Laryngoscope
Investigative Otolaryngology

ORIGINAL RESEARCH OPEN ACCESS

Otolaryngology Workforce Projections in the United States, 2021–2036

Lorik Berisha | Aman M. Patel | Alan Nguyen | Roshan V. Patel | Sapan M. Patel | Hassaam S. Choudhry | Rohini Bahethi | David W. Wassef | Paul T. Cowan | Ghayour S. Mir | Andrey Filimonov

Department of Otolaryngology—Head and Neck Surgery, Rutgers New Jersey Medical School, Newark, New Jersey, USA

Correspondence: Lorik Berisha (lb738@njms.rutgers.edu)

Received: 28 October 2024 | **Revised:** 21 February 2025 | **Accepted:** 24 February 2025

Keywords: adequacy | demand | otolaryngology | regional disparities | supply | workforce projections

ABSTRACT

Objective: To analyze projections of otolaryngology workforce supply and demand in the U.S. from 2021 to 2036.

Methods: Otolaryngology workforce projection data from the Bureau of Health Workforce (BHW), Health Resources and Services Administration's (HRSA) Health Workforce Simulation Model (HWSM), and National Center for Health Workforce Analysis (NCHWA) were collected and analyzed to project supply versus demand from 2021 to 2036. The adequacy of the projected otolaryngology workforce, measured as the supply–demand ratio, was the main outcome measurement.

Results: In 2021, it was assumed that the supply of otolaryngologists matched the demand. From 2021 to 2036, the total otolaryngologist supply is projected to decrease from 11,800 full-time equivalents (FTEs) to 11,620 FTEs, a 1.5% decline, while total demand is projected to increase by 1050 FTEs (8.9% increase) to 12,850 FTEs. This projects a growing shortfall of 1230 FTEs, resulting in 90.4% workforce adequacy. The projected adequacy is geographically disparate, with 98% workforce adequacy in metropolitan areas versus 35.1% in nonmetropolitan areas by 2036. By this date, otolaryngology is projected to have the third highest rate of workforce adequacy (90.4%) among eight surgical specialties studied.

Conclusion: Though the HRSA's HWSM predicts a minor shortfall in the otolaryngology workforce supply compared to demand by 2036, the impact on workforce adequacy is significant. Regional variations and scenario outcomes underscore the need for continued research to update these forecasts, which carry important implications for physicians, patients, and policymakers in addressing workforce disparities and ensuring equitable access to otolaryngologic care across the nation.

Level of Evidence: 4.

1 | Introduction

The landscape of healthcare workforce planning presents unique challenges in anticipating future medical needs. While traditional workforce analyses rely on survey data, large databases, epidemiological studies, and trend-based projections, these methods face limitations in evaluating the interconnectedness of healthcare providers and the impact of emerging technologies [1–3]. For surgical specialties like otolaryngology, these analytical challenges are particularly significant as they should account for evolving surgical techniques, disease patterns, and patient demographics.

The evolution of workforce analysis in otolaryngology has revealed complex supply and demand patterns. In 1997, the Academy of Otolaryngology–Head and Neck Surgery (AAO-HNS) documented 9017 practicing otolaryngologists, equivalent to 3.36 specialists per 100,000 population. While deemed adequate then, projections suggested a decrease due to workforce aging and population growth [4]. These predictions were

TABLE 1 | Otolaryngology workforce supply compared to demand for total, metro, and nonmetro populations by year.

	Total supply (FTE)			Status quo demand (FTE)			Reduced barriers demand (FTE)			Percent adequacy					
										Total		Metro		Nonmetro	
Year	Total	Metro	Nonmetro	Total	Metro	Nonmetro	Total	Metro	Nonmetro	Status quo (%)	Reduced barriers (%)	Status quo (%)	Reduced barriers (%)	Status quo (%)	Reduced barriers (%)
2021	11,800	11,170	630	11,800	10,160	1640	15,150	13,060	2090	100.0	77.9	109.9	85.5	38.4	30.1
2022	11,750	11,120	630	11,950	10,310	1640	15,250	13,170	2080	98.3	77.0	107.9	84.4	38.4	30.3
2023	11,670	11,060	610	12,030	10,390	1640	15,380	13,290	2090	97.0	75.9	106.4	83.2	37.2	29.2
2024	11,630	11,020	610	12,100	10,460	1640	15,530	13,430	2100	96.1	74.9	105.4	82.1	37.2	29.0
2025	11,590	10,990	600	12,210	10,580	1630	15,660	13,550	2110	94.9	74.0	103.9	81.1	36.8	28.4
2026	11,540	10,970	570	12,280	10,660	1620	15,800	13,690	2110	94.0	73.0	102.9	80.1	35.2	27.0
2027	11,510	10,960	550	12,370	10,750	1620	15,950	13,840	2110	93.0	72.2	102.0	79.2	34.0	26.1
2028	11,490	10,930	560	12,450	10,840	1610	16,030	13,930	2100	92.3	71.7	100.8	78.5	34.8	26.7
2029	11,520	10,970	550	12,480	10,870	1610	16,180	14,080	2100	92.3	71.2	100.9	77.9	34.2	26.2
2030	11,460	10,920	540	12,540	10,940	1600	16,320	14,210	2110	91.4	70.2	99.8	76.8	33.8	25.6
2031	11,450	10,920	530	12,630	11,030	1600	16,450	14,330	2120	90.7	69.6	99.0	76.2	33.1	25.0
2032	11,500	10,970	530	12,700	11,100	1600	16,560	14,440	2120	90.6	69.4	98.8	76.0	33.1	25.0
2033	11,510	10,970	540	12,740	11,140	1600	16,630	14,510	2120	90.3	69.2	98.5	75.6	33.8	25.5
2034	11,550	11,010	540	12,740	11,160	1580	16,730	14,620	2110	90.7	69.0	98.7	75.3	34.2	25.6
2035	11,560	11,020	540	12,810	11,240	1570	16,820	14,720	2100	90.2	68.7	98.0	74.9	34.4	25.7
2036	11,620	11,080	540	12,850	11,310	1540	16,920	14,830	2090	90.4	68.7	98.0	74.7	35.1	25.8

Note: This table presents the projected supply of otolaryngologists (FTE) and the corresponding demand under status quo and reduced barriers scenarios for both metro and nonmetro populations from 2021 to 2036. The percentage adequacy of the workforce, which is defined as the ratio of projected supply to projected demand, per year is also shown.

