Current Management of CPAP After Otologic and Neurotologic Surgery

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Background: Obstructive sleep apnea is a highly prevalent disorder often treated with continuous positive airway pressure (CPAP). CPAP transmits high pressures through the Eustachian tube, and has significant implications for patients undergoing surgery of the middle ear, inner ear, and lateral skull base. In such patients, nothing is known regarding the likelihood of surgical complications with CPAP use, or medical complications with its cessation. No consensus or guidelines exist for postoperative management of this vitally important but potentially hazardous therapy.
Objective: To gain an understanding of the current state of practice with regards to postoperative CPAP management in patients undergoing middle ear, stapes, cochlear implant, and lateral skull base surgeries.
Methods: An electronic survey was sent to all members of the American Neurotology Society via email.
Results: The survey was completed by 54 neurotologists. Duration of postoperative CPAP limitation had similar distribution for surgery of the middle ear, stapes, and skull base: fewer surgeons recommend immediate use, with more advising $\leq$1 week and $\geq$2 week abstinence. For cochlear implantation, immediate use is most commonly advocated. The rationale for restricting postoperative CPAP use varied by surgery type. Subgroup analysis showed no variations by region; however, surgeons with >15 years of experience tend to advocate for earlier return to CPAP than those with less experience.
Conclusion: Current neurotology practice varies widely concerning CPAP management after otologic and neurotologic surgeries, both with regard to duration of CPAP abstinence and in rationale for its limitation. **Key Words:** Cochlear implants—Complications—CPAP—Lateral skull base—Middle ear—Neurotology—OSA—Otology—Postoperative—Stapes.

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Obstructive sleep apnea (OSA) is a disorder in which upper airway collapse during sleep results in airflow reduction or cessation, leading to blood oxygen desaturations and sleep fragmentation. Poor sleep results in daytime sleepiness, lost productivity (1), increased motor vehicle accidents (2), and decreased quality of life (QOL) (3). Chronic intermittent hypoxia is associated with hypertension (4), heart disease (4), stroke (5,6), diabetes (7,8), metabolic syndrome (8), sudden cardiac death (9), and all-cause mortality (8). OSA is increasingly prevalent, affecting 17 to 24% of women and 34 to 49% of men (10,11). Continuous positive airway pressure (CPAP) is the gold standard treatment, preventing airway collapse and reversing respiratory disturbances and sleep fragmentation (12–14). This noninvasive treatment reduces sleepiness (12) and improves QOL (12,15), though data conflict on cardiovascular outcome improvement (16–20).

CPAP transmits pressure to the middle ear (ME) via the Eustachian tube (ET). CPAP levels of 5, 10, and 15 cm H_2O cause near-equivalent ME pressures in adults, both awake (21–23) and asleep (24). Although pressures 100-fold higher are usually required to perforate an intact TM (25), case reports exist of CPAP resulting in air entry through an intact skull base (26), oval window (27,28), or TM (29). The forces transmitted to these structures have significant implications for patients undergoing surgery of the ME, inner ear, and lateral skull base. In such patients, nothing is known regarding likelihood of surgical complications with CPAP use, or medical complications with its cessation. No consensus or guidelines exist for postoperative management of this vitally important but potentially hazardous therapy.

We attempted to discern current state of practice regarding postoperative CPAP management among neurotologists; we found wide variation.

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TABLE 1. *Respondents' years of experience*

Years of experience	0–5	6–10	11–15	16–20	21–25	26–30	>30
Number of respondents	9	10	12	4	6	8	5

METHODS

An electronic survey was sent out via the American Neurotology Society (ANS) newsletter, assessing surgeons' region, experience, and practice regarding postoperative CPAP restrictions (length and rationale) for four procedural categories—ME surgery, stapes surgery, cochlear implantation (CI), and skull base surgery (Appendix 1, http://links.lww.com/MAO/B8). A free-text comment section provided space for respondents to share additional information. Descriptive statistics were used to report response distributions. Pearson χ^2 was calculated for subgroup analysis using SPSS version 23 (IBM; Armonk, NY). Subgroup analysis was performed for experience and region.

