Usage Patterns of CT and MRI in the Evaluation of Otologic Disease

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Objective: To evaluate the current trends and usage patterns of radiographic imaging for otologic disease by specialty, length of practice, practice setting, geographic region, and pediatric volume.
Study Design: Cross-sectional study.
Setting: Survey of physicians.
Subjects: General Otolaryngologists and Otologists/Neurotologists (O/N) of the American Academy of Otolaryngology – Head and Neck Surgery (AAO-HNS).
Methods and Outcome Measures: An electronic questionnaire was distributed to AAO-HNS members. Respondents were separated into groups by specialty, length of practice, practice setting, region, and pediatric exposure. Chi-square tests were performed for the determination of significance.
Results: The survey was sent to 5,168 members of AAO-HNS. The response rate was 10.6% (n = 546) and 18.1% for only O/N (n = 143). Most respondents were generalists (74%), in practice >20 years (51%), with a primarily adult practice (95%). O/N were more often academics (44 versus 17% combined, 40% private; $p < 0.001$) and saw fewer children (80 fewer than 25%; $p < 0.001$). Compared with generalists, O/N were more likely to respond with more frequent and earlier magnetic resonance imaging (MRI) utilization in the workup of the majority of otologic diseases. Significant differences in usage patterns for various conditions were demonstrated across all categories, but specialty training was the most common. Generalists (34 versus 12% of O/N; $p < 0.001$), physicians practicing >20 years (32 versus 18% of < 5 yrs; $p = 0.006$), and private practice physicians (34 versus 14–20% of others; $p < 0.001$) relied more heavily on the radiology report to interpret MRI scans.
Conclusion: Subspecialty training seems to be the main variable correlating with significant differences in the use of MRI and computed tomography imaging in patients with otologic disease. **Key Words:** CT—Imaging—MRI—Neurotology—Otology.

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Imaging has consistently been a useful tool in the assessment of the complex temporal bone anatomy, as well as the evaluation and treatment of otologic pathology. The revolutionary development of computed tomography (CT) imaging in the 1970s allowed for sequential slices to be reconstructed into a three-dimensional map of the temporal bone (1,2). CT imaging of the temporal bone benefits from its high spatial resolution and ability to display small, discrete structures of the middle and inner ear. While bony resolution is excellent in CT imaging, soft tissue delineation is more difficult to obtain, and the advent of magnetic resonance imaging (MRI) has augmented, and in some aspects replaced, the use of CT in the diagnosis, management, and follow-up of otologic disease (3–7). MRI has allowed for further delineation of cerebellopontine angle, petrous apex, and middle ear/mastoid lesions. Newer sequences, such as diffusion weighted, as well as further development of high-energy MRI, have allowed for higher resolution and further characterization of lesions (3,6,8–10). MRI studies have been a valuable tool for follow-up of cholesteatoma in children, but there is currently growing evidence for a role of this imaging modality in evaluating other otologic complaints in the pediatric population, particularly for diagnostic value of intracranial pathology (11–14).

Furthermore, as relative even to other CT imaging, temporal bone CT requires a high dose of radiation. With the standard z-axis ultra-high-resolution technique for temporal bone CT, a dose index of over 80 milligray (mGy) is administered, compared with 30 to 70 mGy for a routine head CT (15,16). MRI inherently avoids the associated risks of radiation, by functioning to emit a radiofrequency to align the nucleic spin of hydrogen atoms, then capturing the energy released from these molecules as they transition energy states (9). The magnet of the MRI scanner is measured in Tesla (T), with most scanners containing a 1.5 or 3.0 T magnet. With

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technological advances, 7.0 and even 11.7 T scanners have come into practice (8,9).

Otolaryngology training currently includes the use and interpretation of multiple imaging modalities, primarily centered around CT imaging, due to speed and availability (17). However, the use of MRI is increasing and, given the great potential of alternative imaging modalities in otolaryngology, practice patterns will be expected to change (10). There is no data in the literature discussing the practice patterns of MRI and CT usage in Otolaryngology. It was our goal to study these patterns specifically in relation to Otology and Neurotology, given the high utility of both radiographic techniques in this subspecialty.

METHODS

Institutional Review Board approval at Penn State Milton S. Hershey Medical Center was obtained. An electronic survey using the RedCAP data collection system was distributed via email to members of the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) identifying as Neurotologists, Otologists, and General Otolaryngologists. Twelve items on the questionnaire (see supplemental digital content, http://links.lww.com/MAO/B204) assessed demographics and the usage of CT and MRI imaging in the diagnosis of otologic disease. Geographic location of current practice was selected from 51 options via dropdown menu, and answers were reorganized into the four main geographic regions (Northeast, Midwest, South, West) according to the United States Census Bureau regional divisions (18).

Data were compiled into a password-protected, deidentified master excel document. In addition to analysis by subspecialty training (General Otolaryngologists, Otologists/Neurotologists [O/N]), responses were also separated by practice setting (private, academic, combined academic/private), length of practice (LOP) (0–5 yrs, 6–10 yrs, 11–15 yrs, 16–20 yrs, and more than 20 yrs), geographical region (Northeast, West, South, Midwest), and pediatric volume (less than 10%, 10–25%, 25–50%, 50–75%, and more than 75%).

Frequency and relative frequency numbers were used to summarize the distribution of our key variables, which were all categorical. The bivariate association between variables was performed using Pearson χ^2 test of independence, or the Mantel-Haenszel χ^2 test for linear associations when applicable. Multiple logistic regression models were performed using predictors of subspecialty, length of practice, practice setting, region, and pediatric volume. Responses to two questions used in the multivariate models were dichotomized. First, answers to ''which imaging studies do you feel more comfortable reading: CT or MRI?'' were combined such that ''Always CT'' or ''Somewhat CT'' were analyzed together compared with all other responses. Similarly, responses to ''do you rely on radiology/report for MRI?'' were split into one group for ''Always'' and ''Often'' and another for ''Never, I read my own MRI'' and ''Sometimes.'' Results of the logistic regression were reported as the odds ratios and their 95% confidence intervals (CI) for each category of the predictor compared with the reference level. All analyses were performed using statistical software SAS version 9.4 (SAS Institute, Cary, NC). All tests were two-sided and the statistical significance level used was 0.05.

