Abstract

Background: There are significant racial disparities in head and neck cancer (HNC) outcomes. Racial differences in survival may be explained by differential access to high-quality care. The goal of this study was to evaluate the association of race and ethnicity with the quality of the treating hospital, and receipt of guideline-compliant care among HNC patients.

Methods: Retrospective cohort study of data from the California Cancer Registry dataset linked with discharge records and hospital characteristics. The study cohort included adult patients with HNC diagnosed between January 1, 2010, and December 31, 2019. Outcome measures included the quality of treating hospital, and NCCN guideline-compliant care.

Results: Black (OR 0.76, 95% CI 0.67 to 0.85) and Hispanic (OR 0.68, 95% CI 0.63 to 0.74) patients were less likely to be treated in top-quality hospitals compared with non-Hispanic White patients, after adjusting for demographic, and clinical factors. This association disappeared for Black patients, but persisted for Hispanic patients, after additionally adjusting for socioeconomic status and insurance status. Black patients with advanced-stage disease were less likely to be treated with dual-modality therapy (OR 0.82, 95% CI 0.70 to 0.96), however, this association disappeared after adjusting for demographic, and clinical factors, and hospital quality.

Conclusion: There are significant racial and ethnic disparities in quality of care for patients with HNC. Our findings suggest that differential access to high-quality care may account for some of the racial disparities in HNC survival, and highlight the need for continued investigation into the drivers of racial disparities in HNC outcomes.

Keywords: head and neck cancer; health status disparities; minority health; quality indicators, health care; quality of care; high-volume hospitals; mediation analysis

Introduction

There are significant racial disparities in head and neck cancer (HNC) outcomes in the United States. Black patients have worse survival outcomes than White patients, even after adjusting for disease stage, treatment received, and socioeconomic status.[1–8] Racial differences in survival may be explained by differential access to high-quality care. Previous studies have suggest that racial minority individuals are more likely to be treated in low-quality hospitals.[9,10] However, these studies used surrogate measures such as case volume, and cancer center designation, rather than direct measures of hospital quality. Furthermore, racial disparities in quality of care have not been adequately studied in the HNC population. The goal of this study was to evaluate the association of race and ethnicity with the quality of the treating hospital, and receipt of guideline-compliant care among HNC patients. In order to define hospital quality in a way that is relevant to HNC outcomes, we sought to utilize a composite measure of head and neck cancer-specific hospital quality that includes direct measures of quality of care, and is associated with survival outcomes.

Materials and Methods

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 study cohort comprised adult patients with HNC diagnosed between January 1, 2010, and December 31, 2019. Patients with squamous cell carcinoma of the following sites were included: oral cavity, oropharynx, hypopharynx, and larynx (see supplemental materials for details). Patients with distant metastasis were excluded since these patients are not usually treated with curative intent. Disease stage was defined using the SEER-AJCC stage. Cases from 2010 – 2017 were classified according to the AJCC staging 7th edition,[11] while cases from 2018 – 2019 were classified according to the AJCC staging 8th edition.[12] Race/ethnicity was categorized in CCR as non-Hispanic White, Black, Hispanic, Asian/Pacific Islander, or Other. CCR obtains this information

from the patient's medical records. Marital status was categorized as "married" or "single" (single-never married, divorced, widowed). Neighborhood socioeconomic status (SES) was classified into quintiles: lowest (SES-1) to highest (SES-5). Insurance status was categorized as commercial, Medicare, Medicaid, other insurance, uninsured, or unknown.

CCR provides information on the reporting hospital, and whether the patient was treated 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. The following variables were determined for each hospital: National Cancer Institute (NCI)-designated cancer center, National Comprehensive Cancer Network (NCCN) certification status, and American College of Surgeons (ACoS) certification status, and annual case volume (mean number of HNC patients treated annually). Compliance with the following NCCN guidelines was assessed for each hospital: 1) adjuvant RT for surgically resected advanced (T3, T4, and N2-3) disease, and 2) dual Modality therapy for advanced disease. These metrics were chosen because they are relevant to HNC and are measurable with the available dataset. Adverse event (AE) rates were calculated for each hospital using Agency for Healthcare Research and Quality (AHRQ) Patient Safety Indicators (PSI), calculated from the HCAI dataset using the AHRQ PSI software.

