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Insurance Disparities in Quality of Care Among Head and Neck Cancer Patients

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KEY POINTS

Question: Is insurance status associated with quality of care among head and neck cancer (HNC) patients?

Findings: This retrospective cohort study found that Medicare, Medicaid, and uninsured patients were less likely to receive care in top-quality hospitals, which are associated with receipt of guideline-compliant care, and improved survival. Medicaid, and uninsured patients were less likely to receive guideline-compliant care, independent of hospital quality.

Meaning: Significant insurance disparities in quality of care for patients with HNC.

Abstract

Importance: Significant insurance status disparities have been demonstrated in head and neck cancer (HNC) outcomes. The effects of insurance status on HNC outcomes may be explained by differential access to high-quality care.

Objective: To evaluate the association of insurance status with the quality of the treating hospital, and receipt of guideline-compliant care among HNC patients.

Design and Setting: Retrospective cohort study of data from the California Cancer Registry (CCR) dataset linked with discharge records and hospital characteristics from the California Department of Health Care Access and Information (HCAI)

Participants: Adult patients with HNC diagnosed between January 1, 2010 and December 31, 2019.

Exposures: Insurance status.

Main outcomes and measures: Quality of treating hospital, NCCN guideline-compliant care, and overall survival (OS).

Results: Treatment in top tertile hospitals (HR 0.82, 95% CI 0.77 to 0.87) was associated with improved OS compared with the lowest tertile. Medicare (OR 0.79, 95% CI 0.74 to 0.85), Medicaid (OR 0.63, 95% CI 0.57 to 0.69), and uninsured status (OR 0.39, 95% CI 0.30 to 0.50) were associated with lower likelihood of treatment in top-quality hospitals. Among patients with advanced disease, Medicaid (OR 0.72, 95% CI 0.62 to 0.83) and uninsured patients (OR 0.64, 95% CI 0.44 to 0.93) were less likely to receive dual-modality therapy. Among patients with surgically-resected advanced disease, Medicaid (OR 0.73, 95% CI 0.58 to 0.93) was associated with lower likelihood of receiving adjuvant RT.

Conclusions and Relevance: There are significant insurance disparities in quality of care for patients with HNC. These findings highlight the need for continued health insurance reform in the US, to improve the quality of insurance coverage, in addition to expanding access to health insurance.

Introduction

Significant insurance status disparities have been demonstrated in head and neck cancer (HNC) outcomes. Uninsured and Medicaid patients are more likely to present with advanced disease, are less likely to receive appropriate treatment, and have worse survival, even after adjusting for disease stage and treatment modality.[1–4] The effects of insurance status on HNC outcomes may be explained by differential access to high-quality care. Several studies have shown uninsured and Medicaid patients are more likely than patients with commercial insurance to be treated in low-volume hospitals.[5,6] However the association between insurance status and quality of HNC care has not been examined. The goal of our study was to evaluate the association of insurance status with the quality of the treating hospital, and receipt of guideline-compliant care among HNC patients.

Material and Method

This study was approved by the State of California Committee for the Protection of Human Subjects, and was considered exempt by the Stanford University Institutional Review Board at our institution. Data were extracted from the California Cancer Registry (CCR) dataset linked with discharge records and hospital characteristics from the California Department of Health Care Access and Information (HCAI). The CCR is the largest, contiguous-area, population-based cancer registry system in the country.[7] The HCAI Patient Discharge Data consists of a record for each inpatient discharge from a California-licensed hospital. The study cohort comprised adult patients with HNC diagnosed between January 1, 2010 and December 31, 2019. Patients with tumors of the following sites were included: oral cavity, oropharynx, hypopharynx, and larynx.

Tumor sites were determined according to the following ICD-O-3 codes available in CCR: oropharynx (C01.9, C02.4, C05.1-05.2, C09.0-09.1, C09.8-09.9, C10.0, C10.2-10.4, C10.8-10.9), oral cavity (C02.0-02.3, C02.8-03.1, C03.9-04.1, C04.8-05.0, C06.0-06.2), larynx (C32.0-32.3, C32.8-32.9), and hypopharynx (C12.9-

13.2, C13.8-13.9).[8] The following ICD-O-3 morphology codes for squamous cell carcinoma were included: 8070/3, 8071/3, 8072/3, 8073/3, 8074/3, 8075/3, 8078/3.[8] Disease stage was defined using the SEER-AJCC stage. Cases from 2010 – 2017 were classified according to the AJCC staging 7th edition,[9] while cases from 2018 – 2019 were classified according to the AJCC staging 8th edition.[10] In order to reconcile differences in the staging schema of the 7th and 8th editions of the AJCC staging systems, T classification was categorized as T1-3 versus T4, and nodal classification was categorized as N0 versus N1-3 when analyzing survival and use of high-quality and low-quality hospitals. CCR obtains information on initial course of treatment, including surgical resection of primary site, radiotherapy (RT), and chemotherapy, from the patient's medical records, and from the treating physicians if necessary. CCR collects information on insurance carrier at time of initial diagnosis and/or treatment from the treating facility. Insurance status was categorized as commercial, Medicare, Medicaid, other insurance (TRICARE, Military, Veterans Affairs, Indian/Public Health Service), uninsured, or unknown. Race/ethnicity was categorized as non-Hispanic White, Black, Hispanic, Asian/Pacific Islander, or Other. Marital status was categorized as "married" (including common law) or "single" (single-never married, divorced, widowed). Neighborhood-level socioeconomic status (SES) in the CCR was classified into quintiles, lowest (SES-1), lower-middle (SES-2), middle (SES-3), higher-middle (SES-4) and highest (SES-5) based on the Yost score, a composite index of socioeconomic status based on principal component analysis of block group level census variables such as education, income and occupation.[15]

