Published in final edited form as:

Laryngoscope. 2012 April ; 122(4): 868–872. doi:10.1002/lary.22182.

Case Report: Persistent Alternobaric Vertigo at Ground Level

Charles D. Bluestone, MD,

Distinguished Professor of Otolaryngology, University of Pittsburgh School of Medicine

J. Douglas Swarts, PhD,

Assistant Professor of Otolaryngology, University of Pittsburgh School of Medicine

Joseph M. Furman, MD, PhD, and

Professor of Neurology & Otolaryngology, University of Pittsburgh School of Medicine

Robert F. Yellon, MD

Professor of Otolaryngology, University of Pittsburgh School of Medicine

Abstract

We recently encountered a 15-year-old female with bilateral tympanostomy tubes who manifested persistent severe vertigo, at ground level, secondary to a unilateral middle-ear pressure of +200 mmH₂O elicited by an obstructed tympanostomy tube in the presence of chronic nasal obstruction. We believe this is a previously unreported scenario in which closed-nose swallowing insufflated air into her middle ears, resulting in sustained positive middle-ear pressure in the ear with the obstructed tube. Swallowing, when the nose is obstructed, can result in abnormal negative or positive pressures in the middle-ear, which has been termed the *Toynbee phenomenon*. When confronted with patients who have vertigo, the possibility that nasal obstruction and the Toynbee phenomenon are involved should be considered.

Introduction

The term *alternobaric vertigo* (AV) was first coined by Lundgren who described it as a diving hazard.¹ Soon thereafter, he reported AV in Swedish Air Force pilots.² AV is classically encountered during flying or deep-sea diving, usually during ascent, occasionally during descent, as the result of asymmetrical middle-ear pressures (Figure 1). The vertigo is usually transitory but has been described as lasting for several minutes and is often associated with nausea and vomiting. Here, we describe an unusual case of AV occurring spontaneously at ground level that, to our knowledge, has not been previously reported.

Case History

K.C. was a 15-year-old female with achondroplasia who presented to the Emergency Department at the Children's Hospital of Pittsburgh of UPMC with acute onset of vertigo severe enough to cause falling; she was admitted. She had been vertiginous intermittently for three weeks, but the condition worsened and became persistent. Initially, a blocked ventriculo-peritoneal shunt inserted at age 3 years as a treatment for hydrocephaly was

Correspondence: Charles D. Bluestone, MD, Division of Pediatric Otolaryngology, Children's Hospital of Pittsburgh of UPMC, One Children's Hospital Drive, 4401 Penn Avenue, Faculty Pavilion, Floor 7, Pittsburgh, PA 15224, Tel: 412-692-5902; Fax: 412-692-6974; bluecd@chp.edu.

Presented, in part, at the 10th International Symposium on Recent Advances Otitis Media, New Orleans, LA, June 7, 2011.

No reprints available.

Conflict of Interest: None

thought to be the cause, but imaging studies showed the shunt to be patent. Still complaining of dizziness, she was referred to the Pediatric Otolaryngology Department. Her medical history included chronic nasal obstruction that had been getting progressively worse, and treatment for allergic rhinitis during that time. Her past otologic history was significant in that she had bilateral myringotomies with placement of Armstrong-type tympanostomy tubes for recurrent acute otitis media and chronic otitis media with effusion on three occasions. Finally, three years before her admission for vertigo, she had bilateral long-term T-tympanostomy tubes placed due to the continued recurrence of middle-ear disease.

On physical examination, she had gross mid-face hypoplasia associated with mouth breathing. No nystagmus was noted. Examination of the ears revealed bilateral long-term T-tympanostomy tubes in the tympanic membranes, but their patency could not be determined. There was no middle-ear effusion visualized in either ear. Examination of the nose revealed moderately severe edema with grossly enlarged turbinates and serous drainage. An attempted flexible fiber-optic nasal and nasopharyngeal examination was not tolerated by the patient. The rest of the examination of the head and neck was within normal limits.