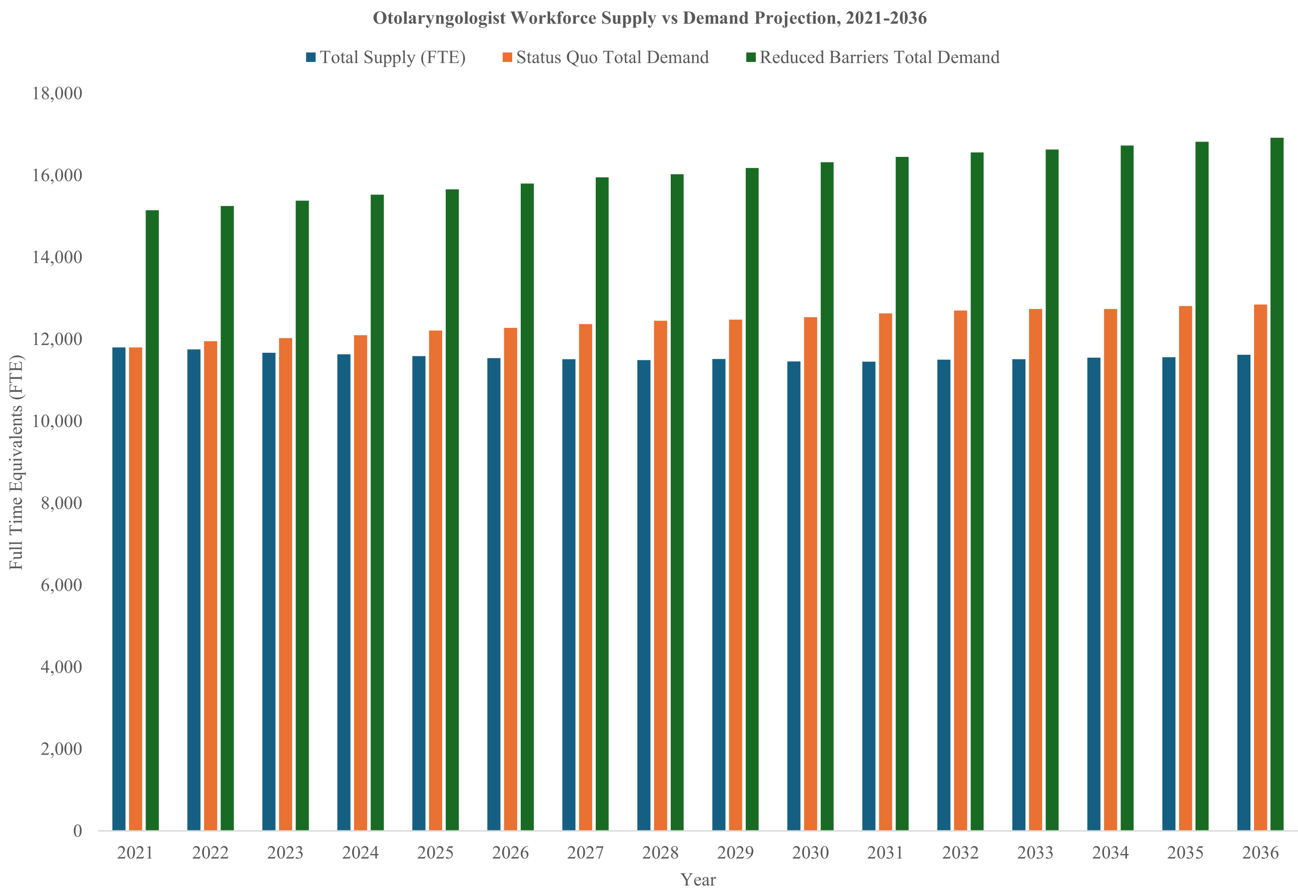

FIGURE 1 | Illustrates the projected workforce supply and demand for otolaryngologists in the United States from 2021 to 2036, measured in full-time equivalents (FTEs). The *y*-axis represents the total number of otolaryngologists in FTEs, where one FTE corresponds to a physician working full-time. The x-axis denotes the projected years from 2021 to 2036. The figure includes three projections: (1) total supply (FTEs) under the status quo scenario, assuming no major workforce changes; (2) total demand (FTEs) under the status quo scenario, which models expected service utilization based on current patterns; and (3) total demand (FTEs) under the reduced barriers scenario, which estimates the increased demand if healthcare access disparities were eliminated. This figure ensures a clear comparison of future supply versus demand trends in otolaryngology.

challenged by a 2004 follow-up study that revealed an increase to 3.2 otolaryngologists per 100,000 people from 3.0 in 1995 [5]. Recent analyses show that demand for otolaryngology services has grown faster than supply, creating a widening gap [6–8]. This trend aligns with broader surgical specialty patterns, evidenced by Association of American Medical Colleges' (AAMC) projections indicating a shortage of 15,800–30,200 surgeons across specialties by 2034 [9].

The geographical distribution and supply of otolaryngologists have significant implications for national healthcare delivery. Provider density directly impacts access to otolaryngology care and the prevalence of related health conditions [10], though numerous individual and contextual factors also influence these outcomes [11]. To address these complex dynamics, this study employs the Health Workforce Simulation Model (HWSM), developed by the National Center for Health Workforce Analysis (NCHWA) within the Health Resources and Services Administration (HRSA) of the United States Department of Health and Human Services. This microsimulation model provides comprehensive analysis capabilities for workforce trends, with the NCHWA continuously updating workforce data to inform public and private sector decision-making. Our analysis examines the projected supply and demand for otolaryngologists from 2021 to 2036, accounting for various scenarios, including potential reductions in barriers to care that could worsen existing supply–demand imbalances. Although the HWSM has been instrumental in studying workforce patterns for primary care physicians, physician assistants, nurse practitioners, and pharmacists [12, 13], this study marks its first application to otolaryngology, providing insights into potential shortages and geographic distribution under different scenarios.

2 | Methods

No Institutional Review Board approval is required for this non-human subject research.

2.1 | Data Sources

Data for this study were obtained from the Department of Health and Human Services, HRSA, specifically from the NCHWA Health Workforce Projections website [14]. The HWSM, developed by the Bureau of Health Workforce (BHW), provided the estimates. This model is an integrated microsimulation tool,

TABLE 2 | "What if scenarios" that change otolaryngology total supply (FTEs).

Year	Supply (status quo)	Retire early	Retire late	Fewer graduates	More graduates
2021	11,800	11,800	11,800	11,800	11,800
2022	11,750	11,660	11,800	11,680	11,770
2023	11,670	11,470	11,880	11,590	11,740
2024	11,630	11,420	11,840	11,520	11,720
2025	11,590	11,270	11,880	11,380	11,740
2026	11,540	11,170	11,900	11,310	11,740
2027	11,510	11,110	11,900	11,260	11,720
2028	11,490	11,090	11,930	11,190	11,760
2029	11,520	11,030	11,880	11,130	11,790
2030	11,460	11,000	11,920	11,120	11,820
2031	11,450	11,010	11,960	11,090	11,890
2032	11,500	11,000	11,960	11,050	11,920
2033	11,510	11,040	12,000	11,060	11,990
2034	11,550	11,040	12,040	11,030	12,020
2035	11,560	11,070	12,070	11,050	12,070
2036	11,620	11,100	12,100	11,030	12,190

Note: This table shows the projected supply of otolaryngologists (FTEs) from 2021 to 2036 under different scenarios, including status quo, early retirement, late retirement, fewer graduates, and more graduates. It illustrates how these factors may affect the total workforce supply over the projected period.

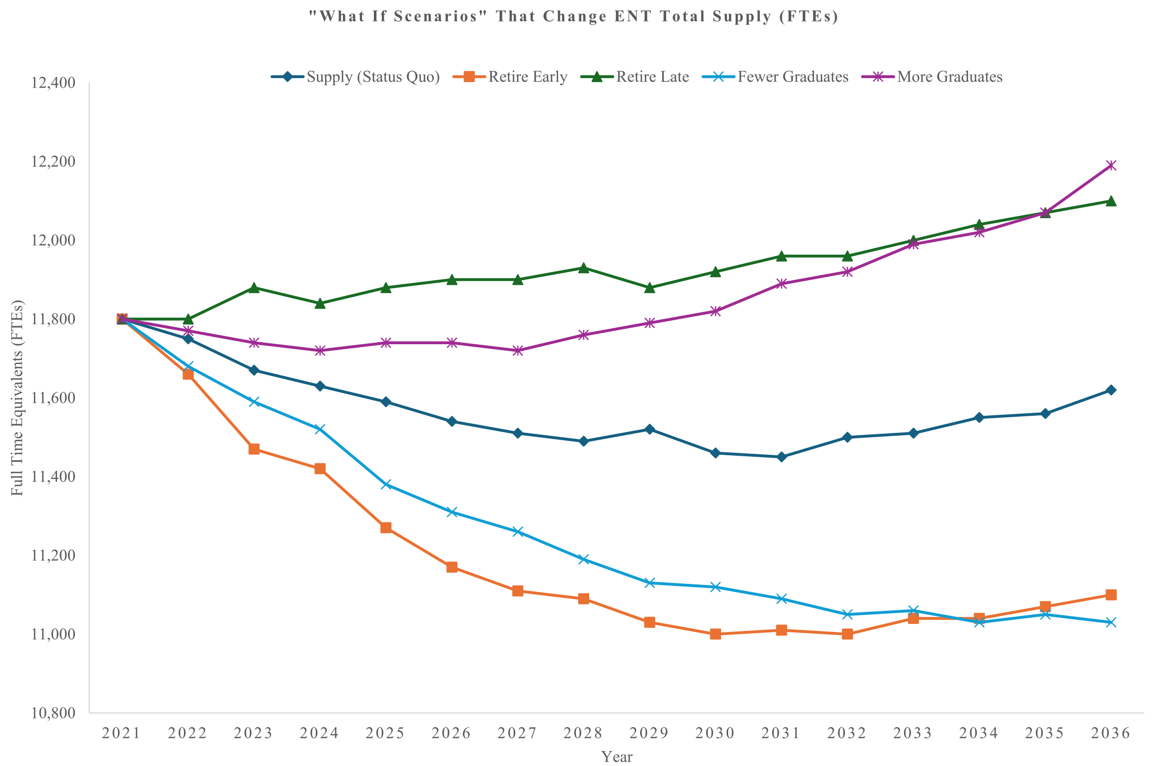

FIGURE 2 | Presents the projected total supply of otolaryngologists from 2021 to 2036, measured in full-time equivalents (FTEs), under five different hypothetical workforce scenarios. The *y*-axis represents the total number of otolaryngologists in FTEs, while the *x*-axis shows the projected years. The five scenarios include: (1) status quo, which assumes no significant workforce changes; (2) early retirement, where physicians retire two years earlier than expected, reducing workforce supply; (3) late retirement, where physicians delay retirement by 2 years, increasing workforce supply; (4) fewer graduates, modeling a scenario where 10% fewer new otolaryngologists enter the workforce annually; and (5) more graduates, assuming 10% additional trainees join the workforce each year. This figure provides a comparative visualization of how different workforce entry and exit trends could impact future otolaryngology workforce supply.