RESULTS

The electronic survey was distributed to 5,179 members of AAO-HNS, with a bounceback rate of 0.15% (n = 11). Of 5,168 successfully delivered surveys, 790 were delivered to O/N. The overall response rate was 10.6% (n = 546) and 18.1% when considering only O/N (n = 143). Demographic data is provided in Table 1. The majority of respondents were generalists (74%), in private practice (72%) and have been in practice greater than 20 years (51%). Academic

TABLE 1. *Demographic data of survey respondents*

Variable	All	General Otolaryngologists (N = 400)	Otologists/ Neurotologists (N = 143)	p Value
Location of practice				0.269
Midwest	104 (20.5%)	82 (21.7%)	21 (16.4%)	
Northeast	112 (22%)	76 (20.1%)	35 (27.3%)	
South	186 (36.6%)	142 (37.6%)	44 (34.4%)	
West	106 (20.9%)	78 (20.6%)	28 (21.9%)	
Length of practice				0.886
0–5 yrs	89 (16.5%)	62 (15.7%)	26 (18.3%)	
6–10 yrs	60 (11.1%)	46 (11.6%)	14 (9.9%)	
11–15 yrs	46 (8.5%)	35 (8.9%)	11 (7.7%)	
16–20 yrs	69 (12.8%)	49 (12.4%)	20 (14.1%)	
More than 20 yrs	275 (51%)	203 (51.4%)	71 (50%)	
Practice setting				<0.001[a]
Academic	102 (18.8%)	40 (10%)	62 (43.7%)	
Combined	50 (9.2%)	26 (6.5%)	24 (16.9%)	
Private	391 (72%)	334 (83.5%)	56 (39.4%)	
Pediatric patient volume				<0.001[a]
Less than 10%	156 (28.6%)	96 (24%)	59 (41.3%)	
10–25%	226 (41.5%)	170 (42.5%)	56 (39.2%)	
25–50%	136 (25%)	114 (28.5%)	22 (15.4%)	
50–75%	16 (2.9%)	13 (3.2%)	2 (1.4%)	
More than 75%	11 (2%)	7 (1.8%)	4 (2.8%)	

[a]Indicates $p < 0.05$.

physicians were significantly (43.7 versus 16.9% combined, 39.4% private; $p < 0.001$) associated with O/N. Geographic distribution was fairly even across four regions, with slightly higher response in the South (36.6%). Nearly all respondents (95%) had a majority adult practice (<50% pediatric). A summary of significant findings to survey responses by category is provided in Table 2. Figures 1–4 demonstrate trends in responses by specialty training, the category most associated with significant differences in practice patterns of imaging utilization.

TABLE 2. *Summary of significant findings to survey responses by category*

Question	Specialty[a]	Length of Practice[a]	Practice Setting	Region	Pediatric Volume[a]
What percentage of your patients have...					
Dizziness	<0.001[b]	0.098	0.244	0.242	<0.001[b]
Tinnitus	<0.001[b]	0.116	0.246	0.019[b]	<0.001[b]
Hearing loss	<0.001[b]	0.797	<0.001[b]	0.865	<0.001[b]
Cholesteatoma	<0.001[b]	0.101	<0.001[b]	0.165	0.182
How often is MRI used in the workup of...					
Pulsatile tinnitus	0.187	0.518	0.408	0.475	0.026[b]
Unilateral tinnitus	<0.001[b]	0.557	0.749	0.975	0.625
Bilateral tinnitus	0.021[b]	0.001[b]	0.405	0.976	0.913
Sudden hearing loss	<0.001[b]	0.006[b]	0.134	0.089	0.002[b]
Asymmetric hearing loss	0.005[b]	0.016[b]	0.393	0.086	0.289
Episodic dizziness	<0.001[b]	0.450	0.792	0.205	0.623
Constant dizziness	0.870	0.186	0.010[b]	0.857	0.256
Cochlear implant evaluation (adult)	<0.001[b]	0.292	<0.001[b]	0.390	0.105
Cholesteatoma (initial)	0.639	0.381	0.349	0.260	0.060
Cholesteatoma (follow-up)	<0.001[b]	0.186	<0.001[b]	0.611	0.186
Menière's disease	<0.001[b]	0.608	0.255	0.316	0.025[b]
Facial nerve palsy	0.043[b]	0.549	0.468	0.212	0.945
Facial pain	<0.001[b]	0.197	0.102	0.211	0.014[b]
Trigeminal pain	<0.001[b]	0.154	0.764	0.359	0.038[b]
Aural fullness	0.555	<0.001[b]	0.547	0.500	0.396
If used, at what point is MRI ordered for...					
Unilateral pulsatile tinnitus	0.012[b]	0.011[b]	0.185	0.063	0.026[b]
Bilateral pulsatile tinnitus	0.116	0.093	0.115	0.515	0.005[b]
Unilateral nonpulsatile tinnitus	<0.001[b]	0.228	0.009[b]	0.380	0.144
Bilateral nonpulsatile tinnitus	0.499	0.294	0.842	0.900	0.907
Sudden hearing loss	<0.001[b]	0.002[b]	0.061	0.224	0.090
Asymmetric hearing loss	0.008[b]	0.006[b]	0.026[b]	0.285	0.440
Episodic dizziness	0.008[b]	0.092	0.025[b]	0.261	0.473
Constant dizziness	0.945	0.594	0.005[b]	0.259	0.766
Menière's disease	<0.001[b]	0.001[b]	0.011[b]	0.892	0.351
Facial nerve palsy	0.120	0.736	<0.001[b]	0.081	0.975
Cholesteatoma (follow-up)	0.353	0.006[b]	0.238	0.282	0.874
Do you rely on radiologist/report for MRI?	<0.001[b]	0.006[b]	<0.001[b]	0.730	0.598
What Tesla MRI does your facility use?	<0.001[b]	0.340	<0.001[b]	0.455	0.401
Which imaging studies do you feel more comfortable reading: CT or MRI?	<0.001[b]	0.031[b]	<0.001[b]	<0.001[b]	0.019[b]
In which of the following do you prefer MRI over CT of temporal bone...					
Inner ear abnormalities	<0.001[b]	0.665	0.047[b]	0.091	0.149
Cholesteatoma (adult)	0.924	0.019[b]	0.286	0.165	0.555
Cholesteatoma (child)	0.501	0.100	0.223	0.497	0.659
Recurrent cholesteatoma (adult)	<0.001[b]	0.225	<0.001[b]	0.602	0.429
Recurrent cholesteatoma (child)	<0.001[b]	0.230	<0.001[b]	0.828	0.328
Enlarged vestibular aqueduct	0.502	0.002[b]	0.684	0.972	0.483
Superior canal dehiscence	<0.001[b]	<0.001[b]	0.003	0.094	0.022[b]
Facial nerve palsy (adult)	<0.001[b]	0.100	0.315	0.994	0.197
Facial nerve palsy (child)	<0.001[b]	0.090	0.508	0.980	0.134
Glomus tympanicum/jugulare	0.708	0.137	0.237	0.622	0.929

[a]Indicates use of Mantel–Haenszel χ^2 test, all others use χ^2 test of independence.
[b]Indicates $p < 0.05$.