Audiometric testing revealed normal hearing bilaterally. Tympanometry (GSI 33 Middle-Ear Analyzer; Grason-Stadler, Eden Prairie, MN.) showed a patent left tympanostomy tube and an obstructed right tympanostomy tube with a +200 mm H₂O middle-ear pressure. Multiple tympanograms taken during the course of the workup consistently showed an abnormally high positive right middle-ear pressure. Eustachian tube function testing, which could only be performed on the left side with the patent tympanostomy tube, revealed abnormal function (see Appendix). Computed tomographic scans of the temporal bones and maxillofacial area revealed dysplastic bones consistent with achondroplasia, with no evidence of middle-ear or mastoid disease or abnormalities of the inner ears; however, the adenoids were enlarged and there was moderate to severe nasal obstruction due primarily to enlarged turbinates. The patient underwent vestibular system testing that was also abnormal (see Appendix).

Her diagnosis of AV was the result of the obstructed tympanostomy tube in her right ear, chronic nasal obstruction, and the Toynbee phenomenon (i.e., closed-nose swallowing), which caused repeated insufflation of positive pressure into her right middle ear during swallowing, resulting in asymmetric middle-ear pressures and vertigo (Figure 2).

In the operating room, the patient had the right tympanostomy tube replaced with a new long-term T-tympanostomy tube, an adenoidectomy, and bilateral reduction of her inferior turbinates. Postoperatively, her vertigo was totally absent and her nasal obstruction and mouth breathing relieved. Balance testing revealed a resolution of her central vestibular abnormality, which allowed a left peripheral vestibular abnormality to be unmasked (see Appendix). Eustachian tube function tests showed the left ear's abnormal function to be unchanged. The right ear, with the newly inserted tympanostomy tube, also had abnormal function (see Appendix).

Discussion

Achondroplasia and otitis media

Achondroplasia, the most common of the chondrodysplasias, is an inherited autosomal dominant disorder characterized by abnormal bone growth that results in disproportionately short arms and legs, short stature, and a large head. As with this child, ventricular shunting is common.³ Patients who have achondroplasia are known to have several otolaryngologic diseases and disorders of the head and neck. One recent study reported that of 22 patients

with achondroplasia, 15 (68%) had an otologic diagnosis that included recurrent acute otitis media and chronic otitis media with effusion; two-thirds of their patients had a history of tympanostomy tube insertions.⁴ That study also reported obstructive sleep apnea in some children and that almost one-half had undergone adenotonsillectomy. To our knowledge, our patient is the first individual with achondroplasia to have Eustachian tube function testing. The pathogenesis of these children's Eustachian tube dysfunction may be related to morphologic abnormalities of the temporal bones and maxillofacial complex. Computed tomographic scans of these individuals show narrowing of the skull base, "towering" of the petrous ridges, and abnormal orientation of the inner and middle-ear anatomy.⁵ Since they have mid-face hypoplasia and abnormalities of the maxillo-facial complex, poor Eustachian tube function may be expected. Conducting Eustachian tube function tests in more of these children could enhance our understanding of the pathogenesis of their middle-ear disease.

Alternobaric vertigo

The prevalence of AV has been reported in as many as 27% of sport divers, which was thought to be a higher frequency than in pilots.⁶ However, a recent study of Portuguese Air Force pilots found a prevalence of 29%, possibly a consequence of the advent of modern high-performance aircraft.⁷ Typically, a diver or flyer who encounters AV has problems equilibrating middle-ear pressures during barometric pressure changes, a history of otitis media, or Eustachian tube dysfunction.⁸ In some, the vertigo occurs during periods of an upper respiratory infection, which presumably adversely affects their Eustachian tube function.⁹ Tjernstrom employed a pressure chamber to compare the Eustachian tube function of 12 divers who had experienced AV with six divers who had not.¹⁰ He exposed both groups to simulated ascents that produced passive opening of their Eustachian tubes and reported that those with a history of AV had higher opening pressures; one-half of the divers with a history of AV experienced vertigo and nystagmus in the chamber. Since the presence of an upper respiratory infection can elevate Eustachian tube opening pressure, AV could occur during these infections.¹¹ Our patient did not have an upper respiratory tract infection, but she did have chronic allergic rhinitis and turbinate and adenoid hypertrophy, all of which may have contributed to her poor Eustachian tube function.