CCR provides information on the reporting hospital, and whether the patient received any cancer-directed treatment at the reporting hospital. Only patients who were treated at the reporting hospital were included. Fragmented care was defined as receiving part of cancer-directed therapy at a different hospital. Hospital accreditation/certification status was determined for the following: National Cancer Institute (NCI)-designated cancer center, National Comprehensive Cancer Network (NCCN) certification status, and American College of Surgeons (ACoS) certification status. Case volume was determined by calculating the average number of HNC patients treated annually. Each hospital was assessed for compliance with the following NCCN guidelines: 1) Adjuvant RT for surgically resected advanced (T3, T4, and N2-3) disease, and 2) Dual Modality

therapy for advanced disease. Each hospital was also assessed for adequate lymph node yield for patients undergoing neck dissection (percentage of neck dissection specimen with 18 or more lymph nodes), which has been shown to be associated with improved survival in HNC patients.[11–15] Adverse event (AE) rates were calculated for each hospital using Agency for Healthcare Research and Quality (AHRQ) Patient Safety Indicators (PSIs). These are based on standardized algorithms that use inpatient administrative data to flag cases with potentially preventable inpatient AEs attributable to hospital care. AEs were calculated for each hospital using PSI 90, a composite PSI that provides an overview of hospital level AE rates. PSIs were calculated from the HCAI dataset using the AHRQ PSI software. Although these specific measures are not broadly endorsed as quality metrics, they were chosen because they are highly relevant to HNC and are measurable with the available dataset. Per CCR guidelines, hospital-specific data were not reported in published results.

The statistical analysis was performed using SAS system, version 9.4 (SAS Institute, Inc., Cary, NC, USA). Patients with distant metastasis were excluded from the analyses since these patients are not usually treated with curative intent. We first examined the associations between the eight hospital-level variable and patient survival using two-level frailty survival model with lognormal distribution to account for potential within-hospital clustering in event times, adjusting for tumor site, T4 disease, nodal metastasis, Charlson comorbidity score, surgical resection, RT, chemotherapy, age, and sex. Within-cluster correlation was also estimated to evaluate the extent of the heterogeneity between hospitals. Principal component analysis (PCA) was then performed on the statistically significant hospital-level variables to generate the composite HNC-specific hospital quality score. PCA is a technique for extracting a few orthogonal linear combinations of the variables that best capture the common information from a larger set of variables.[16] Our approach for generating hospital quality scores using PCA have been previously described.[17,18] The rationale for using PCA to construct the hospital quality score, rather than the regression coefficients in the survival model, is that we hoped to constructed a score could potentially be predictive of other clinical outcomes besides survival. The variance as well as correlations of constructed principal components with the risk prediction based on the survival regression were examined. The first principal component score, which captured the highest proportion of the

overall variance and correlated with the risk prediction, was used to represent the composite hospital quality score, with higher scores indicating higher quality. Hospital quality score was classified into tertiles for ease of interpretation. The association of hospital quality and overall survival (OS) was assessed using unadjusted and adjusted (including tumor site, T4 disease, nodal metastasis, Charlson comorbidity score, surgical resection, RT, chemotherapy, age, sex, insurance status, and neighborhood SES as covariates) survival regression models.

Unadjusted and adjusted logistic regression models were used to assess the association between insurance status and use of top-quality and bottom-quality hospitals. Ordinal regression was not used because the data violated the assumption of proportional odds. For the adjusted models, demographic factors (age, sex, race/ethnicity, marital status, year of diagnosis [analyzed as a categorical variable], neighborhood SES), cancer characteristics (site, T4 disease, nodal metastasis), and clinical characteristics (Charlson comorbidity score, fragmented care) were entered *a priori* into the model. Unadjusted and adjusted logistic regression models were used to assess the association between insurance and guideline-compliant care. For the adjusted models, demographic, cancer, and clinical characteristics were entered *a priori* into the model as described above. In order to examine whether the association between insurance and guideline-compliant care is mediated by hospital quality, sequential modeling was employed with and without adjustment for hospital quality. Missing values for hospital-level variables were handled by performing multiple imputation (MI) using Markov chain Monte Carlo method with 20 repetitions. MI estimates of model parameters were computed by averaging the estimates from 20 imputed models, and the variance and confidence intervals were computed using Rubin's combining formula.[19] Missing values for patient-level variables were coded as unknown, and included in the analysis. An estimate was considered statistically significant at α=0.05.

