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ORIGINAL RESEARCH

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Tympanostomy tube placement for pressure-sensitive vertigo

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Abstract

Objective: To evaluate tympanostomy tube placement in patients with pressure-sensitive vertigo.

Methods: Retrospective case series.

Results: Six patients with pressure-sensitive vertigo reported resolution of their vertigo and other vestibular symptoms after placement of the tympanostomy tubes. All recurrences of symptoms were due to either extrusion or plugging of the tubes. All patients fulfilled the criteria for vestibular migraine. None of the patients had superior canal dehiscence on imaging or precedent event that triggered the problem, and all had a negative fistula test.

Conclusion: Tympanostomy tube placement should be considered in selected patients with vertigo exacerbated by seemingly small changes in atmospheric pressure (e.g., just prior to thunderstorms, air travel, or travel to the mountains). By eliminating the capability of the tympanic membrane to sense changes in pressure with a tube, patients with pressure-induced vertigo (in the absence of perilymph fistula or superior canal dehiscence) may have relief of their symptoms.

Level of Evidence: IV.

KEYWORDS
atmospheric pressure, Meniere's disease, tympanostomy tube, vertigo, vestibular migraine, weather changes

1 | INTRODUCTION

Migraine is thought to be caused by altered processing of sensory stimuli, which most frequently presents with headaches, nausea and vomiting, and possible visual auras.[1] Increasing evidence suggests that migraine can present in an atypical fashion with vertigo, sudden hearing loss, tinnitus, and aural fullness without headaches.[2,3] These constellations of symptoms are similar to those found in Meniere's disease (MD), which is associated with recurring episodes of cochleovestibular dysfunction. Furthermore, it has been reported that individuals with MD can experience quality of life improvement when treated with traditional migraine prophylaxis therapy.[3] Although the exact pathophysiology of both vestibular migraine and MD are unknown, recent research suggests that the symptoms of MD may be due to migraine's effect on the inner ear.[2]

Migraine and MD have been associated with atmospheric pressure sensitivity.[4,5] It is suggested that the prevalence and severity of migraine headaches and MD increase with low-pressure weather systems or at higher altitudes (lower atmospheric pressure).[4,5] Due to the possible association between atmospheric pressure change and the prevalence and severity of MD, tympanostomy tubes have been utilized to relieve MD symptoms.[6,7] The placement of tympanostomy

tubes provides partial or complete resolution of Meniere's symptoms in some patients.[6,7] Given the similarities of vestibular migraine and MD, placement of tympanostomy tubes may reduce the frequency and duration of vestibular migraine in patients with pressure-sensitivity. This case series examines six patients with a history of pressure-sensitive vertigo who underwent tympanostomy tube placement resulting in symptomatic resolution. The sole trigger in these patients was a lower atmospheric pressure. All patients had normal otoscopic exam and met the International Headache Society criteria for vestibular migraine.[8] In addition, Patient 1 fulfilled the diagnostic criteria for MD proposed by the Barany Society.[9]

2 | CASE SERIES

The study protocol was approved by the University of California Irvine's Institutional Review Board Committee (IRB # 2017-3403). The study was performed in accordance with the World Medical Association Declaration of Helsinki and informed consent was obtained from the patients.

2.1 | Patient 1

A 41-year-old man with a history of dizziness, headache, and left ear fullness was originally diagnosed with MD in early 2012 and underwent left endolymphatic sac decompression at an outside institution without resolution of symptoms. He also failed diuretic and migraine therapy. The patient described worsening of vertigo attacks when a car window was rolled down, with weather changes (cloudy or rainy weather), and going to higher altitudes. The examination of the tympanic membranes (TMs) was normal. He also had a normal audiogram and tympanogram when he presented to our institution. Bilateral tympanostomy tubes were placed in June 2014. His symptoms improved significantly after tube placement with no further vertigo attacks. In December 2016, the patient returned with recurrence of vertigo symptoms during rain storms and was found to have extruded tubes. The tubes were replaced, and he was vertigo-free until January 2019. He presented once again with vertigo attacks with cloudy or rainy weather and was found to have an extruded right tube which was subsequently replaced. The patient's symptoms resolved after the re-insertion of the right tube. The patient continues to do well after 8 years after his initial tube placement with no adjuvant medical therapy.