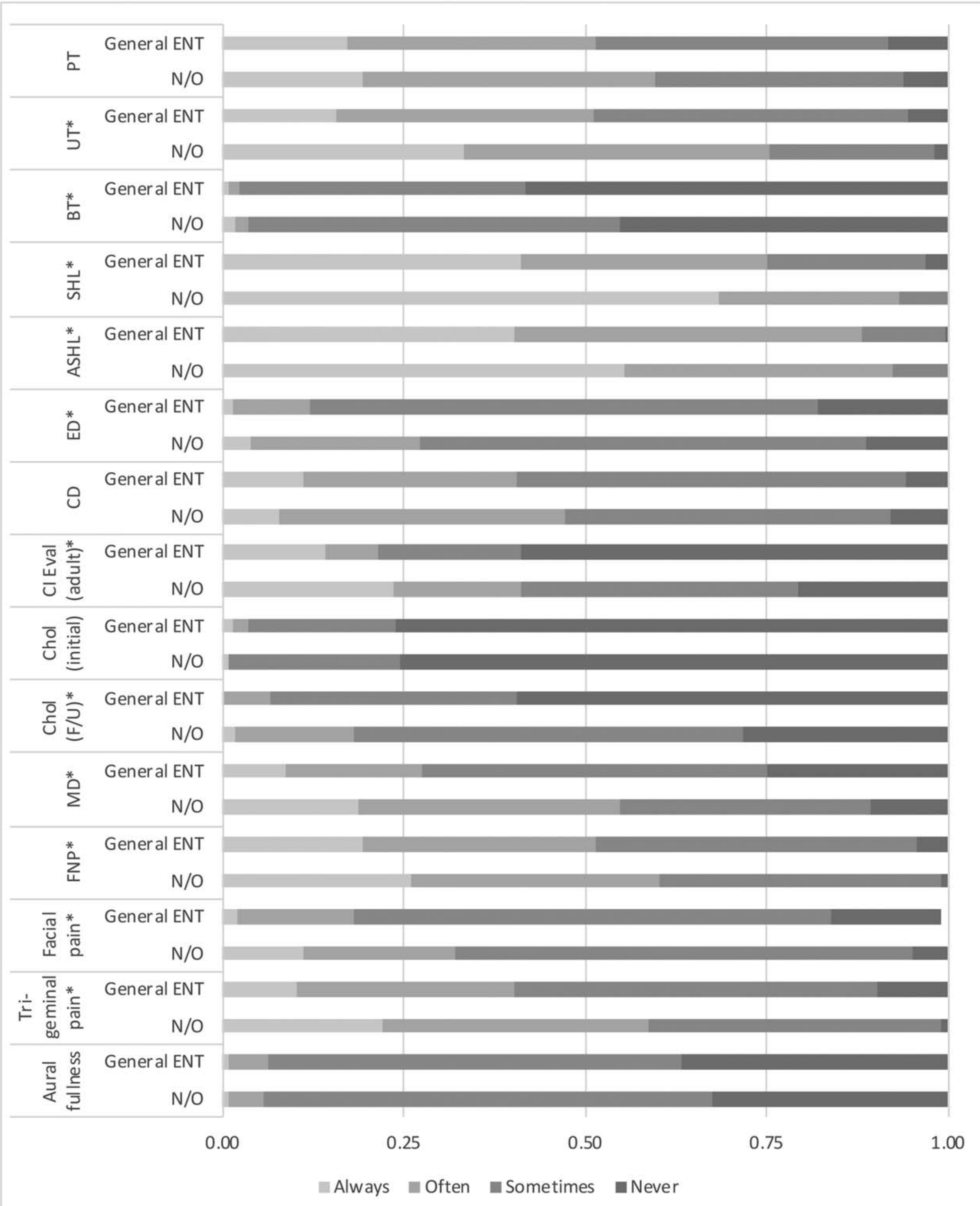

FIG. 1. Trends in MRI utilization for various otologic conditions by specialty training. *X*-axis denotes response rate; *denotes statistical significance. ASHL indicates asymmetric hearing loss; BT, bilateral tinnitus; CD, constant dizziness; chol, cholesteatoma; CI, cochlear implant; ED, episodic dizziness; FNP, facial nerve palsy; MD, Menière's disease; MRI, magnetic resonance imaging; PT, pulsatile tinnitus; SHL, sudden hearing loss; UT, unilateral tinnitus.