Results

Association between Hospital Quality and Survival

We identified 23,933 patients, treated at 467 hospitals, meeting the inclusion criteria. This excludes 5,082 patients, who were not treated at the reporting hospital. The mean age was 64.8 (SD 12.3) years. Patient characteristics are shown in Table 1. The following hospital factors were associated with OS and were included

in the PCA: NCCN certification status (HR 0.92, 95% CI 0.85 to 0.99); ACoS certification status (HR 1.10, 95% CI 1.06 to 1.15); case volume (HR 0.99 per doubling, 95% CI 0.97 to 1.00); percentage of surgically resected advanced disease treated with adjuvant RT (HR 1.02 per 10% increment, 95% CI 1.00 to 1.04); percentage of advanced disease treated with dual modality therapy (HR 0.93 per 10% increment, 95% CI 0.91 to 0.95); neck dissection lymph node yield (HR 1.01 per 10% increment, 95% CI 0.99 to 1.01); and PSI (HR 1.02, 95% CI 1.02 to 1.03). The eigenvalue and proportion of variance explained by each principal component are shown in Supplemental Table 1. The first principal component score (out of a total of 6) captured 31% of the overall variance, and included: annual case volume; percentage of surgically resected advanced disease treated with adjuvant RT; percentage of advanced disease treated with dual modality therapy; PSI; NCCN certification status; and ACoS certification status. The mean hospital quality score was 0 (standard deviation = 1), and the median was -0.21 (IQR -0.42 to 0.69), with higher values representing better hospital quality. Correlations between hospital quality score and the component hospital variables are shown in Supplemental Table 2. Hospital-level variables by hospital quality tertile are shown in Supplemental Table 3. The results of unadjusted and adjusted survival analysis of the association between hospital quality tertile and survival are shown in Table 2. Unadjusted analysis showed that patients treated in hospitals ranked in 2nd (HR 0.76, 95% CI 0.68 to 0.85) and 3rd tertile (HR 0.63, 95% CI 0.56 to 0.72) had improved OS compared with patients treated in hospitals ranked in the lowest tertile. This persisted (HR 0.89, 95% CI 0.81 to 0.97 for mid tertile, and HR 0.87, 95% CI 0.79 to 0.95 for top tertile) after adjusting for site, T classification, nodal metastasis, Charlson comorbidity score, surgical resection, RT, chemotherapy, age, sex, insurance status, and neighborhood SES. A sensitivity analysis was performed for the adjusted analysis by excluding oropharyngeal cancer cases. The association remained for top tertile hospitals (HR 0.86, 95% CI 0.78 to 0.94), but not mid tertile hospitals (HR 0.91, 95% CI 0.83 to 1.00).

Association between insurance and hospital quality

Unadjusted analysis showed that Medicare (OR 0.68, 95% CI 0.64 to 0.72), Medicaid (OR 0.50, 95% CI 0.46 to 0.55), and uninsured (OR 0.30, 95% CI 0.23 to 0.38) patients were less likely to receive care in top-

quality hospitals compared with patients with commercial insurance (Table 3). Medicare (OR 0.78, 95% CI 0.73 to 0.84), Medicaid (OR 0.60, 95% CI 0.54 to 0.66), and uninsured status (OR 0.38, 95% CI 0.29 to 0.49) remained associated with lower likelihood of treatment in top-quality hospitals after adjusting for age, sex, race/ethnicity, marital status, year of diagnosis, neighborhood SES, site, T4 disease, nodal metastasis, Charlson comorbidity score, and fragmented care. Other insurance and unknown insurance were associated with lower likelihood of treatment in top-quality hospitals in the unadjusted analysis, but this persisted only for other insurance in the adjusted analysis. Unadjusted analysis showed that Medicare (OR 1.54, 95% CI 1.40 to 1.69), and Medicaid (OR 1.41, 95% CI 1.22 to 1.62) patients were more likely to receive care in bottom-quality hospitals compared with patients with commercial insurance. This association also persisted in the adjusted model (OR 1.29, 95% CI 1.15 to 1.44 for Medicare, and OR 1.27, 95% CI 1.09 to 1.48 for Medicaid). Year of diagnosis was also associated with use of top-quality and bottom quality hospitals. Patients diagnosed in 2010 – 2015 were less likely to be treated in top-quality hospitals compared with those diagnosed in 2016 – 2019. Patients diagnosed in 2010 – 2017 were more likely to be treated in bottom quality hospitals compared with those diagnosed in 2018 – 2019.

Association between insurance and receipt of guideline-compliant care

Among patients with advanced (T3, T4, and N2-3) disease, unadjusted analysis showed that Medicare (OR 0.79, 95% CI 0.73 to 0.87), Medicaid (OR 0.86, 95% CI 0.76 to 0.97), and uninsured patients (OR 0.70, 95% CI 0.50 to 0.97) were less likely to receive dual-modality therapy compared to commercially-insured patients (Table 4). Medicaid (OR 0.69, 95% CI 0.60 to 0.80), and uninsured status (OR 0.60, 95% CI 0.42 to 0.87) remained associated with lower likelihood of receiving dual-modality therapy, after adjusting for demographic factors (age, sex, race/ethnicity, marital status, year of diagnosis, neighborhood SES), cancer characteristics (site, T4 disease, nodal metastasis), and clinical characteristics (Charlson comorbidity score, fragmented care). These associations persisted after additionally adjusting for hospital quality (OR 0.72, 95% CI 0.62 to 0.83 for Medicaid; and OR 0.64, 95% CI 0.44 to 0.93 for uninsured). Medicare was no longer associated with receipt of dual-modality therapy in either of the adjusted models. In the final model, treatment in top-

quality (OR 1.62, 95% CI 1.39 to 1.90) hospitals was associated with a higher likelihood of receiving dual-modality therapy.