2.2 | Patient 2

A 61-year-old woman presented in 2013 with vertigo and nausea after traveling from her home by the ocean to her weekend home in the mountains (elevation 6752 feet). She would travel from the ocean to the mountains weekly leading to vertigo. She had normal examination of the TMs, audiogram, and tympanogram. The patient had tympanostomy tubes placed bilaterally with the resolution of symptoms. In 2014, she again experienced vertigo while driving to the mountains. Examination showed that the tubes had extruded. The tubes were replaced, and she again experienced resolution of symptoms. In June 2018, she returned asking for the tubes to be removed because she thought she no longer needed them, having been free of vertigo for several years. Three weeks after removal of the tubes and paper patch myringoplasty, she went to her mountain home with recurrence of vertigo. On examination, bilateral TM perforations had closed. The tubes were replaced again with resolution of her pressure sensitivity. She continues to do well without vertigo 9 years after initial tube placement.

2.3 | Patient 3

A 38-year-old woman presented with recurrent vertigo episodes during or slightly before thunderstorms or after flying in an airplane. She had moved from the Midwest to California to reduce her exposure to weather changes. She stated that "I can tell when a storm is coming" 1 day before rainstorms. She had a normal examination of the TMs, audiogram, and tympanogram. Bilateral myringotomy and tubes were placed with resolution of her low-pressure-induced vertigo. At 1 year posttympanostomy, she had resolution of her symptoms despite weather changes. Three years after her initial visit with us and after replacement of the tubes in a subsequent visit, she moved back to the Midwest.

2.4 | Patient 4

A 51-year-old woman presented in 2012 for recurrent vertigo episodes and aural fullness in her right ear during or slightly before thunderstorms and after flying in airplanes. She had an unsuccessful endolymphatic sac surgery prior to presentation. She had a normal examination of the TMs, audiogram, and tympanogram. She stated that "I can predict an upcoming thunderstorm before it happens" due to pressure in the ear and vertigo onset. Right myringotomy and tube were placed with resolution of her low-pressure-induced vertigo. One year later, she was admitted to the hospital due to a severe vertigo episode and right aural pressure during an on-going rainstorm. She was found to have a plugged tympanostomy tube. The tube was unplugged with a straight needle, which resolved her symptoms. She continued to report resolution of her symptoms 2 years since her last visit with the tube in place.

2.5 | Patient 5

A 41-year-old man presented with recurrent vertigo episodes during or slightly before thunderstorms. He also experienced vertigo when driving in the car with the windows rolled down or after airplane flights. He had a normal otoscopic exam, audiogram, and tympanogram.