To the best of our knowledge, this is the first patient to undergo vestibular testing during AV. Her central vestibular function abnormalities during the persistent vertiginous period resolved following postoperative elimination of the high positive middle-ear pressures. Even though the mechanism whereby positive pressure affects the vestibular system remains uncertain, one study in guinea pigs found that positive middle-ear pressure resulted in an objective vestibular response.¹²

Toynbee phenomenon (Effect of closed-nose swallowing on the middle ear)

The Toynbee maneuver, as a test of Eustachian tube function, is well known to otolaryngologists. It was originally described in 1853 by Toynbee, who noted that swallowing with the nose manually compressed caused a feeling of increased pressure in the middle ears.¹³ Pressure cycles are thought to arise as a consequence of changes in nasopharyngeal volume produced by the elevation of the soft palate and contraction of the pharyngeal muscles during swallowing.¹⁴ These pressures can be transmitted through the Eustachian tube to the middle ear, which, depending upon the timing of tubal opening with respect to the nasopharyngeal pressure cycle, results in either an initial positive or negative middle-ear pressure. Generally, the test is considered to indicate normal Eustachian tube function when there is a residual negative middle-ear pressure that is equilibrated to ambient pressure by a subsequent open-nose swallow. But, some adults who have normal-appearing tympanic membranes, no history of middle-ear disease, and thought to have normal Eustachian tube function do not have a residual negative pressure following the maneuver.

In a study by Elner and co-workers¹⁵ of the 94 normal adults, only 74 (79%) could change middle-ear pressures by performing the Toynbee maneuver. Of these, 36% had evidence of positive residual pressures.

Bluestone and colleagues suggested that any type of nasal obstruction (i.e., pathophysiology) could create the “Toynbee phenomenon” during swallowing.¹⁶ Finkelstein and co-workers studied the Toynbee phenomenon in adults who had intranasal packing.¹⁷ They measured the nasopharyngeal and middle-ear pressures during swallowing; nasopharyngeal pressures ranged from a maximum positive pressure of +450 mm H₂O to a negative pressure as low as -320 mm H₂O. The middle-ear pressure recordings, measured with tympanometry during closed-nose swallowing, varied among subjects but reached a maximum of + 190 mm H₂O—a value that may reflect the maximum pressure that the tympanometer can measure. Buchman and co-workers studied the effects of nasal obstruction on Eustachian tube function and middle-ear status using ferrets.¹⁸ Unilateral nasal obstruction had no effect on middle-ear pressures, but bilateral obstruction resulted in middle-ear pressures of approximately + 170 mm H₂O. The high positive pressures persisted for the duration of the 6- to 8-week post-obstruction follow-up period, but none of the animals developed a middle-ear effusion. In K.C., tympanometry recorded + 200 mm H₂O pressures when her nose and nasopharynx were obstructed, which is consistent with both the clinical and laboratory studies described above. Similarly, no middle-ear effusion developed in K.C., consistent with the result for ferrets with prolonged high middle-ear positive pressure.

Summary and Conclusions

We present a unique case in which the Toynbee phenomenon arose as a consequence of nasal obstruction and an obstructed tympanostomy tube producing a persistent, unilateral high positive middle-ear pressure that, due to its asymmetry, stimulated the vestibular system causing AV. Even though AV has been replicated in the laboratory employing a pressure chamber, we believe this is the first reported case of AV occurring spontaneously at ambient pressures. In conclusion, when confronted with patients who have vertigo, the possibility that nasal obstruction and the Toynbee phenomenon are involved should be considered, especially in those patients who have Eustachian tube dysfunction.

Acknowledgments

Supported, in part, by a grant from the National Institutes of Health, NINC07667.