Among patients with surgically-resected advanced disease, unadjusted analysis showed that Medicare (OR 0.53, 95% CI 0.45 to 0.61), and Medicaid (OR 0.63, 95% CI 0.52 to 0.78) patients were less likely to receive adjuvant RT compared to commercially-insured patients (Table 5). Only Medicaid (OR 0.69, 95% CI 0.55 to 0.87) remained associated with lower likelihood of receiving adjuvant RT, after adjusting for demographic factors, cancer characteristics, and clinical characteristics. This association persisted after additionally adjusting for hospital quality (OR 0.73, 95% CI 0.58 to 0.93). Uninsured status was not associated with receipt of adjuvant RT in any of the models. In the final model, treatment in top-quality (OR 3.56, 95% CI 2.83 to 4.48) and mid-quality (OR 2.20, 95% CI 1.74 to 2.77) hospitals were associated with a higher likelihood receiving adjuvant RT.

Discussion

This is the first study to evaluate the association of health insurance status with use of high-quality hospitals, and receipt of guideline-compliant care among HNC patients. We found that treatment in high-quality hospitals was associated with receipt of NCCN guideline-compliant care, and improved survival. There were significant insurance disparities in the use of high-quality hospitals. Medicare, Medicaid, and uninsured patients were less likely to receive care in top-quality hospitals compared with patients with commercial insurance. Medicare and Medicaid patients were more likely to receive care in bottom-quality hospitals, however, uninsured patients had similar rates of bottom-quality hospital use as commercially-insured patients. There were also insurance disparities in receipt of NCCN guideline-compliant care. Among patients with advanced-stage disease, Medicaid, and uninsured patients were less likely to receive dual-modality therapy compared to commercially-insured patients. Among patients who underwent surgical resection for advanced-stage disease, Medicaid patients were less likely to receive adjuvant RT compared to commercially-insured patients.

Our findings are consistent with previous studies showing that uninsured patients and patients with Medicaid insurance are more likely to present with advanced disease, and have worse survival.[1–4] Our study

provides further context by examining insurance disparities in quality of care as a possible explanation for the disparities in outcomes. A few studies have shown that uninsured and Medicaid patients with HNC are less likely to receive definitive treatment.[2,20] However, these studies did not evaluate the quality of care provided. Our study shows that, even among patients receiving definitive care, there were insurance disparities in receipt of guideline-compliant care.

Our study revealed insurance status disparities in use of high-quality hospitals, a factor that was significantly associated with improved survival. We found that Medicaid patients were less likely to receive care in top-quality hospitals, and more likely to receive care in bottom-quality hospitals. This is consistent with previous studies showing the association of Medicaid insurance with poor outcomes.[1–4,21] However, our study also found that Medicare insurance was associated with lower likelihood of treatment in top-quality hospitals, and higher likelihood of treatment in bottom-quality hospitals. This is consistent with studies of other cancer sites showing low rates of high-quality and high-volume hospital use among Medicare patients.[22,23] We also found that treatment in high-quality hospitals was associated with receipt of guideline-compliant care. However, the relationship between insurance status and receipt of guideline compliant care did not appear to be mediated by hospital quality. This finding indicates that patients without commercial, who receive care at high-quality hospitals still experience barriers in accessing high-quality care. This is consistent with the findings of a single-institution study, which found that Medicaid-insured HNC patients experienced longer diagnosis-to-treatment times, and had worse survival compared with other insurance types.[21] The reasons for this are unclear, but potential barriers may include lack of coverage for certain medication, procedures, and services.

The findings of our study highlight the need for continued health insurance reform in the US. The Affordable Care Act (ACA) has helped millions of Americans acquire health insurance coverage, which has led to improved access to primary care for Medicaid patients. [24,25] The ACA has also had positive impacts on HNC outcomes. Several studies have shown that Medicaid expansion was associated with a decrease in uninsured rates and increase in rates of early-stage cancer diagnosis among HNC patients.[26,27] Some studies have also shown improved HNC survival following the establishment of the ACA.[20,28] Despite these positive results, the

findings of our study show that disparities in quality of care and outcomes still exist among those with health insurance coverage, based on insurance type. Our findings suggest that patients with non-commercial insurance experience barriers in accessing high-quality care. This highlights the need to improve the quality of insurance coverage, in addition to expanding access to health insurance.

The strengths of our study include its large sample size, and use of high-quality cancer registry data from a diverse patient population. The CCR is the largest, contiguous-area, population-based cancer registry system in the country.[7] CCR data are representative of all cancer cases in California, since cancer reporting is mandated by California law. Linkage of CCR data to HCAI also allowed us to capture hospital adverse events rates, and other clinical information that is not usually available in cancer registry data. Another strength of this study is the use of a multifaceted approach, examining hospital volume, adherence to national guidelines, adverse event rates, and accreditation/certification status, to define HNC-specific hospital quality.