The statistical analysis was performed using SAS system, version 9.4 (SAS Institute, Inc., Cary, NC, USA), and the R package "sensmediation" (R Core Team 2021, Vienna, Austria). Head and neck cancer-specific hospital quality scores were generated using principal component analysis (PCA) including the following hospital-level factors: 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. 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.[13] Our approach for generating the head and neck-specific hospital quality scores has been previously described in detail.[14] Hospital quality score was classified into tertiles for ease of interpretation. Our previous work has shown that treatment in hospitals ranked in 2nd (HR 0.89, 95% CI 0.81 to 0.97) and 3rd (HR 0.87, 95% CI 0.79 to 0.95)

tertiles were associated with improved overall survival compared with treatment in hospitals ranked in the lowest tertile, after adjusting for clinical and sociodemographic factors.[14] Logistic regression models were used to assess the association between race/ethnicity and use of top-quality and bottom-quality hospitals. Ordinal regression was not used because the assumption of proportional odds was violated. For the adjusted models, a sequential modeling approach was used to understand the roles of SES and insurance status in racial/ethnic differences in use of high-quality hospitals. The following predictors were sequentially entered *a priori* into the models: 1) demographic and clinical factors (age, sex, marital status, year of diagnosis, tumor site, T4 disease, nodal metastasis, Charlson comorbidity score, fragmented care); 2) neighborhood SES; and 3) insurance status. We further used a generalized structural equation model that assessed the independent mediation effects of neighborhood SES and insurance status on the association between race/ethnicity and hospital quality. We used the counterfactual framework that allows for definitions of direct and indirect (mediation) effects and aimed to decompose a total effect into direct and indirect effects in the context of nonlinear models. No interaction terms between race and mediators were included in the mediation analyses because the interaction effects were not statistically significant. Because the outcome variable was not continuous, the proportion mediated on risk difference scale was calculated using a transformation of the odds ratios. A *%mediation* macro developed by Valeri and VanderWeele,[15] which provides a very versatile counterfactual approach, was used to assess the mediation effect.

To assess the robustness of our mediation analysis, we performed sensitivity analyses by considering a possible unobserved confounder that may impact both the mediator and outcome. We used a method that tests a wide range of sensitivity parameters (ρ), which measures the strength of effect of an unobserved confounder, to examine the possible effect due to the unobserved mediator-outcome confounder.[16,17] The sensitivity parameters are defined as the correlation between error terms in mediator and outcome regression models that are assumed to be bivariate standard normally-distributed. The sensitivity parameters were varied over a wide range (correlations from -0.9 to 0.9). The goal was to examine the level of sensitivity parameter required to reduce the estimated mediation effect (natural indirect effect, or NIE) to nuance.

Logistic regression models were used to assess the association between insurance and guideline-compliant care. For the adjusted models, sequential modeling was employed in order to examine whether the association between race/ethnicity and guideline-compliant care is mediated by insurance status and hospital quality. The following predictors were sequentially entered *a priori* into the models: demographic and clinical factors (age, sex, marital status, neighborhood SES, year of diagnosis, tumor site, T4 disease, nodal metastasis, fragmented care and Charlson comorbidity score); 2) insurance status; and 3) hospital quality.

For the regression models, T classification was categorized as T1-3 versus T4, and nodal classification was categorized as N0 versus N1-3, in order to reconcile differences in the staging schema of the 7th and 8th editions of the AJCC staging systems. However, the original staging schemes were used to define NCCN guideline-compliant care, since treatment decisions were made based on the staging scheme used at the time of diagnosis. Multiple imputation (MI) was used to handle missing values for hospital-level variables by 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.[18] Missing values for patient-level variables were coded as unknown, and included in the analysis. However, sensitivity analysis was performed by repeating the analyses, while using MI to handle missing patient-level variables. An estimate of α=0.05 was considered statistically significant. 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.