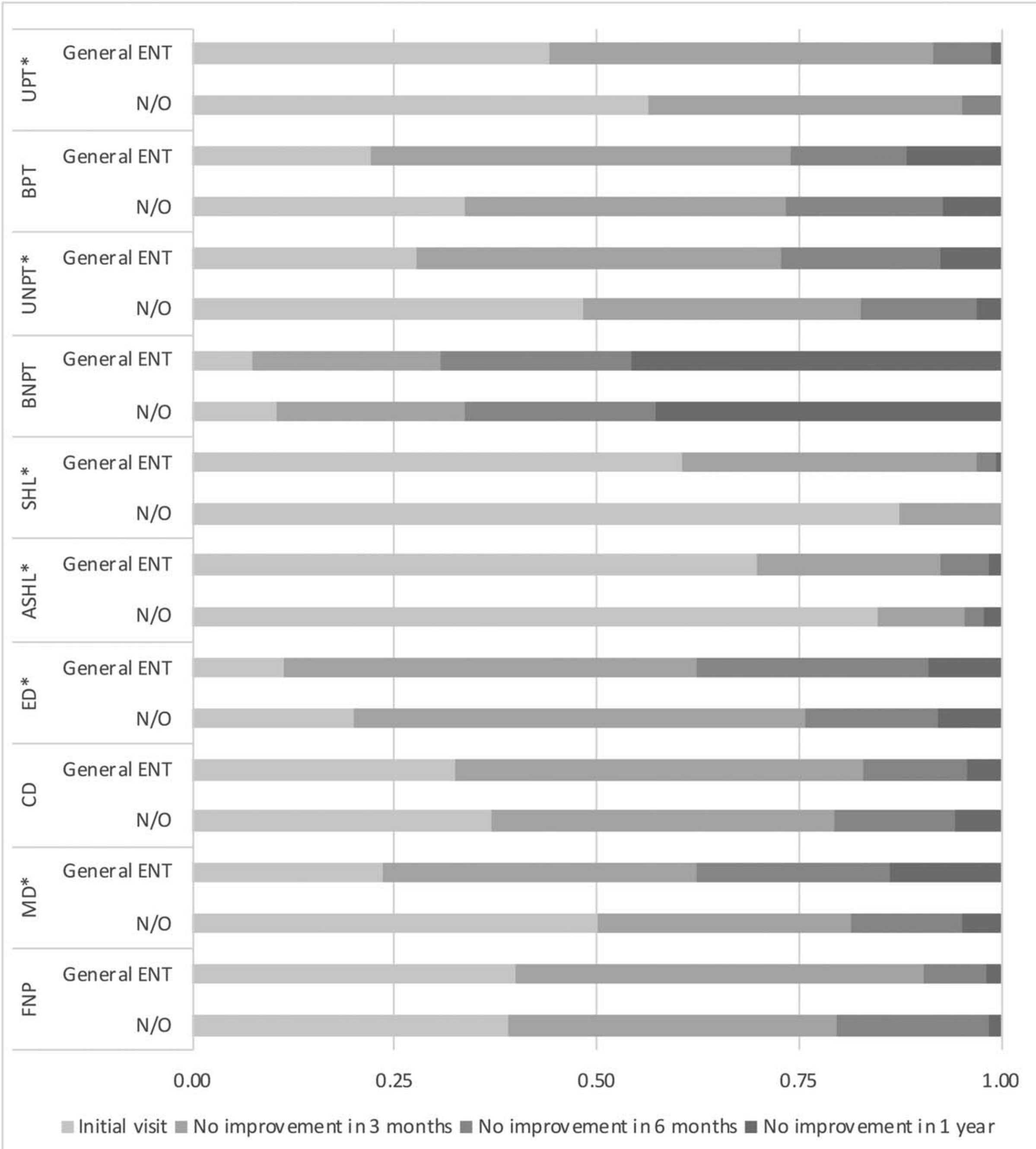

FIG. 2. Timeline for MRI utilization for otologic conditions by specialty training. *X* axis denotes response rate; *denotes statistical significance. ASHL indicates asymmetric hearing loss; BNPT, bilateral nonpulsatile tinnitus; BPT, bilateral pulsatile tinnitus; CD, constant dizziness; ED, episodic dizziness; FNP, facial nerve palsy; MD, Menière's disease; MRI, magnetic resonance imaging; SHL, sudden hearing loss; UNPT, unilateral nonpulsatile tinnitus; UPT, unilateral pulsatile tinnitus.

Otologic Disease in Practice

As expected, O/N reported significantly ($p < 0.001$) higher proportions (>25%) of patients with dizziness (58 versus 17%), tinnitus (70 versus 45%), hearing loss (94 versus 61%), and cholesteatoma (38 versus 1%). Of note, 99% of generalists reported a practice of less than 25% cholesteatoma. Private practice physicians saw significantly ($p < 0.001$) fewer patients with hearing loss (64 versus 85% for academics, 80% for combined) and cholesteatoma (5 versus 29% for academics, 18% for combined), with no differences for dizziness and tinnitus. Regional differences were significant ($p = 0.019$) for patients with tinnitus, with Midwestern physicians seeing fewer patients (40 versus 47–59%). Dizziness (20–37% versus 0%) and tinnitus

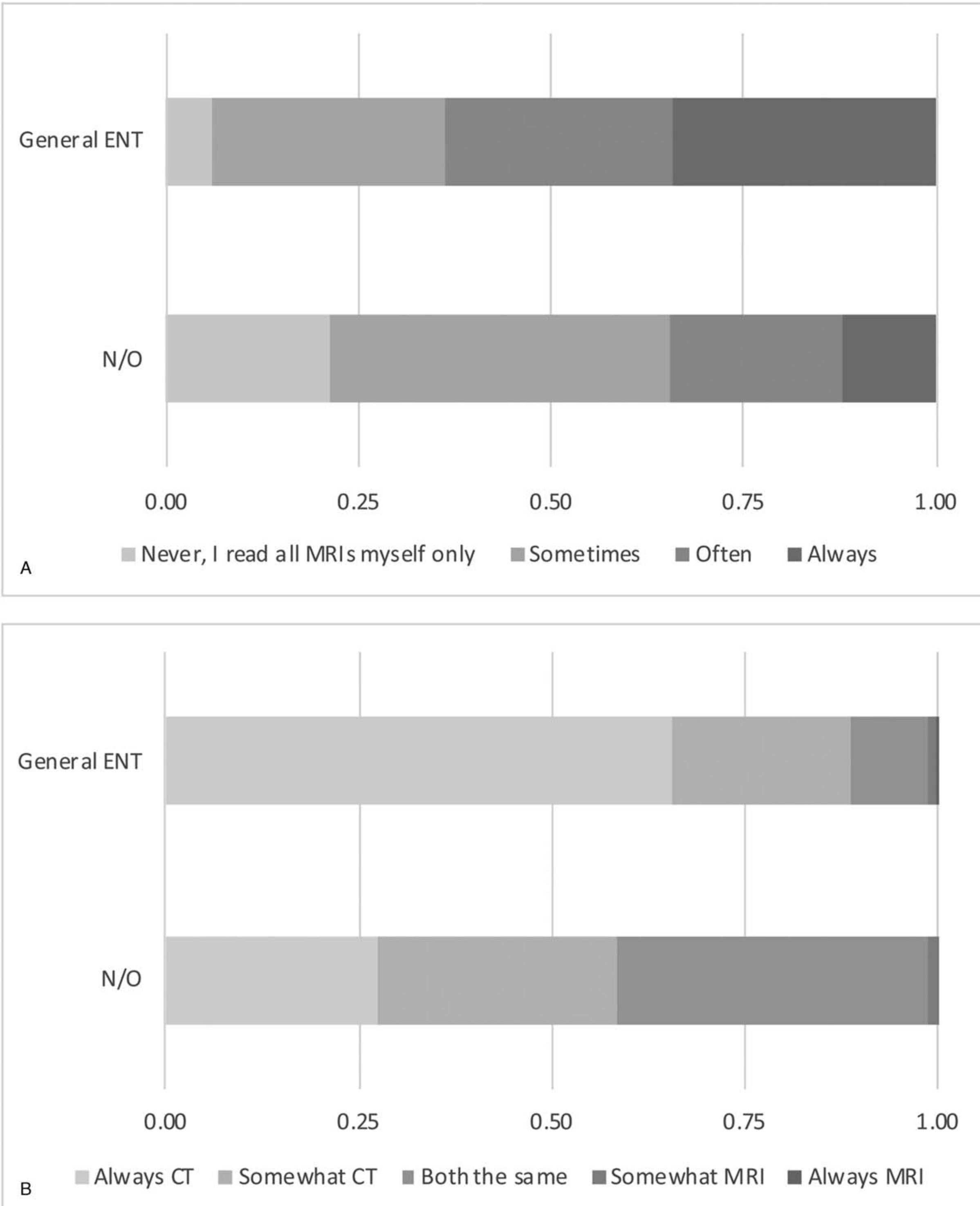

FIG. 3. Reliance on radiology report for MRI (*A*) and comfort reading CT in comparison with MRI (*B*) by specialty training. *X*-axis denotes the rate. *denotes statistical significance. CT indicates computed tomography; MRI, magnetic resonance imaging.

(39–62% versus 18%) were significantly ($p < 0.001$) more common in adult practices. Hearing loss also significantly differed ($p < 0.001$) with pediatric exposure, with over half of physicians in primarily adult (<10% pediatrics) or pediatric (>75%) practices seeing hearing loss. No difference in cholesteatoma was observed by pediatric exposure, nor were any differences were observed in the types of patient concerns by LOP.