RESULTS

Fifty-four neurotologists, of all levels of experience (Table 1), completed the survey. The ANS has 687 members (7.9% response) including emeritus members, trainees, and nonsurgeons. The South accounted for the most respondents (39%), followed by Midwest (24%) and West (24%), then Northeast (13%) (Fig. 1). Figure 2A–H depicts the response distribution regarding duration and rationale for CPAP restrictions after ME surgery (A, B), stapes surgery (C, D), CI (E, F), and lateral skull base surgery (G, H).

In every category, a few surgeons do not explicitly discuss CPAP with patients. Distribution of restriction length is similar between surgery of ME, stapes, and skull base: fewer surgeons recommend immediate use, with more advising $\leq$1 or $\geq$2 weeks abstinence. However, for CI, the majority of respondents allow immediate use.

Survey options regarding rationale differed by procedure category, based on author reasoning. After ME surgery, the vast majority of CPAP restrictors think it might disrupt or displace the repair. For stapes surgery, most respondents fear increased risk of pneumolabyrinth with SNHL, followed by disruption of TM flap healing. As noted, CI does not merit CPAP limitation for most neurotologists. Most limit CPAP after skull base surgery out of concern for pneumocephalus, followed by CSF leak.

Practice region was not associated with differences in length or rationale for CPAP restrictions. Experience was not associated with rationale differences, but had an effect on duration. Surgeons with >15 years' experience were *more* likely than younger counterparts to advise

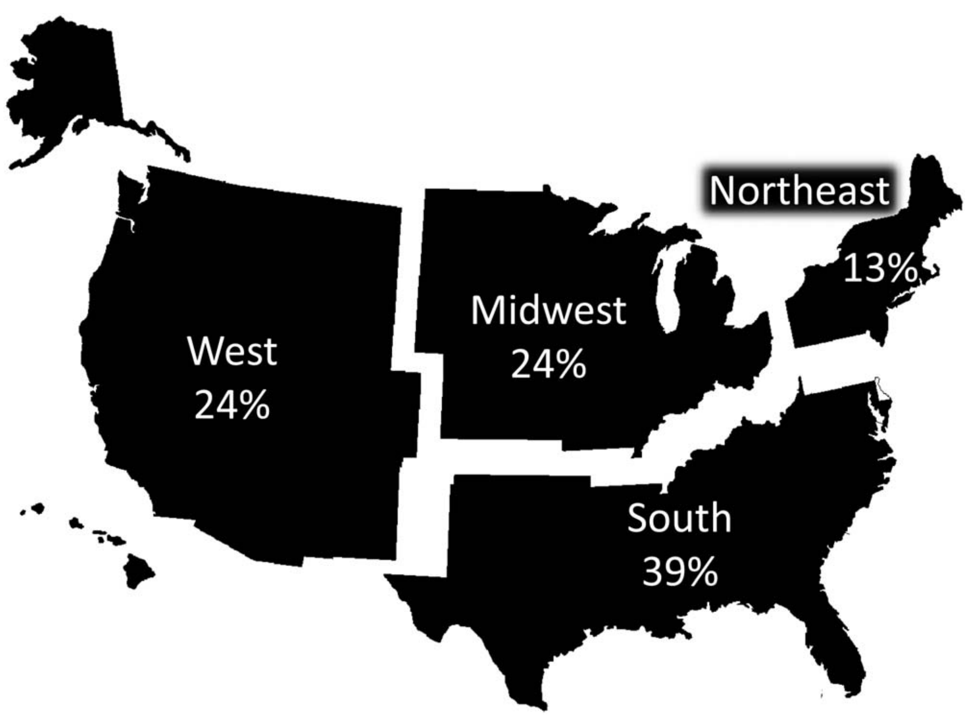

FIG. 1. Responses by region.