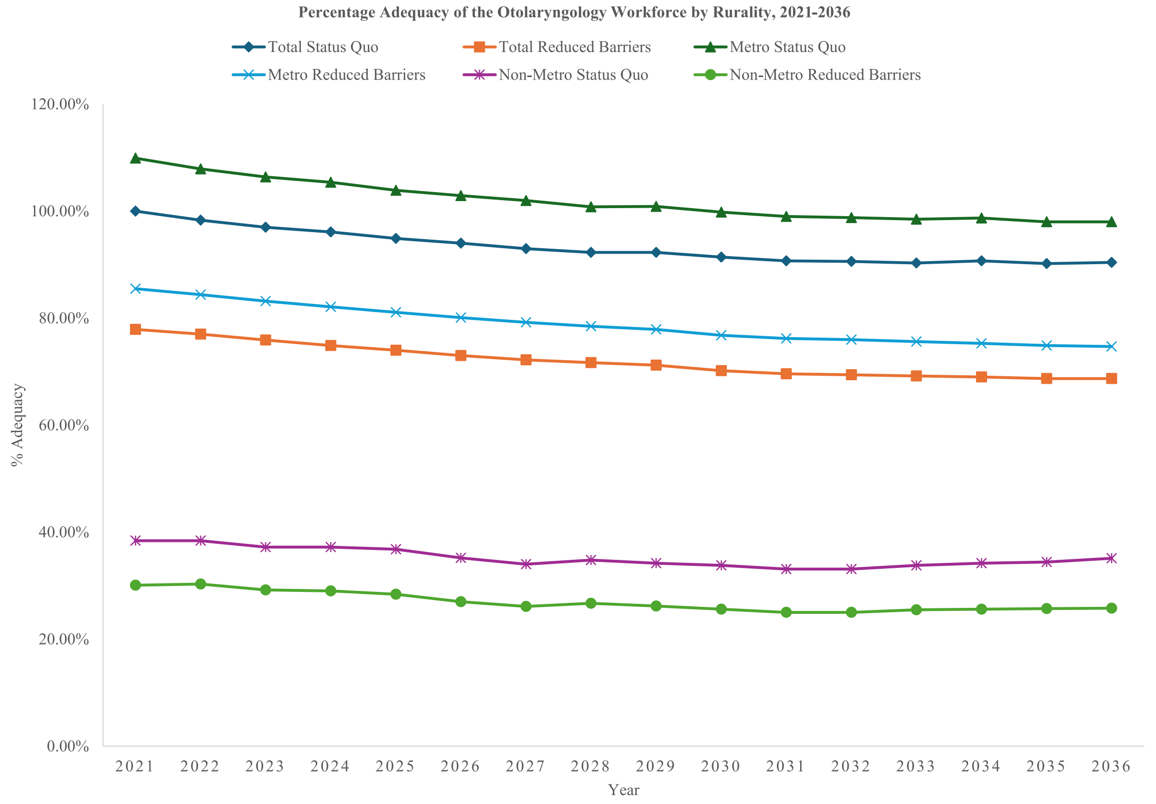

FIGURE 3 | Illustrates the percentage adequacy of the otolaryngology workforce from 2021 to 2036, calculated as the ratio of supply to demand, both measured in full-time equivalents (FTEs). The *y*-axis represents workforce adequacy as a percentage, where 100% indicates supply meets demand, while the *x*-axis represents the projected years. The figure includes trends for total, metropolitan, and nonmetropolitan populations under both status quo and reduced barriers scenarios, highlighting geographic disparities in workforce adequacy.

projecting the current and future supply and demand for healthcare workers by occupation, geographic location, and year. Detailed technical documentation for the HRSA's HWSM can be found online [15].

2.2 | Workforce Supply Definition and Calculation

Workforce supply, measured in full-time equivalents (FTEs) based on a 40-h workweek, includes actively employed professionals and those seeking employment. Initial supply calculations aggregate data from national healthcare surveys, professional association databases, and state licensure information. The HWSM employs microsimulation techniques to model annual workforce changes, incorporating new entrants from medical programs, attrition due to retirement, mortality, and shifts in training capacity. HWSM supply scenarios include the continuation of current trends, early or delayed retirement by 2 years, and variations in workforce entry with 10% more or fewer new graduates annually.

2.3 | Demand Modeling

Workforce demand, also measured in FTEs, represents the number of providers needed to meet healthcare needs based on population health-seeking behavior and financial access. The HWSM calculates demand using county-level population demographics to generate a representative sample, historical healthcare utilization patterns to predict future service use, and physician staffing ratios to estimate required workforce sizes.

Demand projections follow two key scenarios: the status quo scenario and the reduced barriers scenario. The status quo scenario assumes that recent national healthcare utilization patterns will persist and evaluates whether the projected workforce will be sufficient to maintain current levels of care, with the assumption that national demand equaled national supply in 2021.

In contrast, the reduced barriers scenario models the potential impact of eliminating healthcare access disparities, estimating workforce needs if historically underserved populations utilized otolaryngology services at rates comparable to advantaged groups. This scenario accounts for factors such as geographic parity, expanded insurance coverage, and racial equity. By comparing these models, the HWSM provides insight into workforce adequacy under current conditions and the potential strain on physician supply if access barriers were minimized.

2.4 | Projection of Workforce Adequacy

The adequacy of the otolaryngology workforce is expressed as a percentage, calculated by dividing the projected supply of

TABLE 3 | Total supply vs. demand across surgical specialties for 2021 and projected for 2036.

Base year 2021						Projected year 2026				
Profession	**Supply**	**Status quo demand**	**Reduced barriers demand**	**Percent adequacy (status quo) (%)**	**Percent adequacy (reduced barriers) (%)**	**Supply**	**Status quo demand**	**Reduced barriers demand**	**Percent adequacy (status quo) (%)**	**Percent adequacy (reduced barriers)**
Otolaryngology	11,800	11,800	15,150	100	77.9	11,620	12,850	16,920	90.4	68.7
Colorectal Surgery	2770	2770	2750	100	100.7	3330	3320	3320	100.3	100.3
General Surgery	31,920	35,270	37,630	90.5	84.8	37,530	39,570	43,510	94.8	86.2
Neurological Surgery	6630	6630	9410	100	70.5	7170	8000	11,620	89.6	61.7
Orthopedic Surgery	31,410	31,410	37,250	100	84.3	30,900	34,550	41,970	89.4	73.6
Plastic Surgery	10,740	10,740	14,090	100	76.2	8600	11,590	15,630	74.2	55.0
Thoracic Surgery	5190	5190	5820	100	89.2	4270	6130	6950	69.7	61.4
Vascular Surgery	5700	7430	7140	76.7	79.8	5730	8910	8690	64.3	65.9

Note: This table compares the supply and demand of various surgical specialties, including otolaryngology, for the base year 2021 and the projected year 2036 under status quo and reduced barriers scenarios. It includes the percentage adequacy for each specialty, highlighting differences in workforce adequacy across specialties and over time.

TABLE 4 | Sensitivity analysis and polynomial fitting of workforce projections.