TABLE 1 Patients' summary and demographic information

No.	Age	Sex	Chief complaint	Symptoms triggers	Tympanostomy tube placement	Follow-up
1	41	Male	Vertigo (intensity VAS = 10) lasting 3 h the day before thunderstorm, immediate with car window, sound sensitivity, headache, left aural fullness	High altitude, car window rolled down, thunderstorm	Bilateral, vertigo intensity VAS = 1 following tube placement	Blocked or fell out with recurrence of symptoms. Doing well 8 years after tube placement
2	61	Female	Vertigo (intensity VAS = 8) lasting 2–48 h, nausea, while near reaching mountain destination (2-h drive)	High altitude	Bilateral, vertigo intensity VAS = 0 following tube placement	Removed because she thought she no longer needed them. Replaced after her symptoms recurred. Doing well 5.5 years after initial tube placement
3	34	Female	Vertigo (intensity VAS = 9) lasting 2–4 h, light sensitivity, the day before thunderstorm and on flight	Thunderstorm, air flight	Bilateral, vertigo intensity VAS = 1 following tube placement	1 year with no symptoms
4	51	Female	Vertigo (intensity VAS = 9) lasting 3–5 h, sound sensitivity, right aural fullness, the day prior to thunderstorm, during air flight	Thunderstorm, air flight	Right, vertigo intensity VAS = 0 following tube placement	Symptoms recurred with blocked tube then re-opened with resolution of symptoms for 2 years
5	41	Male	Vertigo (intensity VAS = 10) lasting 4–6 h, light and sound sensitivity, headache, the day prior to thunderstorm at the time of other triggers	Thunderstorm, car window rolled down, air flight	Bilateral, vertigo intensity VAS = 3 following tube placement	Resolution of symptoms for 2 years
6	55	Male	Vertigo (intensity VAS = 10) lasting 4–5 h, headache, nausea, vomiting, light hypersensitivity, aural pressure, the day prior to thunderstorm, when reached high altitude or on flight	High altitude, air flight, thunderstorm, roller coaster	Bilateral, vertigo intensity VAS = 2 following tube placement	Resolution of symptoms for 2.5 years

Note: All patients had normal otoscopic exam and met the International Headache Society criteria for vestibular migraine. All patients' tympanic membranes were intact without perforation, retractions, or signs of infection on initial presentation.
Abbreviation: VAS, visual analog scale.

Bilateral myringotomy and tubes were placed with resolution of pressure-induced vertigo. He continues to have resolution of symptoms 2 years post-initial tube placement.

2.6 | Patient 6

A 55-year-old man presented in 2019 with a history of recurrent vertigo episodes. During these episodes, he experienced intense dizziness, headache, nausea, and vomiting. He also reported motion intolerance and hypersensitivity to light. The attacks happened during travels to higher altitudes, airplane takeoffs, and thunderstorms. He stated that he had poor sleep hygiene, a high-stress level, and was consuming processed meat and alcohol when the incidents occurred. He underwent bilateral ear tubes insertion. He has had two replacements of his tympanostomy tubes, most recently in January 2022. Just prior to replacement of the tubes, his vertigo with pressure changes would return and he was found to have extrusion of the tubes and closure of the TM. He has been symptom free while the tubes have been in place.

3 | DISCUSSION

In this cohort, we found that insertion of tympanostomy tubes in patients with vestibular migraine sensitive to pressure changes resolved their vertigo and other vestibular symptoms. CT imaging had ruled out superior canal dehiscence in all patients and none experienced Valsalva-induced vertigo. All six patients had episodic vertigo only with changes in weather or ambient atmospheric pressure (Table 1). This suggests that their disease was most likely modulated

by changes in pressure. Once the tubes were in place, patients only experienced worsening of their symptoms when the tube(s) was blocked, extruded, or removed.

Changes in atmospheric pressure have been associated with increased frequency and severity of migraine symptoms. Approximately 53% of individuals with migraine experience worsening of symptoms with changes in atmospheric pressure.[10] Davis et al.[4] demonstrated that a sample of 667 hikers climbing a mountain at 4349 m had increased chance of having a migraine episode. Similar to changes in altitude, different weather patterns cause fluctuations in atmospheric pressure. Schmidt et al.[5] collected data from 397 MD participants in the UK using a mobile phone application over a year and found that during low atmospheric pressure (below 1.013 bar), there was an increased risk of experiencing Meniere's symptoms.