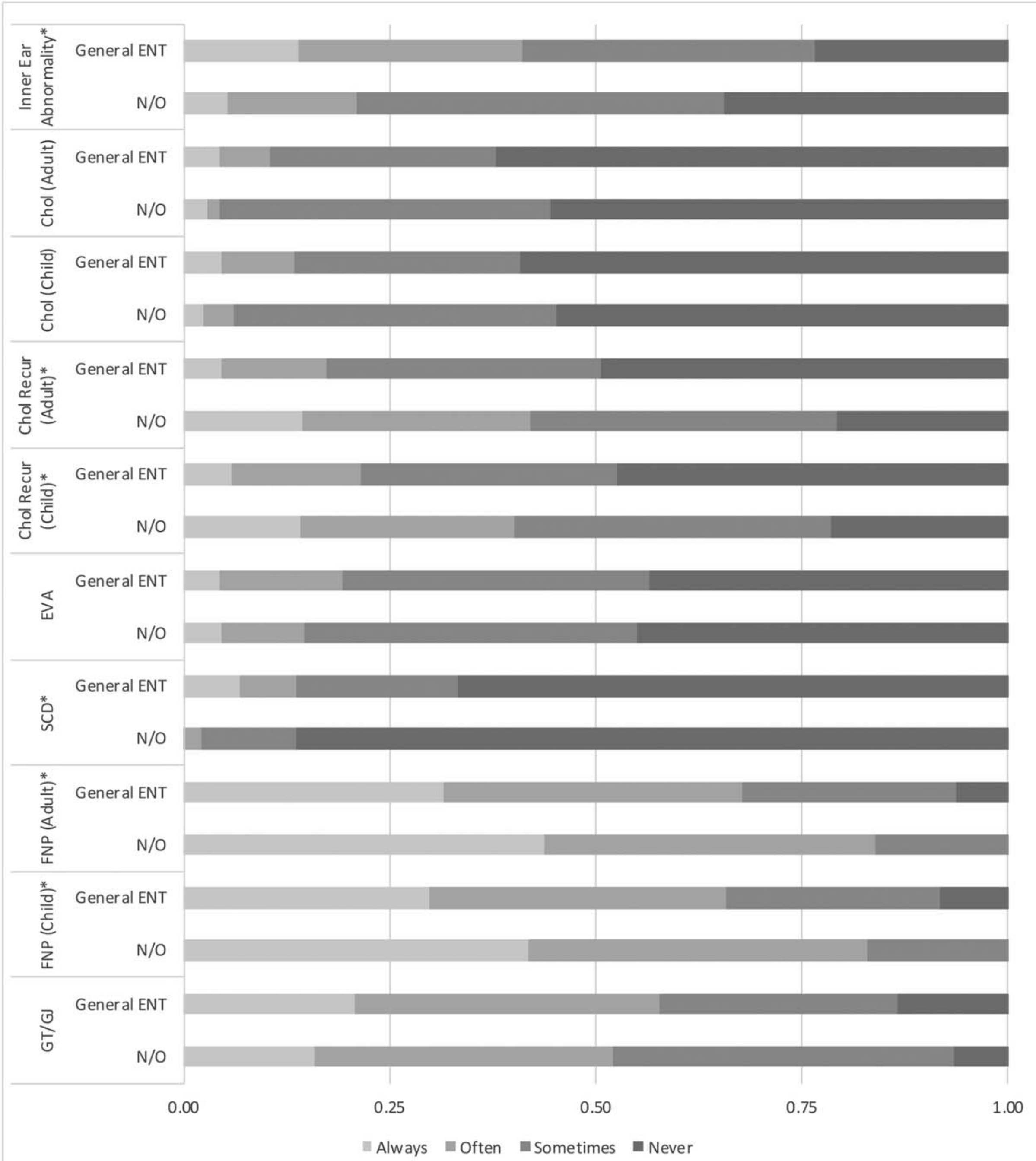

FIG. 4. Preference of MRI over CT scan for various otologic diseases by specialty training; *X* axis denotes response rate; *denotes statistical significance. chol indicates cholesteatoma; CT, computed tomography; EVA, enlarged vestibular aqueduct; FNP, facial nerve palsy; GT/GJ, glomus tympanicum/glomus jugulare; MRI, magnetic resonance imaging; SCD, semicircular canal dehiscence.

MRI Ordering Practice to Assess Otologic Conditions

More O/N reported ''Always'' and ''Often'' using MRI than generalists to assess many disease states, including unilateral ($p < 0.001$) and bilateral tinnitus ($p = 0.021$), sudden ($p < 0.001$) and asymmetric hearing loss ($p = 0.005$), episodic dizziness ($p < 0.001$), Menière's disease (MD) ($p < 0.001$), facial nerve palsy (FNP) ($p = 0.043$), facial and trigeminal pain ($p < 0.001$), cochlear implantation (CI) evaluation in adults ($p < 0.001$) and cholesteatoma follow-up ($p < 0.001$). Notably, 76% of both generalists and O/N reported never using MRI for initial cholesteatoma evaluation (Fig. 1).

O/N also used MRI earlier than generalists to assess unilateral pulsatile ($p = 0.012$) and nonpulsatile tinnitus ($p < 0.001$), asymmetric ($p = 0.008$) and sudden hearing loss (SHL) ($p < 0.001$), episodic dizziness ($p = 0.008$), and MD ($p < 0.001$). Generalists ordered MRI earlier for the evaluation of FNP. Of note all O/N obtained MRI within 3 months without symptom improvement in SHL (Fig. 2).

LOP was significantly associated with MRI use in bilateral tinnitus ($p = 0.001$), SHL ($p = 0.006$), asymmetric hearing loss ($p = 0.016$), and aural fullness ($p < 0.001$). Physicians with shorter LOP reported ''Always'' and ''Often'' using MRI more than those with longer LOP to assess sudden and asymmetric hearing loss. However, these physicians also more often reported never using MRI to assess bilateral tinnitus and aural fullness.

LOP was also associated with time to ordering MRI for unilateral pulsatile tinnitus ($p = 0.011$), SHL ($p = 0.002$), asymmetric hearing loss ($p = 0.006$), MD ($p = 0.001$), and cholesteatoma follow-up ($p = 0.006$). Physicians in practice >20 years ordered MRI less frequently for initial evaluation of unilateral pulsatile tinnitus, SHL, and asymmetric hearing loss. For cholesteatoma management, physicians with greater LOP were less aggressive with MRI follow-up.

Practice setting had significant effect on MRI use to evaluate constant dizziness ($p = 0.010$), adult CI ($p < 0.001$), and cholesteatoma follow-up ($p < 0.001$). More academics ''Always'' or ''Often'' used MRI for CI and cholesteatoma follow-up, while more private and combined physicians used MRI for constant dizziness.