Metric	Fewer graduates	More graduates	Retire early	Retire late	Supply	Demand	Reduced barriers
Total Best Degree	2	2	2	1	6	2	6
Metro Best Degree	2	2	2	1	2	2	6
NonMetro Best Degree	6	6	6	6	6	6	6
Total Perturbation Mean RMSE	18.397	16.116	25.838	26.567	15.143	22.145	30.891
Metro Perturbation Mean RMSE	15.824	17.362	23.836	20.945	14.039	23.4	29.364
NonMetro Perturbation Mean RMSE	6.8492	8.9802	8.945	9.542	8.0447	7.3275	7.2662
Total Perturbation Std RMSE	2.8241	1.7014	2.5388	0.94135	1.2247	3.3096	4.9003
Metro Perturbation Std RMSE	2.3443	1.8123	2.4552	1.4513	0.81235	3.8152	5.6201
NonMetro Perturbation Std RMSE	0.51374	0.41683	0.46025	0.34523	0.47047	0.35506	0.15187
Total c0	1.8533e+07	1.5246e+07	2.9793e+07	−24,107	8.7358e−19	−1.011e+07	−4.4956e-19
Total c1	−18,211	−15,046	−29,320	17.765	1.0543e-14	9912.2	−5.4257e-15
Total c2	4.4765	3.715	7.2164	NA	1.4378e-12	−2.4265	−7.3995e-13
Total c3	NA	NA	NA	NA	1.4583e-09	NA	−7.5049e-10
Total c4	NA	NA	NA	NA	9.8607e-07	NA	−5.0746e-07
Total c5	NA	NA	NA	NA	−9.6943e−10	NA	4.9597e-10
Total c6	NA	NA	NA	NA	2.3843e-13	NA	−1.2094e-13
Metro c0	1.6481e+07	1.2819e+07	2.6527e+07	−37,198	1.3509e+07	−8.8838e+06	−3.6591e-19
Metro c1	−16,199	−12,660	−26,109	23.926	−13,302	8696.1	−4.4161e-15
Metro c2	3.9828	3.1285	6.4268	NA	3.2773	−2.1254	−6.0226e-13
Metro c3	NA	NA	NA	NA	NA	NA	−6.1084e-10
Metro c4	NA	NA	NA	NA	NA	NA	−4.1303e-07
Metro c5	NA	NA	NA	NA	NA	NA	4.0257e-10
Metro c6	NA	NA	NA	NA	NA	NA	−9.7879e-14
NonMetro c0	1.1184e-19	1.3011e-19	1.7474e-19	9.8844e-20	1.5627e-19	−6.093e-20	−8.3655e-20
NonMetro c1	1.3498e-15	1.5702e-15	2.1089e-15	1.1929e-15	1.886e-15	−7.3534e−16	−1.0096e−15
NonMetro c2	1.8409e−13	2.1415e−13	2.8761e-13	1.6269e-13	2.5721e-13	−1.0029e-13	−1.3769e-13

(Continues)

TABLE 4 | (Continued)

Metric	Fewer graduates	More graduates	Retire early	Retire late	Supply	Demand	Reduced barriers
NonMetro c3	1.8671e-10	2.172e-10	2.9171e-10	1.6501e-10	2.6088e-10	−1.0171e-10	−1.3965e-10
NonMetro c4	1.2625e-07	1.4686e-07	1.9724e-07	1.1157e-07	1.764e-07	−6.8776e-08	−9.4428e-08
NonMetro c5	−1.2382e−10	−1.4434e−10	−1.939e−10	−1.0954e-10	−1.7341e-10	6.8421e-11	9.34e-11
NonMetro c6	3.0365e-14	3.5471e-14	4.7662e-14	2.6893e-14	4.2628e-14	−1.6992e-14	−2.3066e-14

Note: This table details the statistical modeling methods for projecting otolaryngology workforce supply and demand. It includes the optimal polynomial degree for each scenario and region (total, metropolitan, nonmetropolitan) and metrics such as root mean square error (RMSE) and standard deviations for perturbation analyses. Polynomial coefficients for each scenario and region are also provided.

otolaryngology FTEs by the projected demand each year. This metric indicates potential shortages or surpluses in the workforce; metrics greater than 100% suggest a surplus, while less than 100% indicate a shortage.

2.5 | Statistical Analysis

Forecasts for FTE numbers in otolaryngology supply and demand from 2021 to 2036 were generated using the HWSM's model. Analysis was conducted in Microsoft Excel, across different workforce scenarios and geographic settings. Additionally, customized Python scripts were employed to conduct a sensitivity analysis of polynomial regression fits, explore variation in retirement and training pathways, and integrate scenario-based projections for total, metropolitan, and nonmetropolitan populations. To validate the accuracy of HWSM projections, polynomial regression models were applied to estimate workforce trends, generating predicted values with 95% confidence intervals. These predictions were then compared to HWSM estimates, allowing for cross-validation and identification of discrepancies. This approach enabled cross-validation to identify optimal model complexity, bootstrap resampling for coefficient stability, and perturbation analyses to quantify the impact of data noise.

Furthermore, Root Mean Square Error (RMSE) was calculated to assess predictive accuracy across workforce scenarios, with separate evaluations for metropolitan, nonmetropolitan, and total populations. A high RMSE suggests greater deviation between projected and actual workforce estimates, indicating lower predictive accuracy and higher uncertainty in workforce trends, while a low RMSE suggests strong alignment between model predictions and expected workforce patterns, indicating higher reliability and precision in forecasting.

3 | Results

3.1 | Status-Quo Estimates

In 2021, the otolaryngology workforce in the United States was estimated to include 11,800 FTEs. By 2036, projections indicate that this total supply will decrease by 1.5%, resulting in 11,620 FTEs. Initially, in 2021, the supply met the demand of 11,800 FTEs. However, the projected total demand is anticipated to rise by 1050 FTEs, marking an 8.9% increase by the year 2036.

In metropolitan areas, there were 11,170 FTEs in 2021. By 2036, the supply is expected to decrease slightly by 0.8% to 11,080 FTEs, while demand is projected to increase by 11.3%, from 10,160 FTEs in 2021 to 11,310 FTEs in 2036. This equates to an adequacy of 98.0% by 2036 (Table 1).

In nonmetropolitan areas, the supply in 2021 was 630 FTEs, which is projected to decline by 14.3% to 540 FTEs by 2036. Meanwhile, demand is expected to decrease by 6.1%, from 1640 FTEs in 2021 to 1540 FTEs by 2036, which equates to an adequacy of 35.1%, highlighting a significant imbalance (Figure 1).

TABLE 5 | Comparison of HWSM total population projections and polynomial regression total population predictions: trends and scenarios from 2021 to 2036.

Year	Fewer graduates actual	Fewer graduates prediction (range)	More graduates actual	More graduates prediction (range)	Retire early actual	Retire early prediction (range)	Retire late actual	Retire late prediction (range)	Supply actual	Supply prediction (range)	Demand actual	Demand Prediction (range)	Reduced barriers scenario actual	Reduced barriers scenario prediction (range)
2021	11,800	11,799 (11,775–11,823)	11,800	11,791 (11,767–11,815)	11,800	11,782 (11,745–11,819)	11,800	11,796 (11,766–11,825)	11,800	11,807 (11,784–11,830)	11,800	11,823 (11,796–11,850)	15,150	15,111 (15,078–15,143)
2022	11,680	11,686 (11,668–11,705)	11,770	11,765 (11,746–11,783)	11,660	11,638 (11,609–11,666)	11,800	11,813 (11,787–11,840)	11,750	11,739 (11,721–11,757)	11,950	11,925 (11,904–11,946)	15,250	15,258 (15,232–15,283)
2023	11,590	11,583 (11,568–11,598)	11,740	11,746 (11,731–11,761)	11,470	11,508 (11,485–11,530)	11,880	11,831 (11,807–11,855)	11,670	11,679 (11,665–11,693)	12,030	12,022 (12,005–12,038)	15,380	15,401 (15,381–15,421)
2024	11,520	11,488 (11,475–11,501)	11,720	11,735 (11,722–11,747)	11,420	11,392 (11,373–11,412)	11,840	11,849 (11,828–11,870)	11,630	11,627 (11,614–11,639)	12,100	12,114 (12,100–12,128)	15,530	15,540 (15,523–15,558)
2025	11,380	11,402 (11,390–11,415)	11,740	11,731 (11,719–11,743)	11,270	11,291 (11,273–11,310)	11,880	11,867 (11,847–11,886)	11,590	11,582 (11,570–11,594)	12,210	12,201 (12,188–12,215)	15,660	15,677 (15,660–15,693)
2026	11,310	11,326 (11,313–11,338)	11,740	11,735 (11,722–11,747)	11,170	11,205 (11,186–11,224)	11,900	11,884 (11,867–11,902)	11,540	11,545 (11,533–11,557)	12,280	12,284 (12,270–12,298)	15,800	15,809 (15,792–15,826)
2027	11,260	11,258 (11,245–11,271)	11,720	11,746 (11,733–11,759)	11,110	11,133 (11,113–11,153)	11,900	11,902 (11,886–11,918)	11,510	11,516 (11,503–11,529)	12,370	12,362 (12,347–12,377)	15,950	15,938 (15,920–15,956)
2028	11,190	11,199 (11,185–11,213)	11,760	11,764 (11,751–11,778)	11,090	11,075 (11,054–11,096)	11,930	11,920 (11,905–11,935)	11,490	11,495 (11,482–11,508)	12,450	12,434 (12,419–12,450)	16,030	16,063 (16,045–16,081)
2029	11,130	11,149 (11,136–11,163)	11,790	11,790 (11,776–11,803)	11,030	11,032 (11,011–11,053)	11,880	11,938 (11,922–11,953)	11,520	11,482 (11,468–11,495)	12,480	12,502 (12,487–12,518)	16,180	16,185 (16,166–16,203)
2030	11,120	11,108 (11,095–11,121)	11,820	11,823 (11,810–11,836)	11,000	11,003 (10,983–11,023)	11,920	11,955 (11,939–11,971)	11,460	11,476 (11,464–11,489)	12,540	12,566 (12,551–12,580)	16,320	16,302 (16,284–16,320)
2031	11,090	11,076 (11,064–11,089)	11,890	11,864 (11,852–11,876)	11,010	10,989 (10,969–11,008)	11,960	11,973 (11,956–11,990)	11,450	11,479 (11,467–11,491)	12,630	12,624 (12,610–12,638)	16,450	16,416 (16,399–16,433)
2032	11,050	11,053 (11,041–11,065)	11,920	11,912 (11,900–11,924)	11,000	10,989 (10,970–11,007)	11,960	11,991 (11,972–12,010)	11,500	11,490 (11,478–11,502)	12,700	12,677 (12,663–12,691)	16,560	16,527 (16,510–16,543)
2033	11,060	11,039 (11,026–11,052)	11,990	11,968 (11,955–11,980)	11,040	11,003 (10,984–11,023)	12,000	12,009 (11,987–12,030)	11,510	11,509 (11,497–11,522)	12,740	12,726 (12,711–12,740)	16,630	16,633 (16,616–16,650)