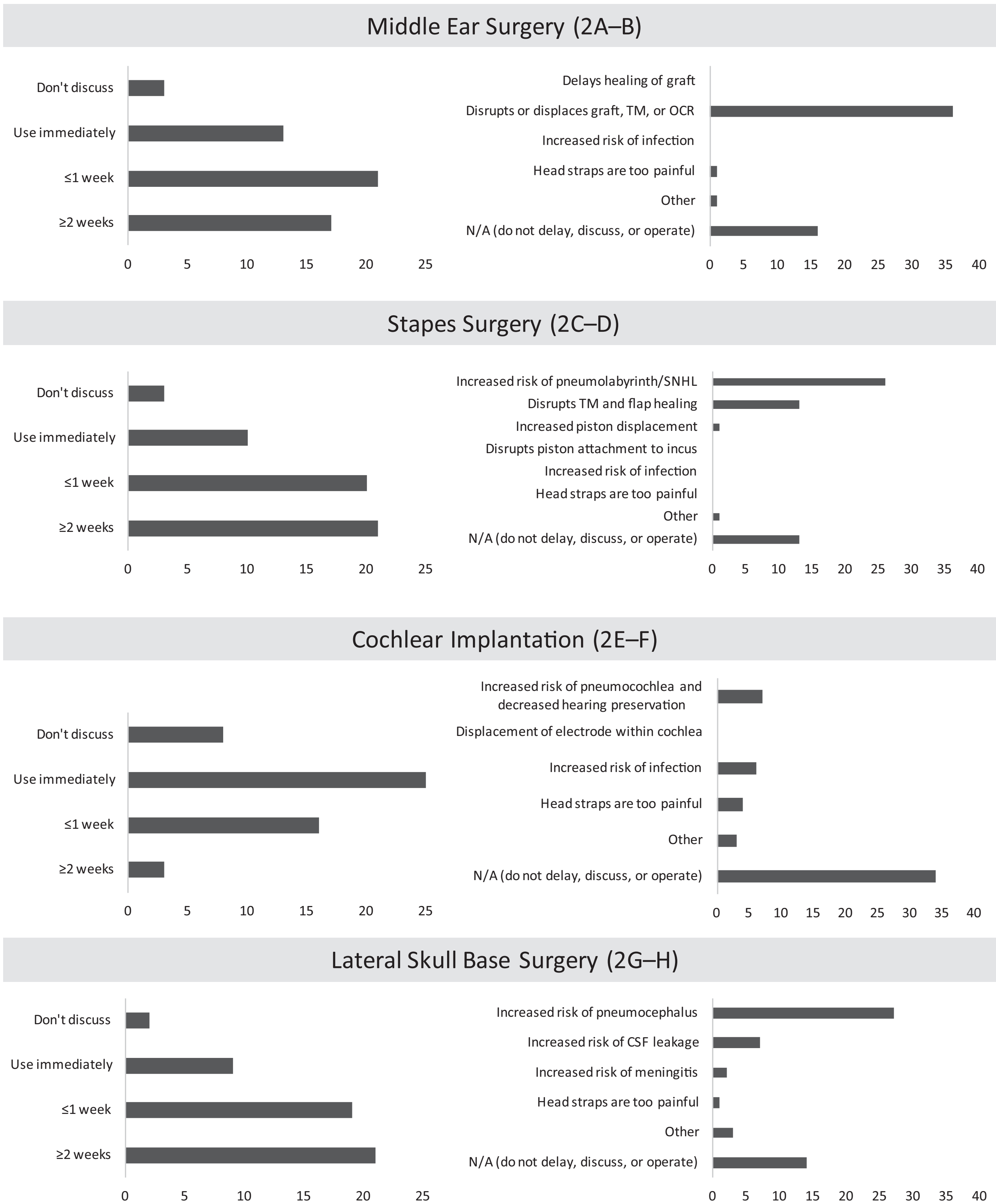

FIG. 2. Distribution of duration and rationale for CPAP restrictions. CPAP indicates continuous positive airway pressure.

immediate CPAP use after ME (19% vs 6%, $p = 0.002$) and skull base surgery (38% vs 3%, $p = 0.001$), and *less* likely to recommend lengthy ($\geq$2 wk) CPAP abstinence for stapes (22% vs 52%, $p < 0.05$) and skull base surgery (19% vs 57%, $p = 0.001$). No difference was observed regarding CI ($p = 0.91$).

DISCUSSION

Surveyed neurotologists display significant variability regarding postoperative CPAP use or restriction; we attribute this to lack of literature on surgical and medical complications.