Appendix

Vestibular laboratory testing

The vestibular testing was performed at the UPMC Center for Balance Disorders at the Eye and Ear Institute of Pittsburgh. The testing consisted of ocular motor screening, static positional testing, alternate binaural bithermal caloric testing, and rotational testing. Testing was performed on two occasions, once preoperatively and 6 months postoperatively. Testing used standard techniques described in detail elsewhere.¹⁹

Initial testing indicated normal ocular motor function, no positional nystagmus, severely reduced caloric responses bilaterally, and mildly reduced rotational responses with evidence of an ongoing vestibular-ocular reflex asymmetry. Upon repeat testing postoperatively, ocular motor function was again normal and there was again no positional nystagmus. Caloric testing indicated a significant left reduced vestibular response that had been masked by central suppression preoperatively. Rotational testing was normal. These results

suggested that the patient initially had both central suppression of peripheral responses and an ongoing vestibulo-ocular reflex asymmetry. However, postoperatively, vestibulo-ocular reflex symmetry returned to normal and central suppression resolved thereby allowing a left reduced vestibular response to become manifest. The absence of a directional preponderance on rotational testing postoperatively despite asymmetric caloric responses indicates central nervous system compensation for a unilateral peripheral vestibular reduction in the left ear. This compensation only followed the surgical correction of the nasal obstruction and replacement of the obstructed long-term tympanostomy tube in the right ear with a new long-term tympanostomy tube. The presence of a left reduced vestibular response, which was unmasked postoperatively, suggests that the patient's persistent peripheral vestibular reduction on one side was secondary to the persistent nature of the dysfunction due to the alternobaric vertigo.

Eustachian tube function testing

Eustachian tube function was evaluated at the ENT Research Center at the Children's Hospital of Pittsburgh of UPMC using the forced-response test. This test employs airflow from a constant-rate step pump attached to a probe in the ear canal to evaluate the physiological characteristics of the Eustachian tube function. The forced-response test can only be performed when the tympanic membrane has a perforation or a functioning tympanostomy tube. The testing equipment and protocol are described in detail elsewhere.²⁰

At the first visit, only the patient's left ear could be tested because the right tympanostomy tube was obstructed. Both passive and active resistances were higher than normal; however, the closing pressure was lower than normal. There was evidence of weak tubal dilation on swallowing, thus the Eustachian tube dilatory efficiency was poor. Postoperatively, Eustachian tube function testing was performed bilaterally. The test results for the right ear were similar to those of the left ear at the first visit. The forced response flow-trace showed constriction, consistent with airflow disruption, during swallowing, which is characteristic of abnormal function in patients with chronic otitis media with effusion.²¹ Postoperatively, the left Eustachian tube would not remain patent at either of the standard flow-rates; instead, it oscillated between the open and closed condition.

Based on these tests, Eustachian tube function, both pre- and postoperatively, was abnormal. The patient had relatively weak tubal dilation in the face of airflow obstruction during swallowing, and the low closing pressures suggest bilaterally semipatulous Eustachian tubes. These tests imply that the patient was insufflating nasopharyngeal gas into the middle ear during swallowing, which, given the obstructed right tympanostomy tube, created unilaterally persistent high positive middle-ear pressure.

References

1. Lundgren CEG. Alternobaric vertigo-A diving hazard. *Brit Med J*. 1965; 2:511–513. [PubMed: 14321224]
2. Lundgren CEG, Malm LU. Alternobaric vertigo among pilots. *Aerosp Med*. 1966; 37:178–180. [PubMed: 5906039]
3. Hunter AG, Bankier A, Rogers JG, Sillence D, Scott CL Jr. Medical complications of achondroplasia: a multicentre patient review. *J Med Genet*. 1998; 35:705–712. [PubMed: 9733026]
4. Collins WO, Choi SS. Otolaryngologic manifestations of achondroplasia. *Arch Otolaryngol Head Neck Surg*. 2007; 133:237–244. [PubMed: 17372080]
5. Cobb SR, Shohat M, Mehlinger CM, Lachman R. CT of the temporal bone structure in achondroplasia. *Am J Neuroradiol*. 1988; 9:1195–1199. [PubMed: 3143244]