Migraine is thought to be caused by altered perception of normal sensory stimuli, like sound, light, smell, and touch.[1,10] Central sensitization is the process where trigeminal and cervical nociceptors are especially sensitive to normal sensory stimuli leading to allodynia and migraine.[11] The existing evidence on the mechanism of barometric changes in migraine-related pathologies is limited. Nevertheless, pressure changes can be considered a somatosensory stimulus like light or sound and are detectable by the TM. The TM is a sensitive baroreceptor and most subjects are aware of pressure changes of less than 100 mmH_2O (0.009678 bar), corresponding to a volume displacement of the TM of less than 15 μl.[12] Therefore, the ear is sensitive to changes of a 0.25% of the middle ear and mastoid volume of 6000 μl.[12] Migraine, including vestibular migraine, could therefore be caused by slight alterations in atmospheric pressures. Sato et al.[13] hypothesized that barometric sensors are most probably located in the ampullae of the semicircular ducts of the inner ear of mice. They demonstrated that low barometric pressure in mice induces superior vestibular nucleus activation and that a similar mechanism might contribute to meteoropathy symptoms in humans.[13] Other studies reported that overpressure in the middle ear or a pressure difference between the endolymph and perilymph might increase vestibular neuronal activation in guinea pigs.[14,15] In birds, the paratympanic organ, located in the middle ear and innervated by the facial nerve, detects barometric pressure changes.[16,17] Nonetheless, no comparable mechanism has yet been elucidated in humans.

We hypothesize that the TMs are our anatomic pressure sensors. The only anatomic part of the body that is sensitive to atmospheric pressure changes that is exposed on the outer surface of the body is the TM. When we travel to elevation, the only way the brain can sense the ambient pressure has changed is through the TM and the differential between the ear canal air pressure and middle ear pressure. Therefore, we assumed that the TMs are most likely the body's pressure sensors. Based on that we assumed that when there is low atmospheric pressure, the TMs are sensing this change and send a signal centrally. However, due to the active migraine phenomenon, the central signal is amplified. This amplified response is likely leading to vestibular migraine and thus vertigo in the patients. This is akin to light-induced migraine headaches. Except that instead of light, the low-pressure signal is transmitted from the TM and the response is a vestibular migraine and not a headache. It is theoretically possible that there is a neural pathway that sends input into the vestibular nuclei when a low atmospheric pressure change is sensed by the TM. However, by eliminating the capability of the tympanic membrane to sense changes in pressure by placing a tympanostomy tube, patients with vestibular migraine may have relief of their symptoms similar to patients with MD.

There have been studies that showed a reduction in MD symptoms following the placement of tympanostomy tubes. Montandon et al.[7] found that insertion of a transtympanic ventilation tube relieved Meniere's symptoms in 82% of their 28 patients over a 2-year period. Ogawa et al.[6] placed tympanostomy tubes in 15 MD patients and found that approximately 20% had complete remission, whereas 47% showed decreased frequency of their vertigo episodes. Lastly, Kitahara et al.[18] demonstrated that treating patients suffering from MD with tympanic ventilation tubes in addition to medication, significantly reduced vertigo attacks to none and improved hearing by at least 10 dB, following 2 years of treatment.

The selected patients in this case series with pressure-sensitive vertigo re-enforce previous studies on MD that have shown full resolution of their symptoms with tympanostomy tube placement. The tubes can be placed either unilaterally or bilaterally depending on the patient's symptoms. If patients' symptoms are not triggered by pressure changes, prophylactic medications can be used to treat their symptoms.[3] In other words, if patients have other triggers aside from low-pressure-induced vertigo, the tube can only eliminate the low-pressure-induced vertigo. Therefore, some patients may need additional medical therapy for other causes and lifestyle and dietary changes. Because tympanostomy placement is a relatively benign procedure that can be done in an office setting, it can be offered to individuals whose symptoms are primarily due to pressure changes after other etiologies have been ruled out. Despite the interesting and promising results, this is a small case series. Future studies should examine larger cohorts of patients presenting with vestibular migraine and treated with tympanostomy tube to allow the proposal of new guidelines. Additionally, psychiatric comorbidities, such as anxiety and depression evaluated by Beck Anxiety Inventory and Beck Depression Inventory, have to be considered in future studies.

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CONFLICTS OF INTEREST

Hamid R. Djalilian holds equity in MindSet Technologies, Elinava Technologies, and Cactus Medical LLC. He is a consultant to NXT Biomedical. The remaining authors declare no conflict of interest.

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