It is curious that a few respondents do not discuss CPAP restrictions with their patients at all; we presume this arises from an unstated preference for patients to continue CPAP postoperatively. However, many patients hesitate to continue preoperative habits that might interfere with surgical sites; explicit discussion may eliminate confusion.

Duration of CPAP Restriction

Many surgeons are comfortable with immediate CPAP use postoperatively; multiple respondents mentioned that medical events (heart attack, stroke, etc) should be feared as much as surgical complications. We could not gauge whether immediate-use advocacy arises from fear of medical complications or from confidence in low incidence of surgical complications. However, we presume most surgeons advocating lengthy restriction fear CPAP-related surgical complications.

Responses regarding duration of CPAP restriction were similar for ME, stapes, and skull base surgeries—immediate use less commonly advocated than intermediate or lengthy abstinence. Despite the rare incidence and devastating consequences of pneumolabyrinth and SNHL, surgeons were no more cautious restarting CPAP after stapes surgery. Duration of CPAP limitation was much more liberal for CI. Potential explanations include an extremely low risk of meningitis (30,31), packing of the round window or cochleostomy, or implantees' reduced risk for hearing loss due to preexisting profound loss; however, with increasing indications for hearing preservation (32–34), this attitude may change over time.

Rationale for CPAP Restriction

The vast majority of surgeons who restrict CPAP after ME surgery are attempting to prevent disruption or displacement of the graft, TM, or ossicular reconstruction. Air pressure transmitted through the ET exerts force against the reconstructed TM; postoperatively, packing in the ME and external auditory canal may increase the effective mass of the TM-graft unit and its adherence to surrounding rigid structures, decreasing propensity for shift. However, packing amount, consistency, and location necessary to resist TM-graft unit deformation during CPAP is unknown. Rationale for CPAP restriction after stapes surgery predictably centers around SNHL from pneumolabyrinth. However, the pressure required to force air around a stapedotomy or stapedectomy prosthesis into the vestibule, with or without blood patch or packing, is unknown. Rationale for avoiding CPAP after lateral skull base surgery is due to risk of pneumocephalus and subsequent CSF leak. Some respondents, however, note that untreated OSA itself can increase intracranial pressure, increasing risk for CSF leak after skull base surgery despite CPAP restriction. Balancing intracranial and extracranial pressures is critical for appropriate healing, to seal the subarachnoid space and prevent CSF leak. Interestingly, average intracranial pressure is 7 to 15 mm Hg (9–20 cm H2O), equivalent to most CPAP settings.

Subgroup Analysis

Despite obesity's (highly correlated with OSA) higher prevalence in the South and Midwest than the Northeast and West (35,36), no regional variation was observed in postoperative management of CPAP among surveyed neurotologists. We postulated that more exposure to patients with OSA (thus more CPAP users) among Southern and Midwestern surgeons would render them either more comfortable with using CPAP soon postoperatively, or more aware of its complications, but neither materialized. As noted, we attribute this to inadequate data on safety.

More experienced surgeons allow return to CPAP therapy sooner on average than their younger counterparts; many explanations are possible. Lengthy experience with few complications may produce comfort with postoperative CPAP. Alternatively, less experienced surgeons educated in the obesity epidemic era may be more sensitive to its prevalence, and more likely to create a standard protocol for restriction. Less experienced surgeons seeking to build a practice may be singularly risk-averse and wish to avoid anything that could give the appearance of surgical complication; however, no evidence supports increased defensive medical practice in younger practitioners (37,38).

Eustachian Tube

Some surgeons pack the ET orifice with gelfoam, attempting to prevent air transmission. One surgeon thinks since many OSA patients are obese they will likely have more redundant tissue around the ETs, requiring a higher opening pressure than that delivered by CPAP. Li and Li (21) examined transmission of CPAP pressure to the ME in patients with OSA and controls after equalizing maneuvers, and found consistently *higher* ME pressures in OSA patients (who had higher average BMI than controls), which argues against this redundant tissue hypothesis.

Limitations

This study has many limitations. Survey-based research is prone to nonresponse bias. The sample size of 54 is small, though the overall neurotology workforce is also small; estimates are between 300 and 400 practicing in the US (39). Questions regarding rationale were limited to a single choice for the main factor, but several surgeons commented that their recommendations derive from multiple patient- and surgery-specific factors. Nevertheless, this study serves as a preliminary gauge of the state of practice; even with the limitations listed, it is safe to say that there is no best practice consensus of postoperative CPAP use among neurotologists.