(Continues)

TABLE 5 | (Continued)

Year	Fewer graduates actual	Fewer graduates prediction (range)	More graduates actual	More graduates prediction (range)	Retire early actual	Retire early prediction (range)	Retire late actual	Retire late prediction (range)	Supply actual	Supply prediction (range)	Demand actual	Demand Prediction (range)	Reduced barriers scenario actual	Reduced barriers scenario prediction (range)
2034	11,030	11,034 (11,019–11,049)	12,020	12,031 (12,016–12,045)	11,040	11,032 (11,010–11,055)	12,040	12,026 (12,003–12,050)	11,550	11,536 (11,522–11,551)	12,740	12,770 (12,753–12,786)	16,730	16,736 (16,716–16,756)
2035	11,050	11,038 (11,019–11,056)	12,070	12,101 (12,083–12,120)	11,070	11,076 (11,047–11,104)	12,070	12,044 (12,018–12,071)	11,560	11,572 (11,554–11,590)	12,810	12,808 (12,787–12,829)	16,820	16,835 (16,810–16,860)
2036	11,030	11,051 (11,026–11,075)	12,190	12,179 (12,155–12,203)	11,100	11,133 (11,096–11,170)	12,100	12,062 (12,033–12,091)	11,620	11,616 (11,592–11,639)	12,850	12,842 (12,815–12,870)	16,920	16,930 (16,897–16,963)

Note: Actual values, which came from the HWSM model website, and predicted estimates with 95% confidence intervals included as (Range), which came from the polynomial regression fits we employed, are shown for key scenarios, including fewer graduates, more graduates, early and late retirement, total supply, total demand, and reduced barriers to access. Predictions were derived using polynomial regression models to account for nonlinear trends over time.

3.2 | Reduced Barriers Scenario

Under the reduced barriers scenario, the total supply of otolaryngologists from 2021 to 2036 is insufficient to meet demand. For the reference year of 2021, there was a deficit of 3350 FTEs, with shortages of 1890 FTEs in urban areas and 1460 FTEs in nonmetropolitan areas, a shortage which is only expected to worsen (Table 1).

By 2036, this scenario predicts a 1770 FTE increase in demand, representing an 11.7% increase, while concurrently projecting a 1.5% decline, equivalent to 180 FTEs, in the total supply. This projection leaves a supply of 11,620 FTEs to provide care for a total demand of 16,920 FTEs, a discrepancy of over 5300 FTEs (Table 1).

3.3 | "What If Scenarios" That Change Otolaryngology Total Supply (FTE)

The projected total supply of otolaryngologists (measured in FTEs) under various scenarios from 2021 to 2036 shows notable trends. Under the status quo scenario, the supply slightly decreases from 11,800 FTEs in 2021 to 11,620 FTEs by 2036. In the early retirement scenario, there is a significant decrease in supply, dropping from 11,800 FTEs in 2021 to 11,100 FTEs in 2036. Conversely, the late retirement scenario results in a substantial increase in supply, rising from 11,800 FTEs in 2021 to 12,100 FTEs by 2036 (Table 2) (Figure 2).

The scenario with fewer graduates of otolaryngology programs shows a steady decline in supply, starting at 11,800 FTEs in 2021 and decreasing to 11,030 FTEs in 2036. In contrast, the scenario encompassing a greater rate of graduates entering the workforce sees an increase in the supply of otolaryngologists, growing from 11,800 FTEs in 2021 to 12,190 FTEs by 2036 (Table 2) (Figure 2).

3.4 | Adequacy

The adequacy of the otolaryngology workforce showed a yearly decline in both the status quo and reduced barriers scenarios. For the status quo scenario in 2021, the starting supply of 11,800 physicians matched the total status quo demand of 11,800, achieving 100% adequacy. However, adequacy decreases each year as total projected demand outpaces projected supply. By 2036, the projected otolaryngology workforce adequacy is 90.4% under the status quo scenario and only 68.7% under the reduced barriers scenario (Figure 3).

These trends are more pronounced depending on practice setting. In 2021, the status quo scenario showed 109.9% adequacy in metropolitan areas and 38.4% in nonmetropolitan areas. By 2036, workforce supply adequacy is projected to decrease to 98.0% in metropolitan areas and 35.1% in nonmetropolitan areas. In the reduced barriers scenario, adequacy is expected to decrease to 74.7% in metropolitan areas and 25.8% in nonmetropolitan areas by 2036 (Figure 3).

TABLE 6 | Comparison of HWSM metro population projections and polynomial regression metro population predictions: trends and scenarios from 2021 to 2036.