Results

Association between race/ethnicity and hospital quality

We identified 23,245 patients, treated at 465 hospitals, meeting the inclusion criteria. The mean age was 64.8 (SD 12.2) years. Patient characteristics are shown in Table 1. Unadjusted analysis showed that Black (OR 0.73, 95% CI 0.65 to 0.81), and Hispanic (OR 0.70, 95% CI 0.65 to 0.75) patients were less likely to receive care in top-quality hospitals compared with White patients, while Asian/Pacific Islander (OR 1.23, 95% CI 1.12 to 1.35) patients were more likely to receive care in top-quality hospitals (Table 2, Figure 1). These associations

persisted for Black (OR 0.76, 95% CI 0.67 to 0.85), Hispanic (OR 0.68, 95% CI 0.63 to 0.74), and Asian/Pacific Islander (OR 1.12, 95% CI 1.02 to 1.24) patients after adjusting for demographic and clinical factors (age, sex, marital status, year of diagnosis, tumor site, T4 disease, nodal metastasis, Charlson comorbidity score, fragmented care). After additionally adjusting for neighborhood SES, the associations slightly decreased and became non-significant for Black patients (OR 0.89, 95% CI 0.79 to 1.00), slightly decreased but remained significant for Hispanic patients (OR 0.85, 95% CI 0.75 to 0.88), and remained unchanged for Asian/Pacific Islander patients (OR 1.13, 95% CI 1.02 to 1.25). In the final model, additionally adjusting for insurance status, the associations remained non-significant for Black (OR 0.92, 95% CI 0.81 to 1.02), and remained significant for Hispanic (OR 0.84, 95% CI 0.74 to 0.91) and Asian/Pacific Islander (OR 1.16, 95% CI 1.05 to 1.29) patients. Similar results were obtained when using MI to handle missing patient-level variables (Supplemental Table 1). Mediation analysis showed that SES (quintiles 3 – 5 vs. quintiles 1 – 2) accounted for 45.9% (95% CI 18.9% to 73.0%) of the relationship between Black (vs. White) individuals and treatment in top-quality hospitals, while private insurance (vs. all other insurance categories) accounted for 14.7% (95% CI 5.1% to 24.2%). SES accounted for 32.5% (95% CI 22.4% to 42.6%) of the relationship between Hispanic (vs. White) individuals and treatment in top-quality hospitals, while private insurance accounted for 6.9% (95% CI 3.6% to 10.1%). Sensitivity analyses for Black vs. White comparisons showed that an unobserved confounder would need a correlation of 0.2 to reduce the NIE to 0 for SES, and a correlation of 0.1 to reduce the NIE to 0 for insurance (Supplemental Figure 1). For Hispanic vs. White comparisons, a correlation of 0.2 would be needed to decrease the NIE to 0 for SES and insurance (Supplemental Figure 2). Comparing these thresholds with the correlations between the observed mediators (SES and insurance) and hospital quality (Supplemental Table 2) indicates that the unobserved confounder would need to have a similar or stronger association than SES or insurance to nullify the mediation effects.

Unadjusted analysis showed that Black (OR 1.63, 95% CI 1.40 to 1.90), Hispanic (OR 1.33, 95% CI 1.19 to 1.49), and Asian/Pacific Islander (OR 1.18, 95% CI 1.02 to 1.37) patients were more likely to receive care in bottom-quality hospitals compared with White patients (Table 2, Figure 2). These associations persisted for

Black (OR 1.60, 95% CI 1.36 to 1.88), and Hispanic (OR 1.39, 95% CI 1.24 to 1.57) patients, and slightly increased for Asian/Pacific Islander (OR 1.30, 95% CI 1.11 to 1.52) patients, after adjusting for demographic and clinical factors. After additionally adjusting for neighborhood SES, the associations slightly decreased for Black (OR 1.43, 95% CI 1.21 to 1.69), and Hispanic (OR 1.23, 95% CI 1.09 to 1.38) patients, but remained unchanged for Asian/Pacific Islander (OR 1.29, 95% CI 1.10 to 1.51) patients. In the final model, additionally adjusting for insurance status, the associations remained unchanged for Black (OR 1.44, 95% CI 1.22 to 1.70), Hispanic (OR 1.22, 95% CI 1.08 to 1.38), and Asian/Pacific Islander (OR 1.28, 95% CI 1.09 to 1.50) patients. Similar results were obtained when using MI to handle missing patient-level variables (Supplemental Table 1). Mediation analysis showed that SES accounted for 17.9% (95% CI 7.2% to 28.5%) of the relationship between Black individuals and treatment in bottom-quality hospitals, while private insurance accounted for 5.7% (95% CI 1.7% to 9.7%). SES accounted for 20.0% (95% CI 8.9% to 31.0%) of the relationship between Hispanic individuals and treatment in bottom-quality hospitals, while private insurance accounted for 4.7% (95% CI 1.7% to 7.8%). Sensitivity analyses for Black vs. White and Hispanic vs. White comparisons both showed that an unobserved confounder would need a correlation of -0.1 to reduce the NIE to 0 for SES and insurance (Supplemental Figures 3-4). Comparing these thresholds with the correlations between the observed mediators and hospital quality (Supplemental Table 2) indicates that the unobserved confounder would need to have a stronger association than SES or insurance to nullify the mediation effects.