Timeline for ordering MRI also significantly differed by practice setting for unilateral nonpulsatile tinnitus ($p = 0.009$), asymmetric hearing loss ($p = 0.026$), episodic dizziness ($p = 0.025$), constant dizziness ($p = 0.005$), MD ($p = 0.011$), and FNP ($p < 0.001$). More academic and combined physicians ordered MRI upon initial evaluation of unilateral nonpulsatile tinnitus and asymmetric hearing loss. Furthermore, academics ordered MRI earlier for evaluation of episodic dizziness and MD. However, academic physicians were more likely to wait at least 6 months before ordering MRI for constant dizziness, and most private physicians ordered MRI within the first 3 months for FNP.

Physicians with greater pediatric exposure less frequently ordered MRI to evaluate pulsatile tinnitus ($p = 0.026$), SHL ($p = 0.002$), MD ($p = 0.025$), facial pain ($p = 0.014$), and trigeminal pain ($p = 0.038$). Furthermore, increasing pediatric practice was significantly related to delay in ordering MRI to evaluate unilateral ($p = 0.026$) and bilateral pulsatile tinnitus ($p = 0.005$). There were no regional differences in the use of MRI to evaluate otologic conditions.

Radiology Reliance

As depicted in Figure 3A, O/N were significantly ($p < 0.001$) more comfortable reading their own MRI studies, with 34% of generalists always reliant on radiology reports (versus 12% of O/N). More than 20% of O/N reported always interpreting MRI results independent of radiology.

With increasing LOP, physicians were significantly ($p = 0.006$) more reliant on radiology, such that 62% of physicians with >20 years practice ''Always'' or ''Often'' relied on radiology for MRI interpretation (versus 46% with LOP $\leq$ 5 yrs).

Practice setting significantly ($p < 0.001$) differed in radiology reliance for MRI, as 34% of private practice physicians always required radiology reads, compared with 14 and 20% of academic and combined physicians, respectively.

Pediatric exposure and geographic region played no significant role in the interpretation of MRI.

MRI Power

Specialty was significantly ($p < 0.001$) related to type of MRI. Though nearly half of generalists reported not knowing the magnetic power of their MRI (versus 6% of O/N), when the power was known, more generalists accessed a lower power (1.5 T) MRI than O/N.

Practice setting was significantly ($p < 0.001$) related to MRI power, although power was unknown by many private and combined physicians. When known, more private and combined physicians (26 and 22 versus 10%) report exclusive use of 1.5 T MRI.

Geographic regions, pediatric exposure, and LOP had no association with MRI scanning power.

Comparing MRI to CT Use

Overall, a significant relationship ($p < 0.001$) was observed between specialty and comfort reading CT and MRI. As shown in Figure 3B, both groups were more comfortable reading CT; however, CT was ''Always'' or ''Sometimes'' preferred by most generalists, compared with half of O/N. Though no one from either group reported always being more comfortable reading MRI, nearly half of O/N reported reading MRI with the ''Same'' or ''Somewhat More'' comfort than CT, compared with one-tenth of generalists.

Specialty was significantly related to the preference of MRI over CT in several otologic conditions, including inner ear abnormalities ($p < 0.001$), cholesteatoma recurrence in adults ($p < 0.001$) and children ($p < 0.001$), superior canal dehiscence (SCD) ($p < 0.001$), and FNP in adults ($p < 0.001$) and children ($p < 0.001$), depicted in Figure 4. In evaluating cholesteatoma recurrence, nearly half of O/N ''Always'' or ''Often'' preferred MRI over CT for adults and children. When assessing FNP, more O/N always preferred MRI to CT in both adults and children. Fewer O/N ''Always'' or ''Often'' preferred MRI over CT compared with generalists for evaluation of inner ear abnormalities and SCD.

A significant difference ($p = 0.031$) in LOP was observed for comfort reading CT versus MRI. Additionally, shorter LOP was associated with ''Never'' preferring MRI over CT for the diagnosis of cholesteatoma in adult ($p = 0.019$), enlarged vestibular aqueduct ($p = 0.002$), and SCD ($p = 0.001$).

Practice setting was significantly ($p < 0.001$) associated with comfort in reading CT/MRI, such that more private practice physicians always preferred reading CT over MRI than academics. Although no physicians preferred reading MRI, twice as many academics thought as or somewhat more comfortable reading MRI compared with CT than private physicians. Practice setting was significantly associated with imaging modality preference for inner ear abnormalities ($p = 0.047$), cholesteatoma recurrence in adults ($p < 0.001$) and children ($p < 0.001$), and SCD ($p = 0.003$). For evaluation of inner ear abnormalities, more private practice physicians ''Always'' or ''Often'' preferred MRI to CT. However, more academic physicians reported preference of MRI to CT in the evaluation of recurrent cholesteatoma for both adults and children. In the assessment of SCD, more academic and combined physicians never preferred MRI to CT scan compared with private physicians.

Significant regional differences ($p < 0.001$) were observed for comfort reading imaging, where more than half of Southern and Midwestern physicians always preferred reading CT to MRI. Western physicians were as or somewhat more comfortable reading MRI to CT. There were no regional differences in CT/MRI preferences for specific otologic conditions.

Pediatric exposure was significantly ($p = 0.019$) associated with comfort in reading imaging, and SCD was the only specific disease state noted to differ ($p = 0.039$), with MRI preferred to CT when pediatric volume was lower.

Multivariate Logistic Regression Modeling

Multivariate analyses were performed using all categories, and Table 3 depicts significant findings. Generalists were over four times more likely to prefer CT compared with O/N in a multivariate model controlling for LOP, practice setting, region, and pediatric volume. A regional difference was also observed in this model, such that Midwest physicians were nearly five times more likely to prefer CT compared with Western physicians.

In another multivariate model assessing reliance on radiology report to read MRI, subspecialty training was again found to be significant when controlling for other predictors. Generalists were nearly three times more likely to report ''Always'' or ''Often'' relying on radiology to read MRI compared with O/N.

DISCUSSION

Survey studies investigating imaging practice patterns have been performed on specific otolaryngologic disease (19–21). Such studies provide insight to the preferences of practicing physicians on a number of disease states and can inform responses to changing guidelines. We present a unique dataset broadly capturing the current use of imaging in the assessment of various otologic disease reflected by several different practice parameters. Despite a majority of survey respondents being generalists, specialty had the greatest impact on imaging practice, with O/N using MRI earlier and more frequently. Over half of respondents reported LOP greater than 20 years, though physicians with a shorter duration of practice were found to be more comfortable using MRI. Furthermore, although two-thirds of respondents practiced in the private setting, academic physicians demonstrated significantly more comfort using MRI for the evaluation of many otologic diseases.