Our study has several limitations. The AJCC staging schema was not consistent throughout the study period. Consequently, in order to reconcile differences in the staging schema of the 7th and 8th editions of the AJCC staging systems, T classification was categorized as T1-3 versus T4, and nodal classification was categorized as N0 versus N1-3 when analyzing survival and use of high-quality and low-quality hospitals. All adjusted models also included year of diagnosis as a covariate. Differences in socioeconomic status between insurance groups, and the changing sociodemographic composition of Medicaid patients due to Medicaid expansion, may have affected the results of our study. We adjusted for neighborhood-level SES and year of diagnosis to account for these, however, we could not adjust for unmeasured variables such as individual-level SES, social support, and access to transportation, which can influence access to care. Finally, this study was limited to patients treated in California. Therefore, it is unclear if the findings are generalizable to the entire US.

In conclusion, our study shows significant insurance disparities in quality of care for patients with HNC. Medicare, Medicaid, and uninsured patients are less likely to receive care in top-quality hospitals, which are associated with receipt of guideline-compliant care, and improved survival. Medicaid, and uninsured patients are less likely to receive guideline-compliant care, independent of hospital quality. These findings highlight the

need for continued health insurance reform in the US, to improve the quality of insurance coverage, in addition to expanding access to health insurance. Future studies are needed to understand the factors that mediate the relationship between insurance status and quality of care for HNC patients in order to inform health insurance policy strategies.

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Table 1. Patient Characteristics.

Variable	Private (N=10890)	Medicare (N=8725)	Medicaid (N=2457)	Uninsured (N=322)	Other (N=1072)	Unknown (N=467)
Age (mean (SD))	60.6 (11.4)	73 (9.09)	56.6 (9.6)	57.1 (9.92)	62.3 (10.4)	65.4 (11.9)
Female	2587 (23.8%)	2472 (28.3%)	566 (23.1%)	50 (15.5%)	115 (10.7%)	120 (25.7%)
Male	8300 (76.2%)	6252 (71.7%)	1887 (76.9%)	272 (84.5%)	956 (89.3%)	347 (74.3%)

Single	3470 (34.0%)	3796 (45.3%)	1604 (68.2%)	192 (62.1%)	592 (59.7%)	178 (45.5%)
Married	6734 (66.0%)	4592 (54.7%)	747 (31.8%)	117 (37.9%)	399 (40.3%)	213 (54.5%)
Race/ethnicity: non-Hispanic White	7818 (71.8%)	6352 (72.8%)	1175 (47.8%)	165 (51.2%)	698 (65.1%)	318 (68.1%)
Race/ethnicity: Black	557 (5.1%)	440 (5.0%)	313 (12.7%)	26 (8.1%)	126 (11.8%)	21 (4.5%)
Race/ethnicity: Hispanic	1500 (13.8%)	1135 (13.0%)	709 (28.9%)	96 (29.8%)	175 (16.3%)	85 (18.2%)
Race/ethnicity: Asian/Pacific Islander	887 (8.1%)	699 (8.0%)	230 (9.4%)	33 (10.2%)	57 (5.3%)	22 (4.7%)
Race/ethnicity: Other	128 (1.2%)	99 (1.1%)	30 (1.2%)	2 (0.6%)	16 (1.5%)	21 (4.5%)
SES Quintile 1	1099 (10.1%)	1307 (15.0%)	774 (31.5%)	96 (29.8%)	255 (23.8%)	93 (19.9%)
SES Quintile 2	1835 (16.9%)	1659 (19.0%)	605 (24.6%)	71 (22.0%)	230 (21.5%)	102 (21.8%)
SES Quintile 3	2329 (21.4%)	1863 (21.4%)	471 (19.2%)	52 (16.1%)	234 (21.8%)	107 (22.9%)
SES Quintile 4	2790 (25.6%)	1872 (21.5%)	386 (15.7%)	59 (18.3%)	193 (18.0%)	100 (21.4%)
SES Quintile 5	2837 (26.1%)	2024 (23.2%)	221 (9.0%)	44 (13.7%)	160 (14.9%)	65 (13.9%)
Site: Hypopharynx	353 (3.2%)	414 (4.7%)	157 (6.4%)	15 (4.7%)	69 (6.4%)	23 (4.9%)
Site: Larynx	1991 (18.3%)	2394 (27.4%)	651 (26.5%)	90 (28.0%)	275 (25.7%)	114 (24.4%)
Site: Oral cavity	3361 (30.9%)	2990 (34.3%)	735 (29.9%)	95 (29.5%)	245 (22.9%)	154 (33.0%)
Site: Oropharynx	5185 (47.6%)	2927 (33.5%)	914 (37.2%)	122 (37.9%)	483 (45.1%)	176 (37.7%)
T Classification: T1	4125 (37.9%)	3065 (35.1%)	482 (19.6%)	85 (26.4%)	270 (25.2%)	148 (31.7%)
T Classification: T2	3466 (31.8%)	2515 (28.8%)	603 (24.5%)	88 (27.3%)	300 (28.0%)	126 (27.0%)
T Classification: T3	1744 (16.0%)	1503 (17.2%)	560 (22.8%)	53 (16.5%)	230 (21.5%)	98 (21.0%)
T Classification: T4	1555 (14.3%)	1642 (18.8%)	812 (33.0%)	96 (29.8%)	272 (25.4%)	95 (20.3%)
N Classification: N0	4734 (43.5%)	4768 (54.6%)	901 (36.7%)	128 (39.8%)	391 (36.5%)	232 (49.7%)
N Classification: N1	1889 (17.3%)	1357 (15.6%)	408 (16.6%)	52 (16.1%)	174 (16.2%)	67 (14.3%)
N Classification: N2	3887 (35.7%)	2282 (26.2%)	934 (38.0%)	118 (36.6%)	447 (41.7%)	152 (32.5%)
N Classification: N3	355 (3.3%)	270 (3.1%)	196 (8.0%)	20 (6.2%)	56 (5.2%)	12 (2.6%)
N Classification: Unknown	25 (0.2%)	48 (0.6%)	18 (0.7%)	4 (1.2%)	4 (0.4%)	4 (0.9%)
M Classification: M0	10665 (97.9%)	8429 (96.6%)	2348 (95.6%)	308 (95.7%)	1037 (96.7%)	458 (98.1%)
M Classification: M1	225 (2.1%)	296 (3.4%)	109 (4.4%)	14 (4.3%)	35 (3.3%)	9 (1.9%)
Charlson Score: 0	5397	3264	1065	152	329	196