Association between race/ethnicity and receipt of guideline-compliant care

Among patients with advanced disease, unadjusted analysis showed that Black patients (OR 0.82, 95% CI 0.70 to 0.96) were less likely to receive dual-modality therapy, while Hispanic (OR 1.25, 95% CI 1.13 to 1.39), and Asian/Pacific Islander (OR 1.74, 95% CI 1.52 to 2.00) patients were more likely to receive dual-modality therapy, compared to White patients (Table 3). The association disappeared for Black patients (OR 0.86, 95% CI 0.71 to 1.03), but remained for Hispanic (OR 1.20, 95% CI 1.06 to 1.36), and Asian/Pacific Islander (OR 1.25, 95% CI 1.06 to 1.46) patients, after adjusting for demographic factors (age, sex, marital status, year of diagnosis, neighborhood SES), cancer characteristics (site, T4 disease, nodal metastasis), and

clinical characteristics (Charlson comorbidity score, fragmented care). After additionally adjusting for insurance status, the associations remained unchanged for Black (OR 0.88, 95% CI 0.73 to 1.05), Hispanic (OR 1.25, 95% CI 1.10 to 1.41), and Asian/Pacific Islander (OR 1.28, 95% CI 1.09 to 1.51) patients. In the final model, additionally adjusting for hospital quality, the associations remained unchanged for Black (OR 0.89, 95% CI 0.74 to 1.06), Hispanic (OR 1.27, 95% CI 1.13 to 1.44), and Asian/Pacific Islander (OR 1.27, 95% CI 1.08 to 1.49) patients. Other race was associated with lower likelihood of receiving dual-modality therapy in all models (OR 0.57, 95% CI 0.35 to 0.92 in the final model). Treatment in top-quality hospitals was associated with receipt of dual-modality therapy in the final model (OR 1.62, 95% CI 1.39 to 1.90). Similar results were obtained when using MI to handle missing patient-level variables (Supplemental Table 3).

Among patients with surgically-resected advanced disease, unadjusted analysis showed that race/ethnicity was not associated with receipt of adjuvant RT (Black: OR 0.86, 95% CI 0.66 to 1.12; Hispanic: OR 0.94, 95% CI 0.79 to 1.12; Asian/Pacific Islander: OR 1.02, 95% CI 0.82 to 1.28) (Table 4). This remained unchanged (Black: OR 1.09, 95% CI 0.80 to 1.47; Hispanic: OR 1.16, 95% CI 0.95 to 1.42; Asian/Pacific Islander: OR 1.13, 95% CI 0.89 to 1.45) after adjusting for demographic factors, cancer characteristics, and clinical characteristics. This remained unchanged after additionally adjusting for insurance status (Black: OR 1.10, 95% CI 0.82 to 1.49; Hispanic: OR 1.21, 95% CI 0.99 to 1.48; Asian/Pacific Islander: OR 1.17, 95% CI 0.91 to 1.50). In the final model, additionally adjusting for hospital quality, Hispanic patients (OR 1.28, 95% CI 1.04 to 1.57) were more likely to receive adjuvant RT, while the lack of association remained unchanged for Black (OR 1.15, 95% CI 0.84 to 1.57), and Asian/Pacific Islander (OR 1.16, 95% CI 0.90 to 1.50) patients. Other race was not associated with receipt of adjuvant RT in all models (OR 0.96, 95% CI 0.43 to 2.14 in the final model). Treatment in top-quality hospitals (OR 3.56, 95% CI 2.83 to 4.48), and mid-quality hospitals (OR 2.20, 95% CI 1.74 to 2.77) were associated with receipt of adjuvant RT in the final model. Similar results were obtained when using MI to handle missing patient-level variables (Supplemental Table 4). The association of race/ethnicity with use of top-quality hospitals and guideline-compliant care is summarized in Figure 3.