CONCLUSION

Current neurotology practice varies widely concerning postoperative CPAP management, both with regard to duration of and rationale for CPAP limitation. Existing literature does not shed light on the practical implications of CPAP use after such surgeries.

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REFERENCES

1. Streatfeild J, Hillman D, Adams R, et al. Cost-effectiveness of continuous positive airway pressure therapy for obstructive sleep apnea: Health care system and societal perspectives. *Sleep* 2019;42:. zsz181.
2. George CF. Reduction in motor vehicle collisions following treatment of sleep apnoea with nasal CPAP. *Thorax* 2001;56: 508–12.
3. Young T, Peppard PE, Gottlieb DJ. Epidemiology of obstructive sleep apnea: A population health perspective. *Am J Respir Crit Care Med* 2002;165:1217–39.
4. Goldberger JJ, Cain ME, Hohnloser SH, et al. American Heart Association/American College of Cardiology Foundation/ Heart Rhythm Society scientific statement on noninvasive risk stratification techniques for identifying patients at risk for sudden cardiac death: A scientific statement from the American Heart Association Council on Clinical Cardiology Committee on Electrocardiography and Arrhythmias and Council on Epidemiology and Prevention. *Circulation* 2008;118:1497–518.
5. Redline S, Yenokyan G, Gottlieb DJ, et al. Obstructive sleep apnea-hypopnea and incident stroke: The sleep heart health study. *Am J Respir Crit Care Med* 2010;182:269–77.
6. Stone KL, Blackwell TL, Ancoli-Israel S, et al. Sleep disordered breathing and risk of stroke in older community-dwelling men. *Sleep* 2016;39:531–40.
7. Tasali E, Ip MS. Obstructive sleep apnea and metabolic syndrome: Alterations in glucose metabolism and inflammation. *Proc Am Thorac Soc* 2008;5:207–17.
8. Young T, Finn L, Peppard PE, et al. Sleep disordered breathing and mortality: Eighteen-year follow-up of the Wisconsin sleep cohort. *Sleep* 2008;31:1071–8.
9. Gami AS, Olson EJ, Shen WK, et al. Obstructive sleep apnea and the risk of sudden cardiac death: A longitudinal study of 10,701 adults. *J Am Coll Cardiol* 2013;62:610–6.
10. Heinzer R, Vat S, Marques-Vidal P, et al. Prevalence of sleep-disordered breathing in the general population: The HypnoLaus study. *Lancet Respir Med* 2015;3:310–8.
11. Peppard PE, Young T, Barnet JH, et al. Increased prevalence of sleep-disordered breathing in adults. *Am J Epidemiol* 2013;177: 1006–14.
12. Giles TL, Lasserson TJ, Smith BJ, et al. Continuous positive airways pressure for obstructive sleep apnoea in adults. *Cochrane Database Syst Rev* 2006;CD001106.
13. McEvoy RD, Thornton AT. Treatment of obstructive sleep apnea syndrome with nasal continuous positive airway pressure. *Sleep* 1984;7:313–25.
14. Sullivan CE, Issa FG, Berthon-Jones M, et al. Reversal of obstructive sleep apnoea by continuous positive airway pressure applied through the nares. *Lancet* 1981;1:862–5.
15. Zhao YY, Wang R, Gleason KJ, et al. Effect of continuous positive airway pressure treatment on health-related quality of life and sleepiness in high cardiovascular risk individuals with sleep apnea: Best Apnea Interventions for Research (BestAIR) Trial. *Sleep* 2017;40:1–8.
16. Abuzaid AS, Al Ashry HS, Elbadawi A, et al. Meta-analysis of cardiovascular outcomes with continuous positive airway pressure therapy in patients with obstructive sleep apnea. *Am J Cardiol* 2017;120:693–9.
17. Guo J, Sun Y, Xue LJ, et al. Effect of CPAP therapy on cardiovascular events and mortality in patients with obstructive sleep apnea: A meta-analysis. *Sleep Breath* 2016;20:965–74.
18. McEvoy RD, Antic NA, Heeley E, et al. CPAP for prevention of cardiovascular events in obstructive sleep apnea. *N Engl J Med* 2016;375:919–31.
19. Wang X, Zhang Y, Dong Z, et al. Effect of continuous positive airway pressure on long-term cardiovascular outcomes in patients with coronary artery disease and obstructive sleep apnea: A systematic review and meta-analysis. *Respir Res* 2018;19:61.
20. Yu J, Zhou Z, McEvoy RD, et al. Association of positive airway pressure with cardiovascular events and death in adults with sleep apnea: A systematic review and meta-analysis. *JAMA* 2017;318: 156–66.
21. Li J, Li K. Effects of continuous positive airway pressure on middle ear pressure and acoustic stapedial reflex. *Otolaryngol Head Neck Surg* 2016;155:307–11.
22. Lin FY, Gurgel RK, Popelka GR, et al. The effect of continuous positive airway pressure on middle ear pressure. *Laryngoscope* 2012;122:688–90.
23. Yung MW. The effect of nasal continuous positive airway pressure on normal ears and on ears with atelectasis. *Am J Otol* 1999;20:568–72.
24. Thom JJ, Carlson ML, Driscoll CL, et al. Middle ear pressure during sleep and the effects of continuous positive airway pressure. *Am J Otolaryngol* 2015;36:173–7.
25. Keller AP Jr. A study of the relationship of air pressure to myringorupture. *Laryngoscope* 1958;68:2015–29.
26. Ansari AS, Dennis BB, Shah D, et al. An unusual case of infective pneumocephalus: Case report of pneumocephalus exacerbated by continuous positive airway pressure. *BMC Emerg Med* 2018;18:2.
27. Endara-Bravo A, Ahoubim D, Mezerhane E, et al. Alternobaric vertigo in a patient on positive airway pressure therapy. *J Clin Sleep Med* 2013;9:1347–8.
28. McCormick JP, Hildrew DM, Lawlor CM, et al. Otic barotrauma resulting from continuous positive airway pressure: Case report and literature review. *Ochsner J* 2016;16:146–9.
29. Weaver LK, Fairfax WR, Greenway L. Bilateral otorrhagia associated with continuous positive airway pressure. *Chest* 1988;93: 878–9.
30. Farinetti A, Ben Gharbia D, Mancini J, et al. Cochlear implant complications in 403 patients: Comparative study of adults and children and review of the literature. *Eur Ann Otorhinolaryngol Head Neck Dis* 2014;131:177–82.
31. Tarkan O, Tuncer U, Ozdemir S, et al. Surgical and medical management for complications in 475 consecutive pediatric cochlear implantations. *Int J Pediatr Otorhinolaryngol* 2013;77: 473–9.