6. Klingman C, Knauth M, Praetorius M, Plinkert PK. Alternobaric vertigo—really a hazard. *Otol Neurotol*. 2006; 27:1120–1125. [PubMed: 17130801]
7. Subtil J, Varandas J, Galrao F, Dos Santos A. Alternobaric vertigo: prevalence in Portuguese air force pilots. *Acta Otolaryngol*. 2007; 127:843–846. [PubMed: 17762996]
8. Uzun C, Yagiz R, Tas A, et al. Alternobaric vertigo in sport SCUBA divers and risk factors. *J Laryngol Otol*. 2003; 117:854–860. [PubMed: 14670144]
9. Molvaer OI, Albrektson G. Alternobaric vertigo in professional divers. *Undersea Biomed Res*. 1988; 15:271–281. [PubMed: 3212844]
10. Tjernstrom O. Function of the Eustachian tubes in divers with a history of alternobaric vertigo. *Undersea Biomed Res*. 1974; 1:343–351. [PubMed: 4469100]
11. Bluestone CD, Cantekin EI, Beery QC. Effect of inflammation on the ventilatory function of the Eustachian tube. *Laryngoscope*. 1977; 87:493–507. [PubMed: 839939]
12. Suzuki M, Kitano H, Yazawa Y, Kitajimak K. Involvement of round and oval windows in the vestibular response to pressure changes in the middle ear of guinea pigs. *Acta Otolaryngol*. 1998; 118:712–716. [PubMed: 9840510]
13. Toynbee J. On the muscles which open the Eustachian tube. *Proc R Soc Lond*. 1853; 6:286–288.
14. Perlman HB. Mouth of the eustachian tube; action during swallowing and phonation. *AMA Arch Otolaryngol*. 1951; 53:353–369. [PubMed: 14818506]
15. Elner A, Ingelstedt S, Ivaraaon A. The normal function of the Eustachian tube: a study 102 cases. *Acta Otolaryngol (Stockh)*. 1971; 72:320–328. [PubMed: 5146005]
16. Bluestone CD, Paradise JL, Berry QC. Physiology of the Eustachian tube in the pathogenesis and management of middle ear effusions. *Laryngoscope*. 1972; 82:1654–1670. [PubMed: 5079592]
17. Finkelstein Y, Zohar Y, Talmi YP, Nelu L. Study of Toynbee phenomenon by combined intranasopharyngeal and tympanometric measurements. *Ann Otol Rhinol Laryngol*. 1988; 97:119–296.
18. Buchman CA, Doyle WJ, Swarts JD, Bluestone CD. Effects of nasal obstruction on Eustachian tube function and middle ear pressure. *Acta Otolaryngol (Stockh)*. 1999; 119:351–355. [PubMed: 10380742]
19. Furman, JM.; Wuyts, F. Clinical Application of Vestibular Laboratory Testing. In: Luxon, LM.; Martini, A.; Furman, JM.; Stephens, D., editors. *Textbook of Audiological Medicine: Clinical Aspects of Hearing and Balance*. London: Martin Dunitz; 2003. p. 735-756.
20. Bluestone, CD. *Eustachian tube: Structure, Function, Role in Otitis Media*. Hamilton, Ont.: BC Decker; 2005.
21. Swarts JD, Bluestone CD. Eustachian tube function in older children and adults with persistent otitis media. *Int J Ped Otorhinolaryngol*. 2003; 67:853–859.

Figure 1.
Cartoon depicting that alternobaric vertigo can occur in scuba divers and airplane pilots during ascent.

Figure 2. Cartoon showing the pathogenesis of persistent alternobaric vertigo in our patient who had chronic nasal obstruction, the Toynbee Phenomenon, and a unilaterally obstructed tympanostomy tube that created high positive middle-ear pressure.