Over half of all surveyed reported more comfort with CT over MRI, though O/N, academics, and Western physicians were increasingly comfortable reading MRI. O/N reported more comfort integrating MRI into practice, and used MRI earlier in the workup of many otologic conditions. The role of imaging in the practice of otology varies, while O/N are often preparing operative intervention and may need to ascertain intricate bony

TABLE 3. *Multivariate models assessing subspecialty, LOP, practice setting, geographic region, and pediatric exposure for imaging modality preference and reliance on radiology for MRI*

		Which Imaging Studies Do You Feel More Comfortable Reading: CT or MRI? (Always/Sometimes CT Versus Others)			Do You Rely on Radiologist/Report for MRI? (Never/Sometimes Versus Others)		
Variable	Category Versus Reference Level	Odds Ratio	95% CI	p Value	Odds Ratio	95% CI	p Value
Subspecialty	General ENT versus N/O	4.88	(2.78, 8.57)	<0.001[a]	0.35	(0.21, 0.56)	<0.001[a]
LOP	6–10 yrs versus 0–5 yrs	1.41	(0.46, 4.34)	0.554	1.03	(0.50, 2.13)	0.941
	11–15 yrs versus 0–5 yrs	1.14	(0.36, 3.60)	0.820	0.79	(0.36, 1.73)	0.557
	16–20 yrs versus 0–5 yrs	0.81	(0.32, 2.06)	0.651	0.64	(0.31, 1.29)	0.214
	More than 20 yrs versus 0–5 yrs	0.62	(0.30, 1.29)	0.200	0.55	(0.32, 0.95)	0.032[a]
Practice setting	Combined versus academic	1.44	(0.56, 3.70)	0.450	0.97	(0.44, 2.11)	0.936
	Private versus Academic	1.71	(0.85, 3.40)	0.130	0.64	(0.36, 1.12)	0.120
Region	Midwest versus West	4.91	(1.96, 12.30)	<0.001[a]	0.81	(0.44, 1.47)	0.479
	Northeast versus West	1.85	(0.91, 3.74)	0.090	0.76	(0.42, 1.36)	0.351
	South versus West	1.79	(0.96, 3.36)	0.068	1.08	(0.65, 1.81)	0.763
Pediatric volume	10–25% versus <10%	0.87	(0.47, 1.59)	0.648	1.75	(1.08, 2.83)	0.024[a]
	25–50% versus <10%	1.15	(0.54, 2.43)	0.721	1.61	(0.93, 2.78)	0.088
	50–75% versus <10%	0.31	(0.07, 1.30)	0.110	1.39	(0.42, 4.60)	0.594
	>75% versus <10%	0.60	(0.12, 2.95)	0.526	2.21	(0.54, 9.00)	0.267

[a]Indicates $p < 0.05$ (or the odds ratio significantly different from 1).

and soft tissue resolution necessary for surgical planning, O/N are also often seeing patients in referral for diagnostic purposes and may focus on ruling in or out retrocochlear lesions. Therefore, O/N likely have a lower threshold for obtaining imaging, particularly MRI, given the higher otologic patient volume and referral pattern.

Though overall O/N were more comfortable ordering MRI and did so earlier, one exception was in FNP, where generalists ordered MRI sooner. Considering the population of FNP patients interfacing with O/N, there are several possible explanations for this finding, including a response bias given larger population of patients with known iatrogenic injury to the facial nerve and patients with previously diagnosed tumors affecting the facial nerve (22). Alternatively, delay in ordering MRI could be due to a more robust understanding of these injuries, as evidence-based practice suggestions against routine diagnostic imaging for patients with new-onset Bell's palsy, and, although MRI findings may show facial nerve enhancement, such findings do not dictate therapeutic intervention (23).

In the evaluation of SHL, our findings demonstrated more frequent use of MRI by O/N and physicians early in practice, and while O/N ordered MRI earlier, physicians in practice longer often delayed ordering MRI. No significance emerged regarding preference of imaging modality. As the AAO-HNS clinical practice guidelines on the subject recommend against the use of routine CT in the initial evaluation of sudden sensorineural hearing loss, they do recommend utilization of MRI in the eventual assessment for retrocochlear pathology (24).

In the assessment of MD, O/N ordered MRI sooner and more frequently than generalists. This practice is in agreement with the clinical practice guidelines set forth by the AAO-HNS, which suggests there may be utility in MRI particularly to assess the internal auditory canal and posterior fossa in a patient with MD. However, evidence is weak and the decision should be made in collaboration with each patient. Similar to patients with SHL, early MRI screening may identify a retrocochlear lesion amenable to surgery with hearing preservation. At this time, many studies are currently underway to better classify the use of imaging in the diagnosis of MD (25).

To evaluate SCD, recent studies suggest that MRI may be equal or superior to CT for diagnostic purposes, though CT is commonly preferred for surgical planning (26–29). Our findings suggest that O/N may be more likely to use a combination of imaging modalities, as fewer O/N reported ''Always'' or ''Often'' preferring MRI to CT for the condition.

Though many generalists and O/N preferred CT to MRI for initial evaluation of cholesteatoma, in assessing recurrent cholesteatoma, O/N and academics were more likely to use MRI, while nearly half of generalists continued to prefer CT for both initial and recurrent cholesteatoma. For cholesteatoma follow-up, O/N and academics were also more likely to use MRI, although LOP was the only parameter of significance on timeline of follow-up, with younger physicians more aggressive in their MRI intervals.

Interestingly, although O/N more frequently used MRI than generalists in the evaluation of CI for adults, O/N more commonly preferred CT. Bony delineation and identification of cochlear ossification is the clear advantage of preoperative surgical planning with CT scan; however, occult vestibular schwannomas may be missed (30). There is evidence that MRI findings may affect implantation site in up to 10% of patients (31).

Physicians with large pediatric practices rarely used MRI, and if so, delayed use, possibly because MRI in young children often requires sedation. However, as examinations of children to evaluate cholesteatoma burden are likely difficult, one can see why MRI may be a useful alternative to second look surgery in this condition (32).

O/N and academics were more comfortable reading their own MRI, more likely to know the power of their MRI facility and had access to high-quality MRI. Younger physicians were more comfortable reading their own MRI. Resolution of inner ear structures is dependent on MRI power, and as new technology is developed to enhance this resolution, device distribution and selection may play a more significant role in the future for imaging the inner ear (33).

Our study has limitations associated with a self-reported survey, namely recall bias, as we are unable to confirm the true frequency of imaging utilization. Furthermore, nonresponse bias is a present factor in this study, suggesting a difference in the characteristics of responders and nonresponders. The demographics of participating physicians were skewed, particularly with respect to practice setting and LOP. No specific details regarding location of postgraduate training were captured that might better reflect the role that training program may play in future inclusion of imaging techniques in otologic care.

CONCLUSION

Our study demonstrates the varying modern approaches to imaging of otologic disease. Subspecialty training seems to correlate with significantly different responses on the use of MRI and CT imaging in patients with otologic disease. Overall differences in imaging practice between groups, primarily by specialty, are likely due to the purpose of imaging, such that generalists are commonly using imaging for diagnostic purposes, while O/N are preparing surgical approach. There is no strong consensus on these practice patterns and training seems to be the main determinant. This survey will help physicians understand current practices and aid in the development of a general practice guideline. Practice patterns in regards to alternative imaging modalities will likely continue to change as new technologies are developed.