	(49.6%)	(37.4%)	(43.3%)	(47.2%)	(30.7%)	(42.0%)
Charlson Score: 1	1720 (15.8%)	1977 (22.7%)	551 (22.4%)	57 (17.7%)	139 (13.0%)	83 (17.8%)
Charlson Score: 2	706 (6.5%)	1016 (11.6%)	183 (7.4%)	13 (4.0%)	45 (4.2%)	31 (6.6%)
Charlson Score: 3+	815 (7.5%)	1380 (15.8%)	217 (8.8%)	14 (4.3%)	58 (5.4%)	53 (11.3%)
Charlson Score: Unknown	2252 (20.7%)	1088 (12.5%)	441 (17.9%)	86 (26.7%)	501 (46.7%)	104 (22.3%)

Table 2. Overall survival by hospital quality tertile.

	Variable	**Hazard Ratio**	**95% CI**
Unadjust	Low-quality Hospital	1.00	Reference

ed	Mid-quality Hospital	0.76	0.68, 0.85
	High-quality Hospital	0.63	0.56, 0.72
Adjusted	Low-quality Hospital	1.00	Reference
	Mid-quality Hospital	0.89	0.81, 0.97
	High-quality Hospital	0.87	0.79, 0.95
	Site: Oral Cavity	1.00	Reference
	Site: Larynx	0.76	0.71, 0.80
	Site: Hypopharynx	1.04	0.94, 1.14
	Site: Oropharynx	0.51	0.48, 0.55
	T1-3 disease	1.00	Reference
	T4 disease	2.12	2.02, 2.23
	Nodal metastasis: No	1.00	Reference
	Nodal metastasis: Yes	1.82	1.73, 1.92
	Nodal metastasis: Unknown	2.10	1.56, 2.83
	Charlson Score: 0	1.00	Reference
	Charlson Score: 1	1.48	1.40, 1.56
	Charlson Score: 2	1.70	1.59, 1.82
	Charlson Score: 3+	2.37	2.23, 2.52
	Charlson Score: Unknown	1.03	0.96, 1.10
	No surgical resection	1.00	Reference
	Surgical resection	0.48	0.46, 0.51
	No radiotherapy	1.00	Reference
	Radiotherapy	0.56	0.53, 0.59
	No chemotherapy	1.00	Reference
	Chemotherapy	0.92	0.87, 0.97
	Age	1.04	1.04, 1.04
	Male	1.00	Reference
	Female	0.98	0.93, 1.03
	Commercial Insurance	1.00	Reference
	Medicare	1.21	1.14, 1.27
	Medicaid	1.69	1.57, 1.82
	Uninsured	1.49	1.25,1.78
	Other insurance	1.45	1.31, 1.60
	Unknown insurance	1.36	1.19, 1.56
	SES Quintile 1	1.00	Reference
	SES Quintile 2	0.95	0.89, 1.01
	SES Quintile 3	0.82	0.77, 0.88
	SES Quintile 4	0.79	0.74, 0.85
	SES Quintile 5	0.70	0.65, 0.75

Table 3. Association of insurance status with use of high-quality and low-quality hospitals.