Year	Fewer graduates actual	Fewer graduates prediction	More graduates actual	More graduates prediction	Retire early actual	Retire early prediction	Retire late actual	Retire late prediction	Supply actual	Supply prediction	Demand actual	Demand prediction	Reduced barriers scenario actual	Reduced barriers scenario prediction (range)
2021	11,170	11,159 (11,138–11,181)	11,170	11,150 (11,124–11,176)	11,170	11,146 (11,110–11,182)	11,170	11,157 (11,135–11,179)	11,170	11,165 (11,143–11,187)	10,160	10,183 (10,154–10,211)	13,060	13,029 (13,002–13,057)
2022	11,050	11,063 (11,047–11,080)	11,140	11,138 (11,118–11,158)	11,040	11,021 (10,993–11,048)	11,150	11,181 (11,161–11,201)	11,120	11,113 (11,096–11,130)	10,310	10,286 (10,264–10,308)	13,170	13,169 (13,148–13,191)
2023	10,980	10,975 (10,962–10,988)	11,120	11,133 (11,117–11,148)	10,870	10,908 (10,887–10,930)	11,230	11,205 (11,187–11,223)	11,060	11,068 (11,055–11,081)	10,390	10,385 (10,368–10,402)	13,290	13,307 (13,290–13,324)
2024	10,910	10,895 (10,884–10,906)	11,110	11,133 (11,120–11,147)	10,830	10,809 (10,790–10,828)	11,220	11,229 (11,213–11,245)	11,020	11,029 (11,018–11,040)	10,460	10,480 (10,465–10,495)	13,430	13,442 (13,427–13,456)
2025	10,810	10,823 (10,812–10,833)	11,140	11,140 (11,128–11,153)	10,700	10,722 (10,704–10,740)	11,270	11,253 (11,239–11,268)	10,990	10,997 (10,986–11,008)	10,580	10,570 (10,556–10,585)	13,550	13,573 (13,559–13,587)
2026	10,750	10,758 (10,747–10,769)	11,160	11,154 (11,140–11,167)	10,620	10,649 (10,630–10,667)	11,300	11,277 (11,264–11,290)	10,970	10,971 (10,960–10,982)	10,660	10,657 (10,642–10,672)	13,690	13,702 (13,688–13,717)
2027	10,710	10,702 (10,690–10,714)	11,170	11,173 (11,159–11,187)	10,560	10,588 (10,568–10,607)	11,300	11,301 (11,289–11,313)	10,960	10,952 (10,940–10,964)	10,750	10,739 (10,723–10,754)	13,840	13,828 (13,813–13,844)
2028	10,640	10,653 (10,641–10,665)	11,200	11,199 (11,185–11,213)	10,550	10,540 (10,519–10,560)	11,340	11,325 (11,313–11,337)	10,930	10,939 (10,927–10,951)	10,840	10,817 (10,801–10,833)	13,930	13,952 (13,936–13,967)
2029	10,590	10,613 (10,601–10,625)	11,230	11,231 (11,217–11,245)	10,500	10,504 (10,484–10,524)	11,310	11,349 (11,337–11,360)	10,970	10,933 (10,921–10,945)	10,870	10,890 (10,874–10,906)	14,080	14,072 (14,056–14,088)
2030	10,590	10,581 (10,569–10,592)	11,250	11,269 (11,255–11,283)	10,500	10,482 (10,462–10,501)	11,350	11,373 (11,361–11,385)	10,920	10,934 (10,922–10,946)	10,940	10,959 (10,944–10,975)	14,210	14,189 (14,174–14,205)
2031	10,570	10,556 (10,545–10,567)	11,340	11,314 (11,300–11,327)	10,500	10,472 (10,454–10,491)	11,400	11,397 (11,384–11,410)	10,920	10,941 (10,929–10,952)	11,030	11,025 (11,010–11,039)	14,330	14,304 (14,289–14,318)
2032	10,540	10,540 (10,529–10,550)	11,380	11,365 (11,352–11,377)	10,480	10,476 (10,458–10,494)	11,390	11,421 (11,406–11,435)	10,970	10,954 (10,943–10,965)	11,100	11,085 (11,071–11,100)	14,440	14,415 (14,401–14,429)

(Continues)

TABLE 6 | (Continued)

Year	Fewer graduates actual	Fewer graduates prediction	More graduates actual	More graduates prediction	Retire early actual	Retire early prediction	Retire late actual	Retire late prediction	Supply actual	Supply prediction	Demand actual	Demand prediction	Reduced barriers scenario actual	Reduced barriers scenario prediction (range)
2033	10,550	10,531 (10,520–10,542)	11,440	11,422 (11,408–11,435)	10,510	10,492 (10,473–10,511)	11,440	11,445 (11,428–11,461)	10,970	10,974 (10,963–10,986)	11,140	11,142 (11,127–11,157)	14,510	14,524 (14,509–14,539)
2034	10,530	10,530 (10,517–10,543)	11,480	11,485 (11,469–11,500)	10,530	10,521 (10,499–10,543)	11,480	11,468 (11,450–11,486)	11,010	11,001 (10,988–11,014)	11,160	11,194 (11,177–11,212)	14,620	14,629 (14,612–14,646)
2035	10,550	10,538 (10,521–10,554)	11,520	11,554 (11,535–11,574)	10,570	10,563 (10,535–10,591)	11,510	11,492 (11,472–11,512)	11,020	11,034 (11,018–11,051)	11,240	11,242 (11,220–11,264)	14,720	14,732 (14,710–14,753)
2036	10,530	10,553 (10,532–10,574)	11,640	11,630 (11,605–11,656)	10,580	10,618 (10,582–10,653)	11,530	11,516 (11,494–11,538)	11,080	11,074 (11,053–11,096)	11,310	11,286 (11,258–11,314)	14,830	14,831 (14,804–14,859)

Note: Actual values, which came from the HWSM model website, and predicted estimates with 95% confidence intervals included as (Range), which came from the polynomial regression fits we employed, are shown for key scenarios, including fewer graduates, more graduates, early and late retirement, metro supply, metro demand, and reduced barriers to access. Predictions were derived using polynomial regression models to account for non-linear trends over time.

3.5 | Specialty Specific Adequacy

Among the eight surgical specialties in the HRSA dataset (Otolaryngology, Colorectal Surgery, Neurological Surgery, Orthopedic Surgery, Plastic Surgery, and Thoracic Surgery), all had a supply adequacy of 100% in 2021. This indicates that the supply met the demand perfectly. General Surgery, with a 90.5% adequacy, and Vascular Surgery, at 76.7%, fell short of meeting demand (Table 3).

Looking ahead to 2036, Otolaryngology's projected supply adequacy drops to 90.4%, placing it 3rd among surgical specialties. Specialties projected to have even lower adequacy include Neurological Surgery (89.6%), Orthopedic Surgery (89.4%), Plastic Surgery (74.2%), Thoracic Surgery (69.7%), and Vascular Surgery (64.3%). Colorectal Surgery is expected to maintain the highest adequacy at 100.3%, followed by General Surgery at 94.8% (Table 3).

3.6 | Sensitivity Analysis With Polynomial Fitting

Sensitivity analysis revealed variations in the optimal polynomial degree required to model workforce supply and demand across different scenarios and geographic regions. First-degree polynomials provided strong predictive fits for scenarios with gradual, linear trends, such as the status quo and fewer graduates, demonstrating particularly high accuracy in metropolitan areas where workforce trends remained stable (Table 4).

Second-degree polynomials were employed for scenarios with moderate nonlinear trends, such as early retirement and late retirement, effectively capturing the accelerating impact of workforce exit timing on supply projections (Table 4). In contrast, scenarios with substantial variability, such as reduced barriers, required sixth-degree polynomials to accurately model the sharp increases in demand associated with improved healthcare access. These higher-degree polynomials were particularly important in nonmetropolitan regions, where eliminating access disparities had a disproportionate impact on projected workforce needs (Table 4).

Across all scenarios, mean Root Mean Square Errors (RMSEs) were lowest for metropolitan regions (range: 14.0–23.8) compared to nonmetropolitan regions (range: 6.8–9.5). Perturbation analyses confirmed the robustness of these fits, particularly for high-degree polynomials in scenarios with greater complexity, such as reduced barriers (Table 4).

3.7 | Comparison of HWSM Projections and Polynomial Regression Predictions

Tables 5–7 compare the actual workforce projections from the HWSM to the polynomial regression-based predictions, including 95% CIs, across various workforce scenarios. This comparison evaluates whether HWSM estimates align with our predictive model and assesses their accuracy.

For total population projections, HWSM estimates closely align with our predictions, consistently falling within the 95% CI. However, in the reduced barriers scenario, HWSM demand

TABLE 7 | Comparison of HWSM nonmetro population projections and polynomial regression nonmetro population predictions: trends and scenarios from 2021 to 2036.

Year	Fewer graduates actual	Fewer graduates prediction	More graduates actual	More graduates prediction	Retire early actual	Retire early prediction	Retire late actual	Retire late prediction	Supply actual	Supply prediction	Demand actual	Demand prediction	Reduced barriers scenario actual	Reduced barriers scenario prediction (range)
2021	630	639 (629–650)	630	641 (627–655)	630	636 (622–650)	630	653 (638–668)	630	643 (630–655)	1640	1640 (1629–1652)	2090	2081 (2070–2093)
2022	630	623 (615–631)	630	627 (616–637)	620	617 (606–628)	650	641 (630–653)	630	626 (616–636)	1640	1639 (1630–1648)	2080	2088 (2079–2097)
2023	610	608 (601–614)	620	613 (605–622)	600	599 (591–608)	650	630 (621–639)	610	611 (603–619)	1640	1637 (1630–1644)	2090	2094 (2087–2101)
2024	610	593 (588–599)	610	601 (594–609)	590	584 (576–591)	620	619 (611–627)	610	597 (590–604)	1640	1634 (1628–1640)	2100	2099 (2093–2105)
2025	570	580 (575–585)	600	591 (584–598)	570	569 (562–576)	610	610 (602–617)	600	585 (578–591)	1630	1631 (1625–1637)	2110	2103 (2097–2109)
2026	560	568 (562–573)	580	581 (574–588)	550	556 (549–564)	600	601 (593–609)	570	573 (567–580)	1620	1627 (1621–1633)	2110	2107 (2101–2113)
2027	550	556 (550–562)	550	572 (565–580)	550	545 (538–553)	600	593 (585–601)	550	564 (557–571)	1620	1623 (1617–1629)	2110	2109 (2103–2116)
2028	550	546 (540–551)	560	565 (557–573)	540	536 (528–543)	590	586 (577–594)	560	555 (548–563)	1610	1618 (1611–1624)	2100	2111 (2105–2118)
2029	540	536 (530–542)	560	559 (551–567)	530	528 (520–535)	570	580 (571–588)	550	549 (542–556)	1610	1612 (1606–1619)	2100	2113 (2106–2119)
2030	530	528 (522–533)	570	554 (546–562)	500	521 (513–529)	570	574 (566–582)	540	543 (536–550)	1600	1606 (1600–1612)	2110	2113 (2107–2119)
2031	520	520 (515–526)	550	550 (543–557)	510	516 (509–523)	560	570 (562–578)	530	539 (533–546)	1600	1599 (1593–1605)	2120	2113 (2107–2119)
2032	510	514 (508–519)	540	548 (540–555)	520	513 (506–520)	570	566 (559–574)	530	536 (530–543)	1600	1592 (1586–1598)	2120	2111 (2106–2117)
2033	510	508 (503–514)	550	546 (539–553)	530	511 (504–519)	560	564 (556–572)	540	535 (529–542)	1600	1584 (1578–1590)	2120	2109 (2103–2115)
2034	500	504 (497–510)	540	546 (537–554)	510	511 (503–520)	560	562 (553–571)	540	536 (528–543)	1580	1575 (1568–1582)	2110	2107 (2099–2114)
2035	500	500 (492–508)	550	547 (536–558)	500	513 (502–524)	560	561 (550–573)	540	537 (528–547)	1570	1566 (1557–1575)	2100	2103 (2094–2112)

