vestibular function due to tumor growth. Therefore, the consequences of the unilateral vestibular deafferentation on postural control after vestibular schwannoma surgery appeared to be more important for patients without paresis before surgery [33].

The lesion of vestibular nerve is usually correlated to a reduced caloric response ipsilateral to the lesion, therefore patients who had reduced preoperative caloric response appeared to have less postoperative vestibular imbalances compared with patients with normal preFoperative vestibular testing [41,42]. There is also a strong correlation between caloric weakness before surgery and functional vestibular outcomes [43].

4.8. Limitation of the study

This is a retrospective observational study. These preliminary results are encouraging but should be validated by a prospective multicenter study to include many more patients.

An exhaustive cochleovestibular evaluation in postoperative should be done with vocal audiometry and video head impulse test. It would be suitable to get more intermediate clinical and paraclinical data to better characterize the kinetic of imbalance disorders improvement. In addition, long-term evaluation (over two years) is only based on functional score scales (DHI/PGIC). A long-term vestibular evaluation by audiometry, videonystagmography and auditory brainstem response could confirm the results of our study.

5. Conclusion

In this short series, we confirm that vestibular neurotomy in intractable Meniere's disease is a simple and safe surgical procedure, with low rates of surgical complications. We obtained an excellent efficacy in treating dizziness in all 15 patients one month after the surgery. At long-term, this result was globally maintained, except for one patient (8%), who developed contralateral Meniere's disease. The main question that has to be addressed regarding vestibular neurotomy is the risk of poor compensation, with patients having chronic subjective dizziness, disability, and/or imbalance after surgery. In our own series, one single patient (8%) experienced prolonged instability. Further studies are mandatory to shed light on the phenomenon of vestibular compensation and to identify preoperative risk factors.

Disclosure of interest

The authors declare that they have no competing interest.

References

[1] Harcourt J, Barraclough K, Bronstein AM. Meniere's disease. BMJ 2014;349(9):g6544.
[2] Shojaku H, Watanabe Y, Fujisaka M, Tsubota M, Kobayashi K, Yasumura S, et al. Epidemiologic characteristics of definite Ménière's disease in Japan: a long-term survey of Toyama and Niigata prefectures. ORL 2005;67(5):305–9.
[3] Alexander TH, Harris JP. Current epidemiology of Meniere's syndrome. Otolaryngol Clin North Am 2018;43(5):965–70.
[4] Tyrrell JS, Whinney DJD, Ukoumunne OC, Fleming LE, Osborne NJ. Prevalence associated factors, and comorbid conditions for Ménière's disease. Ear Hear 2014;35(4).
[5] Silverstein H, Norrell H, Rosenberg S. The resurrection of vestibular neurectomy: a 10-year experience with 115 cases. J Neurosurg 1990;72(4):533–9.
[6] Basura GJ, Lin GC, Telian SA. Comparison of second-echelon treatments for Ménière's disease. JAMA Otolaryngol Head Neck Surg 2014;140(8):754–61.
[7] Jacobson GP, Newman CW. The development of the dizziness handicap inventory. Arch Otolaryngol Neck Surg 1990;116(4):424–7.
[8] Scott W, McCracken LM. Patients' impression of change following treatment for chronic pain: global specific, a single dimension, or many? J Pain 2015;16(6):518–26.
[9] Carfrae MJ, Holtzman A, Eames F, Parnes SM, upinetti LA. 3 tesla delayed contrast magnetic resonance imaging evaluation of Ménière's disease. Laryngoscope 2008;118(3):501–5.
[10] Nakashima T, Naganawa S, Sugiura M, Teranishi M, Sone M, Hayashi H, et al. Visualization of endolymphatic hydrops in patients with Meniere's disease. Laryngoscope 2009;117(3):415–20.
[11] Herman P, Herve S, Portier F, Tronche S, De Waelec C, Tran Ban Huy P. Maladie de Ménière. In: EMC Oto-Rhino-Laryngologie. Paris: Elsevier Masson SAS; 2003. p. 1–20.
[12] Paradis J, Hu A, Parnes LS. Endolymphatic sac surgery versus intratympanic gentamicin for the treatment of intractable Ménière's disease: a retrospective review with survey. Otol Neurotol 2013;34(8):10.
[13] Lacombe H. Chirurgie des vertiges. Neurochirurgie 2009;55(2):268–71.
[14] Fisch U. Transtemporal supralabyrinthine (middle cranial fossa) vestibular neurectomy: a review of the last 100 cases. Skull Base Surg 1996;6(4):221–5.
[15] Silverstein H, Wanamaker H, Flanzer J, Rosenberg S. Vestibular neurectomy in the United States–1990. Otol Neurotol 1992;13(1):23–30.
[16] Portmann I.V G. Surgical treatment of vertigo by the opening of the endolymphatic sac. Laryngoscope 1965;75(10):1522–32.
[17] Silverstein H. Streptomycin treatment for Meniere's disease. Ann Otol Rhinol Laryngol Suppl 1984;112:44–8.
[18] Sajjadi H, Paparella MM. Meniere's disease. Lancet 2008;372(9636):406–14.
[19] Li CS, Lai JT. Evaluation of retrosigmoid vestibular neurectomy for intractable vertigo in Ménière's disease: An interdisciplinary review. Acta Neurochir (Wien) 2008;150(7):655–61.
[20] Mahattanakul W, Nath F. Selective vestibular neurotomy for Meniére's disease: a neurosurgical procedure? Br J Neurosurg 2005;19(5):409–12.
[21] Pareschi R, Destito D, Falco Raucci A, Righini S, Colombo S. Posterior fossa vestibular neurotomy as primary surgical treatment of Meniere's disease. J Laryngol Otol 2002;116(8):593–6.
[22] Perez R, Ducati A, Garbossa D, Benech F, Fontanella MM, Canale A, et al. Retrosigmoid approach for vestibular neurectomy in Meniere's disease. Acta Neurochir (Wien) 2005;147(4):401–4.
[23] Miyazaki H, Nomura Y, Mardassi A, Deveze A, Miura M, Jike M, et al. How minimally invasive vestibular neurotomy for incapacitating Meniere's disease improves dizziness and anxiety. Acta Otolaryngol 2017;137(7):707–11.
[24] Magnan J, Bremond G, Chays A, Gignac D, Florence A. Vestibular neurotomy by retrosigmoid approach: technique, indications, and results. Otol Neurotol 1991;12(2):101–4.
[25] Fukuhara T, Silverman DA, Hughes GB, Kinney SE, Newman CW, Sandridge SA, et al. Vestibular nerve sectioning for intractable vertigo: efficacy of simplified retrosigmoid approach. Otol Neurotol 2002;23(1):67–72.
[26] Monsell EM, Wiet RJ, Young NM, Kazan RP. Surgical treatment of vertigo with retrolabyrinthine vestibular neurectomy. Laryngoscope 1988;98:835–9.
[27] Leveque M, Seidermann L, Tran H, Langagne T, Ulmer E, Chays A. Vestibular function outcomes after vestibular neurectomy in Meniere disease: can vestibular neurectomy provide complete vestibular deafferentation? Auris Nasus Larynx 2010;37(3):308–13.