		Top Quality Hospital	**Bottom Quality**

				Hospital	
	Variable	**Odds Ratio**	**95% CI**	**Odds Ratio**	**95% CI**
Unadjusted	Commercial Insurance	1.00	Reference	1.00	Reference
	Medicare	0.68	0.64, 0.72	1.54	1.40, 1.69
	Medicaid	0.50	0.46, 0.55	1.41	1.22, 1.62
	Uninsured	0.30	0.23, 0.38	1.29	0.90, 1.86
	Other insurance	0.66	0.58, 0.75	1.00	0.80, 1.25
	Unknown insurance	0.63	0.52, 0.76	2.07	1.60, 2.67
Adjusted	Commercial Insurance	1.00	Reference	1.00	Reference
	Medicare	0.78	0.73, 0.84	1.29	1.15, 1.44
	Medicaid	0.60	0.54, 0.66	1.27	1.09, 1.48
	Uninsured	0.38	0.29, 0.49	0.95	0.63, 1.41
	Other insurance	0.81	0.70, 0.93	0.86	0.68, 1.10
	Unknown insurance	0.89	0.73, 1.10	1.30	0.95, 1.77
	Age	0.99	0.99, 1.00	1.01	1.01, 1.01
	Female	1.00	Reference	1.00	Reference
	Male	0.99	0.93, 1.06	1.01	0.91, 1.12
	White	1.00	Reference	1.00	Reference
	Black	0.92	0.81, 1.03	1.44	1.22, 1.70
	Hispanic	0.84	0.78, 0.91	1.22	1.08, 1.38
	Asian/Pacific Islander	1.16	1.05, 1.29	1.28	1.09, 1.50
	Other	1.06	0.82, 1.37	1.09	0.72, 1.65
	Single	1.00	Reference	1.00	Reference
	Married	1.11	1.04, 1.17	1.01	0.92, 1.10
	SES Quintile 1	1.00	Reference	1.00	Reference
	SES Quintile 2	1.24	1.12, 1.36	1.04	0.90, 1.19
	SES Quintile 3	1.39	1.26,	0.99	0.86,

			1.53		1.13
	SES Quintile 4	1.76	1.60, 1.94	0.68	0.58, 0.78
	SES Quintile 5	2.20	2.00, 2.43	0.55	0.47, 0.64
	Site: Oral Cavity	1.00	Referen ce	1.00	Referen ce
	Site: Larynx	0.79	0.73, 0.85	1.34	1.19, 1.51
	Site: Hypopharynx	0.71	0.61, 0.82	1.47	1.19, 1.83
	Site: Oropharynx	0.77	0.71, 0.83	1.41	1.25, 1.60
	T1-3 disease	1.00	Referen ce	1.00	Referen ce
	T4 disease	1.10	1.02, 1.19	0.94	0.83, 1.05
	Nodal metastasis: No	1.00	Referen ce	1.00	Referen ce
	Nodal metastasis: Yes	1.05	0.99, 1.13	0.80	0.72, 0.89
	Nodal metastasis: Unknown	0.65	0.40, 1.07	1.48	0.79, 2.77
	Charlson Score: 0			1.00	Referen ce
	Charlson Score: 1	0.94	0.87, 1.01	1.12	0.99, 1.26
	Charlson Score: 2	1.02	0.92, 1.13	1.02	0.87, 1.20
	Charlson Score: 3+	0.96	0.87, 1.06	1.35	1.17, 1.55
	Charlson Score: Unknown	1.02	0.95, 1.11	0.89	0.78, 1.02
	Fragmented care	1.09	1.03, 1.16	0.95	0.86, 1.04
	Year of diagnosis: 2010	0.79	0.69, 0.89	1.86	1.49, 2.32
	Year of diagnosis: 2011	0.70	0.61, 0.79	2.24	1.80, 2.78
	Year of diagnosis: 2012	0.73	0.64, 0.83	2.31	1.86, 2.87
	Year of diagnosis: 2013	0.79	0.70, 0.89	2.03	1.63, 2.52
	Year of diagnosis: 2014	0.82	0.73, 0.93	1.85	1.48, 2.30
	Year of diagnosis: 2015	0.81	0.72, 0.92	2.07	1.67, 2.56
	Year of diagnosis: 2016	0.95	0.84, 1.07	1.42	1.14, 1.78
	Year of diagnosis: 2017	0.96	0.85, 1.08	1.43	1.14, 1.78
	Year of diagnosis: 2018	0.96	0.85, 1.09	1.25	0.98, 1.58

	Year of diagnosis: 2019	1.00	Referen ce	1.00	Referen ce

Table 4. Association of insurance status with dual-modality therapy for T3, T4, and N2-3 disease.

	Variable	**Odds Ratio**	**95% CI**
Unadjusted	Commercial Insurance	1.00	Reference
	Medicare	0.79	0.73, 0.87
	Medicaid	0.86	0.76, 0.97
	Uninsured	0.70	0.50, 0.97
	Other insurance	0.87	0.73, 1.03
	Unknown insurance	0.70	0.52, 0.93
Adjusted for demographic factors, clinical factors, insurance status, socioeconomic status, and fragmented care	Commercial Insurance	1.00	Reference
	Medicare	1.01	0.90, 1.14
	Medicaid	0.69	0.60, 0.8
	Uninsured	0.60	0.42, 0.87
	Other insurance	1.04	0.85, 1.28
	Unknown insurance	0.77	0.55, 1.08
Final Model: adjusted	Commercial Insurance	1.00	Reference