REFERENCES

1. Jackler RK, Dillon WP, Schindler RA. Computed tomography in suppurative ear disease: A correlation of surgical and radiographic findings. *Laryngoscope* 1984;94:746–52.
2. Valvassori GE. Update of computed tomography and magnetic resonance in otology. *Am J Otol* 1994;15:203–6.

3. Corrales CE, Fischbein N, Jackler RK. Imaging innovations in temporal bone disorders. *Otolaryngol Clin North Am* 2015;48:263–80.
4. Phelps PD. Imaging in neuro-otology. *Curr Opin Neurol Neurosurg* 1991;4:833–6.
5. Sun W, Guo P, Ren T, Wang W. Magnetic resonance imaging of intratympanic gadolinium helps differentiate vestibular migraine from Ménière disease. *Laryngoscope* 2017;127:2382–8.
6. Lingam RK, Connor SEJ, Casselman JW, Beale T. MRI in otology: Applications in cholesteatoma and Ménière's disease. *Clin Radiol* 2018;73:35–44.
7. Zuo W, Wang F, Yang S, et al. Clinical characteristics of petrosal cholesteatoma and value of MRI-DWI in the diagnosis. *Acta Otolaryngol* 2020;140:281–5.
8. Thylur DS, Jacobs RE, Go JL, Toga AW, Niparko JK. Ultra-high-field magnetic resonance imaging of the human inner ear at 11.7 Tesla. *Otol Neurotol* 2017;38:133–8.
9. Wood R, Bassett K, Foerster. Spry C, Tong L. 1.5 tesla magnetic resonance imaging scanners compared with 3.0 tesla magnetic resonance imaging scanners: Systematic review of clinical effectiveness. *CADTH Technol Overv* 2012;2:e2201.
10. Doshi J, Jindal M, Chavda S, Irving R, De R. Diffusion-weighted magnetic resonance imaging: Its uses in otolaryngology. *J Laryngol Otol* 2009;123:1199–203.
11. Kachniarz B, Chen JX, Gilani S, Shin JJ. Diagnostic yield of MRI for pediatric hearing loss: A systematic review. *Otolaryngol Head Neck Surg* 2015;152:5–22.
12. Levi E, Bekhit EK, Berkowitz RG. Magnetic resonance imaging findings in children with tinnitus. *Ann Otol Rhinol Laryngol* 2015;124:126–31.
13. Bazzi K, Wong E, Jufas N, Patel N. Diffusion-weighted magnetic resonance imaging in the detection of residual and recurrent cholesteatoma in children: A systematic review and meta-analysis. *Int J Pediatr Otorhinolaryngol* 2019;118:90–6.
14. Denoyelle F, Simon F, Chang KW, et al. International Pediatric Otolaryngology Group (IPOG) consensus recommendations: Congenital cholesteatoma. *Otol Neurotol* 2020;41:345–51.
15. Leng S, Diehn FE, Lane JI, et al. Temporal bone CT: improved image quality and potential for decreased radiation dose using an ultra-high-resolution scan mode with an iterative reconstruction algorithm. *AJNR Am J Neuroradiol* 2015;36:1599–603.
16. McCollough CH, Leng S, Sunnegardh J, et al. Spatial resolution improvement and dose reduction potential for inner ear CT imaging using a z-axis deconvolution technique. *Med Phys* 2013;40:061904.
17. Schwartz DT. Counter-Point: Are we really ordering too many CT scans? *West J Emerg Med* 2008;9:120–2.
18. Census Regions and Divisions of the United States. U.S. Department of Commerce Economics and Statistics Administration U.S. Census Bureau. Available at: https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf. Accessed January 30, 2020.
19. Baliyan V, Kordbacheh H, Serrao J, et al. Survey on practice patterns in imaging utilization in patients with Crohn's disease. *Clin Imaging* 2019;54:91–9.
20. Cooper T, Hildrew D, McAfee JS, McCall AA, Branstetter BF, Hirsch BE. Imaging in the diagnosis and management of necrotizing otitis externa: A survey of practice patterns. *Otol Neurotol* 2018;39:597–601.
21. Westfall E, Nelson B, Vernon D, et al. Nasal bone fractures and the use of radiographic imaging: An otolaryngologist perspective. *Am J Otolaryngol* 2019;40:102295.
22. Green JD, Shelton C, Brackmann DE. Iatrogenic facial nerve injury during otologic surgery. *Laryngoscope* 1994;104:922–6.
23. Baugh RF, Basura GJ, Ishii LE, et al. Clinical Practice Guideline: Bell's Palsy. *Otolaryngol Neck Surg* 2013;149 (3 suppl):S1–27.
24. Chandrasekhar SS, Tsai Do BS, Schwartz SR, et al. Clinical Practice Guideline: Sudden hearing loss (Update). *Otolaryngol Head Neck Surg* 2019;161 (1_suppl):S1–45.
25. Basura GJ, Adams ME, Monfared A, et al. Clinical Practice Guideline: Ménière's Disease. *Otolaryngol Head Neck Surg* 2020;162 (2_suppl):S1–55.
26. Tunkel DE, Bauer CA, Sun GH, et al. Clinical practice guideline: Tinnitus. *Otolaryngol Head Neck Surg* 2014;151:S1–40.
27. Browaeys P, Larson TL, Wong ML, Patel U. Can MRI replace CT in evaluating semicircular canal dehiscence? *Am J Neuroradiol* 2013;34:1421–7.
28. Çeliker FB, Özgür A, Çeliker M, et al. The efficacy of magnetic resonance imaging for the diagnosis of superior semicircular canal dehiscence. *J Int Adv Otol* 2018;14:70–3.
29. Inal M, Burulday V, Bayar Muluk N, Kaya A, Şimşek G, Ünal Daphan B. Magnetic resonance imaging and computed tomography for diagnosing semicircular canal dehiscence. *J Craniomaxillofac Surg* 2016;44:998–1002.
30. Amoodi HA, Makki FM, Cavanagh J, Maessen H, Bance M. Cochlear implant rehabilitation for patients with vestibular schwannoma: Report of two cases. *Cochlear Implants Int* 2012;13:124–7.
31. Jiang ZY, Odiase E, Isaacson B, Roland PS, Kutz JW. Utility of MRIs in adult cochlear implant evaluations. *Otol Neurotol* 2014;35:1533–5.
32. Luu K, Chi D, Kiyosaki KK, Chang KW. Updates in pediatric cholesteatoma: Minimizing intervention while maximizing outcomes. *Otolaryngol Clin North Am* 2019;52:813–23.
33. Lane JI, Witte RJ, Bolster B, Bernstein MA, Johnson K, Morris J. State of the art: 3T imaging of the membranous labyrinth. *AJNR Am J Neuroradiol* 2008;29:1436–40.