[28] Silverstein H, Norrell H. Retrolabyrinthine vestibular neurectomy. Otolaryngol Head Neck Surg 1982;90(6):778–82.
[29] Silverstein H, Norrell H, Wanamaker H, Flanzer J. Microsurgical posterior fossa vestibular neurectomy: an evolution in technique. Skull Base Surg 1991;1(1):16–25.
[30] Albera R, Canale A, Parandero F, Ducati A, Lanotte M. Surgical indication in Menière's disease therapy: clinical and epidemiological aspects. Eur Arch Otorhinolaryngology 2011;268(7):967–72.
[31] Magnan J, Chays A, Locatelli P. Chirurgie des vertiges. In: EMC Tech Chir Tête Cou. Paris: Elsevier Masson SAS; 1994. p. 15.
[32] Ris L, Capron B, De Waele C, Vidal PP, Godaux E. Dissociations between behavioural recovery and restoration of vestibular activity in the unilabyrinthectomized guinea-pig. J Physiol 1997;500(2):509–22.
[33] Parietti-Winkler C, Gauchard GC, Simon C, Perrin PP. Pre-operative vestibular pattern and balance compensation after vestibular schwannoma surgery. Neuroscience 2011;172:285–92.
[34] Devèze A, Montava M, Lopez C, Lacour M, Magnan J, Borel L. Vestibular compensation following vestibular neurotomy. Eur Ann Otorhinolaryngol Head Neck Dis 2015;132:197–203.
[35] Shepard NT, Telian SA. Programmatic vestibular rehabilitation. Otolaryngol Neck Surg 1995;112(1):173–82.
[36] Reid CB, Eisenberg R, Halmagyi GM, Fagan PA. The outcome of vestibular nerve section for intractable vertigo: the patient's point of view. Laryngoscope 1996;106(12):1553–6.
[37] Lacour M, Dutheil S, Tighilet B, Lopez C, Borel L. Tell me your vestibular deficit, and i'll tell you how you'll compensate. Ann N Y Acad Sci 2009;1164(1):268–78.
[38] Curthoys IS, Halmagyi GM. Vestibular compensation. Adv Otorhinolaryngol 1999;55:82–110.
[39] Jenkins HA, Honrubia V, Baloh RH. Evaluation of multiple-frequency rotatory testing in patients with peripheral labyrinthine weakness. Am J Otolaryngol Neck Med Surg 1982;3(3):182–8.
[40] Parietti-Winkler C, Gauchard GC, Simon C, Perrin PP. Sensorimotor postural rearrangement after unilateral vestibular deafferentation in patients with acoustic neuroma. Neurosci Res 2006;55(2):171–81.
[41] El-Kashlan HK, Shepard NT, Arts HA, Telian SA. Disability from vestibular symptoms after acoustic neuroma resection. Am J Otol 1998;19(1):104–11.
[42] Humphriss RL, Baguley DM, Moffat DA. Change in dizziness handicap after vestibular schwannoma excision. Otol Neurotol 2003;24(4):661–5.
[43] Batuecas-Caletrio A, Santacruz-Ruiz S, Muñoz-Herrera A, Sousa P, Otero A, Perez-Fernandez N. Vestibular compensation after vestibular schwannoma surgery: normalization of the subjective visual vertical and disability. Acta Otolaryngol 2013;133(5):475–80.