(Continues)

TABLE 7 | (Continued)

Year	Fewer graduates actual	Fewer graduates prediction	More graduates actual	More graduates prediction	Retire early actual	Retire early prediction	Retire late actual	Retire late prediction	Supply actual	Supply prediction	Demand actual	Demand prediction	Reduced barriers scenario actual	Reduced barriers scenario prediction (range)
2036	500	498 (487–508)	550	549 (535–563)	520	516 (502–530)	570	561 (546–576)	540	541 (528–553)	1540	1556 (1545–1568)	2090	2098 (2087–2110)

Note: Actual values, which came from the HWSM model website, and predicted estimates with 95% confidence intervals included as (range), which came from the polynomial regression fits we employed, are shown for key scenarios, including fewer graduates, more graduates, early and late retirement, nonmetro supply, nonmetro demand, and reduced barriers to access. Predictions were derived using polynomial regression models to account for nonlinear trends over time.

projections trended lower than our predictions, suggesting a potential underestimation of increased demand with improved access (Table 5).

For metropolitan projections, HWSM results were highly consistent with polynomial predictions, staying well within the 95% CI across all scenarios (Table 6). The strong alignment indicates reliable workforce modeling in urban areas.

For nonmetropolitan projections, early-year HWSM estimates fit within the 95% CI, but discrepancies grew over time. By 2036, HWSM supply projections were slightly higher than our predictions, suggesting a potential overestimation of rural workforce availability. HWSM demand estimates trended toward the lower bound of our predicted range, possibly underestimating future rural shortages (Table 7).

4 | Discussion

Analysis of the HWSM indicates an inadequate otolaryngology workforce to meet current service demands. By 2036, projections show workforce adequacy at 90.4% under standard scenarios, decreasing to 68.7% with reduced barriers. A significant disparity exists between metropolitan and rural areas, with rural regions showing 25.8% workforce adequacy in the reduced barriers scenario compared to 74.7% in metropolitan areas by 2036 (Table 1). Recent cross-sectional analysis validates these geographic variations, revealing substantial differences in otolaryngologist supply per 100,000 people across hospital referral regions [16].

Geographic distribution patterns show otolaryngologists concentrating in areas with higher specialist density and regions with higher population income and education levels [17, 18]. The tendency of otolaryngologists to establish practices in their residency training locations, predominantly in metropolitan areas, contributes to this distribution pattern [19]. With most residency programs located in metropolitan areas, this pattern perpetuates the rural workforce shortage, indicating a need for reassessment of physician distribution between rural and urban areas.

According to the 2023 AAO-HNS Otolaryngology Workforce report, only 10.3% of otolaryngology offices are located in rural areas [20]. While the 2022 report shows that 19% of physicians in multispecialty groups and 18% in single-specialty groups travel to underserved areas, only 12% of solo practitioners do so. However, solo practitioners spend the most time in these regions, averaging 4.5 days per month, though their declining numbers may impact rural care accessibility [21]. The distribution disparity presents public health challenges, particularly in rural areas, where higher prevalence, severity, and mortality rates of otolaryngologic conditions are observed [22, 23]. Limited access to tertiary care centers and public transportation [24] often leads to delayed diagnoses and worse outcomes, especially in head and neck cancer cases [25]. Increased access to specialized care in underserved regions could enable earlier detection and treatment of conditions such as hearing loss and laryngeal cancer, potentially reducing severity and complications.

Workforce challenges highlighted in this paper are projected to persist across various surgical specialties through 2050, with significant shortages anticipated [26]. This shortage is driven by the slow expansion of training programs, which has not kept pace with the rising demand for surgical care from an aging U.S. population [26]. Moreover, workload projections vary by specialty: ophthalmology and cardiothoracic surgery, which predominantly serve older patients, anticipate increases of 47% and 42%, respectively, while otolaryngology, with 39.6% of procedure-based work in patients under 15 years old, projects a 14% increase [27].

These projections underscore the need for strategic workforce planning to manage rising workloads while maintaining care quality. Addressing geographic disparities, diverse patient demographics, and the complexity of treated conditions requires optimizing residency distribution, implementing rural practice incentives, and expanding telemedicine. The documented workforce inadequacies, particularly in rural areas, highlight the necessity of systematic changes in healthcare delivery models. Targeted interventions are essential to address both current shortages and future workforce demands, ensuring effective and equitable otolaryngologic care.

4.1 | Study Limitations

This analysis underscores the complexities and assumptions involved in forecasting the workforce of otolaryngologists. Firstly, the HWSM model is constrained by the inherent limitations of the microsimulation approach used for supply modeling, as the data utilized comes from professional clinical associations (such as the American Medical Association Masterfile), national surveys (including the American Community Survey and US Bureau of Labor Statistics Survey), state-sponsored surveys, and state licensure files [15]. Furthermore, our projections rely on the HWSM, which assumes equilibrium in baseline supply–demand and may underrepresent rural workforce disparities, limiting geographic precision in provider distribution [15]. While HWSM projections reliably model total and metropolitan workforce trends, they may overestimate rural supply and underestimate demand, underscoring the need for refinements in nonmetropolitan workforce modeling. To improve future forecasts, it is crucial to consider the interdependence of allied health professionals, variations in scope of practice, geographic distribution patterns, the growth of telehealth, and the implications of an aging population and workforce.

Recent critiques have highlighted inaccuracies in past projections by the HRSA compared to AAMC predictions [2], potentially opening the door for focused forecasting efforts from entities like the AAO-HNS. Moreover, the influence of technological advancements and the ongoing adjustments post-COVID-19 pandemic on workforce needs cannot be ignored. Innovations in treatment and expanding telehealth services could alter the demand for otolaryngology services relative to disease prevalence [28, 29]. Nevertheless, the current HWSM model, largely based on prepandemic data, may not fully capture recent shifts in workforce dynamics, such as increased burnout, the transition to remote work, and changes in healthcare utilization patterns. As such, updates to the model are necessary to accurately reflect these evolving trends.

5 | Conclusion

The HWSM projections reveal critical challenges facing otolaryngology workforce capacity through 2036, with implications extending beyond simple supply–demand metrics. The anticipated shortfall is particularly severe in rural areas, where workforce adequacy reaches only 25.8% compared to 74.7% in metropolitan regions, highlighting a fundamental geographic maldistribution of specialists. These workforce inadequacies intersect with multiple systemic factors: concentration of residency programs in urban areas, tendency of specialists to establish practices near their training sites, and barriers to accessing specialized care in rural communities. The situation reflects broader challenges across surgical specialties, where training pipeline limitations struggle to meet the needs of a growing and aging population. However, otolaryngology faces unique challenges due to its diverse patient demographics, spanning from pediatric to geriatric care. Addressing these workforce challenges requires a multifaceted approach: reconsidering residency program distribution, developing innovative care delivery models, creating targeted rural practice incentives, and expanding telemedicine capabilities. Future research should focus on quantifying workforce needs and developing and evaluating interventions to ensure equitable access to otolaryngologic care across all communities.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. M. B. Buntin, J. Connell, and P. Buerhaus, "Projecting the Health Care Workforce Needed in the US," *JAMA Health Forum* 3, no. 8 (2022): e222430, https://doi.org/10.1001/jamahealthforum.2022.2430.