for demographic factors, clinical factors, insurance status, socioeconomic status, fragmented care, and hospital quality	Medicare	1.04	0.93, 1.17
	Medicaid	0.72	0.62, 0.83
	Uninsured	0.64	0.44, 0.93
	Other insurance	1.05	0.86, 1.29
	Unknown insurance	0.78	0.56, 1.09
	Age	0.97	0.96, 0.97
	Female	1.00	Reference
	Male	0.98	0.88, 1.09
	White	1.00	Reference
	Black	0.89	0.74, 1.06
	Hispanic	1.27	1.13, 1.44
	Asian/Pacific Islander	1.27	1.08, 1.49
	Other	0.57	0.35, 0.92
	Single	1.00	Reference
	Married	1.26	1.15, 1.38
	SES Quintile 1	1.00	Reference
	SES Quintile 2	1.02	0.88, 1.18
	SES Quintile 3	1.14	0.98, 1.32
	SES Quintile 4	1.10	0.95, 1.28
	SES Quintile 5	1.21	1.04, 1.41
	Site: Oral Cavity	1.00	Reference
	Site: Larynx	0.29	0.25, 0.33
	Site: Hypopharynx	0.10	0.08, 0.13
	Site: Oropharynx	0.16	0.14, 0.18
	T1-3 disease	1.00	Reference
	T4 disease	0.86	0.78, 0.95
	Nodal metastasis: No	1.00	Reference
	Nodal metastasis: Yes	1.08	0.96, 1.20
	Nodal metastasis: Unknown	0.33	0.13, 0.83
	Charlson Score: 0	1.00	Reference
	Charlson Score: 1	0.91	0.81, 1.02
	Charlson Score: 2	0.89	0.75, 1.04
	Charlson Score: 3+	0.66	0.56, 0.77
	Charlson Score: Unknown	0.60	0.53, 0.68
	Fragmented care	1.77	1.62, 1.94
	Low-quality Hospital	1.00	Reference
	Mid-quality Hospital	1.18	1.00, 1.38
	High-quality Hospital	1.62	1.39, 1.90

Both adjusted models were adjusted for year of diagnosis.

Table 5. Association of insurance status with adjuvant radiotherapy for surgically-resected T3, T4, and N2-3 disease.

	Variable	Odds Ratio	95% CI
Unadjusted	Commercial Insurance	1.00	
	Medicare	0.53	0.45, 0.61
	Medicaid	0.63	0.52, 0.78
	Uninsured	0.66	0.38, 1.16
	Other insurance	0.98	0.71, 1.37
	Unknown insurance	0.79	0.47, 1.33
Adjusted for demographic factors, clinical factors, insurance status, socioeconomic status, and fragmented care	Commercial Insurance	1.00	Reference
	Medicare	0.91	0.75, 1.09
	Medicaid	0.69	0.55, 0.87
	Uninsured	0.80	0.43, 1.50
	Other insurance	1.16	0.81, 1.68
	Unknown insurance	1.19	0.66, 2.17

Final Model: adjusted for demographic factors, clinical factors, insurance status, socioeconomic status, fragmented care, and hospital quality	Commercial Insurance	1.00	Reference
	Medicare	0.95	0.79, 1.15
	Medicaid	0.73	0.58, 0.93
	Uninsured	0.96	0.51, 1.81
	Other insurance	1.18	0.82, 1.71
	Unknown insurance	1.32	0.72, 2.42
	Age	0.98	0.97, 0.98
	Female	1.00	Reference
	Male	1.18	1.00, 1.40
	White	1.00	Reference
	Black	1.15	0.84, 1.57
	Hispanic	1.28	1.04, 1.57
	Asian/Pacific Islander	1.16	0.90, 1.50
	Other	0.96	0.43, 2.14
	Single	1.00	Reference
	Married	1.18	1.01, 1.37
	SES Quintile 1	1.00	Reference
	SES Quintile 2	1.13	0.90, 1.43
	SES Quintile 3	1.26	1.00, 1.60
	SES Quintile 4	1.45	1.14, 1.85
	SES Quintile 5	1.34	1.05, 1.72
	Site: Oral Cavity	1.00	Reference
	Site: Larynx	1.15	0.94, 1.41
	Site: Hypopharynx	0.97	0.63, 1.49
	Site: Oropharynx	1.54	1.26, 1.88
	T1-3 disease	1.00	Reference
	T4 disease	0.96	0.82, 1.13
	Nodal metastasis: No	1.00	Reference
	Nodal metastasis: Yes	2.27	1.94, 2.67
	Nodal metastasis: Unknown	0.53	0.15, 1.92
	Charlson Score: 0	1.00	Reference
	Charlson Score: 1	0.94	0.77, 1.14
	Charlson Score: 2	0.96	0.73, 1.25
	Charlson Score: 3+	0.65	0.51, 0.83
	Charlson Score: Unknown	0.82	0.65, 1.04
	Fragmented care	2.56	2.16, 3.02
	Low-quality Hospital	1.00	Reference
	Mid-quality Hospital	2.20	1.74, 2.77
	High-quality Hospital	3.56	2.83, 4.48

Both adjusted models were adjusted for year of diagnosis.

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