32. Balkany TJ, Connell SS, Hodges AV, et al. Conservation of residual acoustic hearing after cochlear implantation. *Otol Neurotol* 2006;27:1083–8.
33. Brown RF, Hullar TE, Cadieux JH, et al. Residual hearing preservation after pediatric cochlear implantation. *Otol Neurotol* 2010; 31:1221–6.
34. Carlson ML, Patel NS, Tombers NM, et al. Hearing preservation in pediatric cochlear implantation. *Otol Neurotol* 2017;38: e128–33.
35. Centers for Disease C, Prevention. Estimated county-level prevalence of diabetes and obesity – United States. *MMWR Morb Mortal Wkly Rep* 2009;58:1259–63.
36. Myers CA, Slack T, Martin CK, et al. Regional disparities in obesity prevalence in the United States: A spatial regime analysis. *Obesity (Silver Spring)* 2015;23:481–7.
37. Assing Hvidt E, Lykkegaard J, Pedersen LB, et al. How is defensive medicine understood and experienced in a primary care setting? A qualitative focus group study among Danish general practitioners. *BMJ Open* 2017;7:e019851.
38. Studdert DM, Mello MM, Sage WM, et al. Defensive medicine among high-risk specialist physicians in a volatile malpractice environment. *JAMA* 2005;293:2609–17.
39. Vrabec JT. Workforce analysis of neurotologists in the United States. *Otol Neurotol* 2013;34:755–61.