2. S. T. Berkowitz, A. P. Finn, R. Parikh, A. E. Kuriyan, and S. Patel, "Ophthalmology Workforce Projections in the United States, 2020 to 2035," *Ophthalmology* 131, no. 2 (2024): 133–139, https://doi.org/10.1016/j.ophtha.2023.09.018.

3. A. Grover, J. M. Orlowski, and C. E. Erikson, "The Nation's Physician Workforce and Future Challenges," *American Journal of the Medical Sciences* 351, no. 1 (2016): 11–19, https://doi.org/10.1016/j.amjms.2015.10.009.

4. H. C. Pillsbury, C. R. Cannon, S. E. S. Holzer, et al., "The Workforce in Otolaryngology-Head and Neck Surgery: Moving Into the Next Millennium," *Otolaryngology and Head and Neck Surgery* 123, no. 3 (2000): 341–356.

5. C. R. Cannon, E. M. Giaimo, T. L. Lee, and A. Chalian, "Special Report: Reassessment of the ORL-HNS Workforce: Perceptions and Realities," *Otolaryngology–Head and Neck Surgery* 131, no. 1 (2004): 1–15, https://doi.org/10.1016/j.otohns.2004.02.032.

6. L. Kim, R. A. Cooper, and D. W. Kennedy, "Otolaryngology-Head and Neck Surgery Physician Workforce Issues: An Analysis for Future Specialty Planning," *Otolaryngology–Head and Neck Surgery* 146, no. 4 (2012): 584–592.

7. C. A. Hughes, P. McMenamin, V. Mehta, H. Pillsbury, and D. Kennedy, "Otolaryngology Workforce Analysis," *Laryngoscope* 126, no. S9 (2016): S5–S11, https://doi.org/10.1002/lary.26238.

8. T. E. Williams, Jr., B. Satiani, A. Thomas, and E. C. Ellison, "The Impending Shortage and the Estimated Cost of Training the Future Surgical Workforce," *Annals of Surgery* 250, no. 4 (2009): 590–597, https://doi.org/10.1097/SLA.0b013e3181b6c90b.

9. IHS Markit Ltd., *The Complexities of Physician Supply and Demand: Projections From 2019 to 2034* (Association of American Medical Colleges, 2021).

10. G. B. Stanford-Moore, G. Cahill, A. Raj, P. Irakoze, B. Alkire, and M. F. Bhutta, "Density of Health Workforce Correlates to Disease Outcomes: Evidence From Global Data in Otolaryngology," *OTO Open* 6, no. 1 (2022): 2473974X221089840, https://doi.org/10.1177/2473974X221089840.

11. R. M. Andersen, P. L. Davidson, and S. E. Baumeister, "Improving Access to Care in America," in *Changing the US Health Care System: Key Issues in Health Services Policy and Management*, 3rd ed. (Jossey-Bass, 2007), 3–31.

12. R. A. Streeter, G. A. Zangaro, and A. Chattopadhyay, "Perspectives: Using Results From HRSA'S Health Workforce Simulation Model to Examine the Geography of Primary Care," *Health Services Research* 52 (2017): 481–507, https://doi.org/10.1111/1475-6773.12663.

13. J. H. Watanabe, "Examining the Pharmacist Labor Supply in the United States: Increasing Medication Use, Aging Society, and Evolution of Pharmacy Practice," *Pharmacy (Basel)* 7, no. 3 (2019): 137, https://doi.org/10.3390/pharmacy7030137.

14. Health Resources & Services Administration, Workforce Projections n.d. accessed April 1, 2024, https://data.hrsa.gov/topics/health-workforce/workforce-projections.

15. Technical Documentation for HRSA's Health Workforce Simulation Model n.d. U.S. Department of Health & Human Services Health Resources & Services Administration, accessed April 1, 2024, https://bhw.hrsa.gov/dataresearch/projecting-health-workforce-supply-demand/technical-documentation.

16. D. H. Liu, M. Ge, S. S. Smith, C. Park, and E. H. Ference, "Geographic Distribution of Otolaryngology Advance Practice Providers and Physicians," *Otolaryngology–Head and Neck Surgery* 167, no. 1 (2022): 48–55, https://doi.org/10.1177/01945998211040408.

17. M. N. Lango, E. Handorf, and E. Arjmand, "The Geographic Distribution of the Otolaryngology Workforce in the United States," *Laryngoscope* 127, no. 1 (2017): 95–101, https://doi.org/10.1002/lary.26188.

18. S. K. Gadkaree, J. C. McCarty, J. Siu, et al., "Variation in the Geographic Distribution of the Otolaryngology Workforce: A National Geospatial Analysis," *Otolaryngology and Head and Neck Surgery* 162, no. 5 (2020): 649–657, https://doi.org/10.1177/0194599820908860.

19. T. W. Vickery, R. Weterings, and C. Cabrera-Muffly, "Geographic Distribution of Otolaryngologists in the United States," *Ear, Nose, & Throat Journal* 95, no. 6 (2016): 218–222.

20. American Academy of Otolaryngology–Head and Neck Surgery, ed., *The Otolaryngology Workforce in the U.S.: Demographic and Geographic Characteristics*, 2023rd ed. (American Academy of Otolaryngology–Head and Neck Surgery, 2023), https://www.entnet.org/wp-content/uploads/2024/09/2023-Otolaryngology-Workforce.pdf.

21. American Academy of Otolaryngology–Head and Neck Surgery, *The 2022 Otolaryngology Workforce* (AAO-HNS, 2023), www.entnet.org/wp-content/uploads/2023/07/2022-Otolaryngology-Workforce.pdf.

22. J. A. Clarke, A. M. Despotis, R. J. Ramirez, J. P. Zevallos, and A. L. Mazul, "Head and Neck Cancer Survival Disparities by Race and Rural-Urban Context," *Cancer Epidemiology, Biomarkers & Prevention* 29, no. 10 (2020): 1955–1961, https://doi.org/10.1158/1055-9965.EPI-20-0376.

23. M. J. Urban, C. Wojcik, M. Eggerstedt, and A. J. Jagasia, "Rural-Urban Disparities in Otolaryngology: The State of Illinois," *Laryngoscope* 131, no. 1 (2021): E70–E75, https://doi.org/10.1002/lary.28652.

24. A. Meilleur, S. V. Subramanian, J. J. Plascak, J. L. Fisher, E. D. Paskett, and E. B. Lamont, "Rural Residence and Cancer Outcomes in the United States: Issues and Challenges," *Cancer Epidemiology, Biomarkers & Prevention* 22, no. 10 (2013): 1657–1667, https://doi.org/10.1158/1055-9965.EPI-13-0404.

25. A. Talwar, A. J. Gordon, A. F. Bewley, et al., "Distribution of the Head and Neck Surgical Oncology Workforce in the United States," *Head & Neck* 44, no. 11 (2022): 2537–2544, https://doi.org/10.1002/hed.27157.

26. W. M. Oslock, B. Satiani, D. P. Way, et al., "A Contemporary Reassessment of the US Surgical Workforce Through 2050 Predicts Continued Shortages and Increased Productivity Demands," *American Journal of Surgery* 223 (2022): 28–35.

27. D. A. Etzioni, J. H. Liu, M. A. Maggard, and C. Y. Ko, "The Aging Population and Its Impact on the Surgery Workforce," *Annals of Surgery* 238, no. 2 (2003): 170–177.

28. N. Govil, N. Raol, C. S. Tey, S. L. Goudy, and K. P. Alfonso, "Rapid Telemedicine Implementation in the Context of the COVID-19 Pandemic in an Academic Pediatric Otolaryngology Practice," *International Journal of Pediatric Otorhinolaryngology* 139 (2020): 110447, https://doi.org/10.1016/j.ijporl.2020.110447.

29. L. A. Zughni, A. I. Gillespie, J. L. Hatcher, A. D. Rubin, and J. P. Giliberto, "Telemedicine and the Interdisciplinary Clinic Model: During the COVID-19 Pandemic and Beyond," *Otolaryngology–Head and Neck Surgery* 163, no. 4 (2020): 673–675, https://doi.org/10.1177/0194599820932167.