Discussion

Our previous work has shown that treatment in high-quality hospitals (defined by a composite measure including annual case volume, NCCN guideline-compliance, adverse events rates, and cancer center certification status) is associated with improved survival.[14] This current study found that there were significant racial and ethnic disparities in the use of high-quality hospitals. Black and Hispanic patients were less likely to receive care in top-quality hospitals, while Asian/Pacific Islander patients were more likely to receive care in top-quality hospitals compared with White patients. Black, Hispanic, and Asian/Pacific Islander patients were more likely to receive care in bottom-quality hospitals compared with White patients. The relationship between race/ethnicity and hospital quality was mediated by SES and insurance status. There were also racial and ethnic differences in receipt of NCCN guideline-compliant care. Among patients with advanced-stage disease, Hispanic and Asian/Pacific Islander patients were more likely to receive dual-modality therapy, while Black patients had similar likelihood compared to White patients. Among patients with surgically-resected advanced disease, race/ethnicity was not associated with receipt of adjuvant RT when hospital quality was not accounted for. However, Hispanic patients were more likely to receive adjuvant RT after adjusting for hospital quality.

Previous studies suggest that racial and ethnic minority cancer patients with are less likely to receive care in high-quality hospitals. Studies of patients with colorectal cancer have found that racial and ethnic minority patients with colorectal cancer were less likely to receive care in NCI-designated cancer centers and in high-volume hospitals.[19,20] In contrast to our study, these studies used hospital accreditation status and case volume as surrogates for hospital quality. A more recent study analyzing racial and ethnic disparities in use of high-quality hospitals among oral cavity cancer patients utilized a composite measure of oral cancer-specific hospital quality that included oral cavity cancer case volume, cancer center certification status, compliance with NCCN treatment guidelines, and adequate lymph node yield in neck dissection specimens.[21] Similar to our study, this study found that treatment in high-quality hospitals was association with improved survival, and that Black patients were less likely to be treated in high-quality hospitals.

The findings of our study, and previous studies, suggest that access to high quality care may contribute to the racial disparities in HNC outcomes. Our study provides further context by also examining racial disparities

in receipt of guideline-compliant care. We found that Hispanic and Asian/Pacific Islander patients with advanced-stage disease were more likely to receive dual-modality therapy, while Black patients had similar likelihood compared to White patients. These findings differ from those of a previous National Cancer Database study examining factors associated with lower likelihood of receipt of guideline-complaint adjuvant therapy among patients with oral cancer.[22] Similar to our study, they found that Hispanic patients were less likely to miss adjuvant RT compared to White patients. However, in contrast to our study, they also found that Black and Asian/Pacific Islander patients were less likely to miss adjuvant RT compared with White patients. The differences in findings are likely due to the fact that the study only included oral cavity cancer cases. Another study found that, similar to our study, Black patients were less likely to receive NCCN guideline-compliant care for locoregionally-advanced oropharyngeal cancer and oral cavity cancer than White patients.[23] However, in contrast to our study, this study did not compare any other racial or ethnic groups. Furthermore, the authors did not specify what constituted NCCN guideline-compliant care.

Our study found that SES and insurance status mediated the relationship between race/ethnicity and hospital quality. These findings indicate that SES and insurance status are potential drivers of racial and ethnic disparities in access to high-quality hospitals. However, SES and insurance did not appear to mediate the relationship between race/ethnicity and receipt of guideline-compliant care. The findings of our study suggest that there are racial and ethnic differences in quality of care, independent of hospital quality. Although Hispanic patients were less likely to receive care in top-quality hospitals than White patients, and more likely to receive care in bottom-quality hospitals, Hispanic patients were more likely to receive guideline compliant care, after adjusting for hospital quality. The reasons for higher rates of guideline-compliant care among Hispanic patients is unclear. Potential reasons include increased family support during treatment relative to other ethnic groups. Hispanic patients with breast cancer have been reported to experience higher levels of support from family members, compared with non-Hispanic White patients.[24]

Interestingly, our study found that Asian/Pacific Islander patients were more likely to receive care in both top-quality and bottom-quality hospitals. The reasons for this are unclear, but is likely due to the heterogeneity

of this racial group. Asian and Pacific Islander groups are often combined in cancer databases, despite being considered distinct races by the United States Census Bureau (USCB).[25] Furthermore, previous studies have shown differences in cancer incidence and outcomes between Pacific Islander and Asian populations,[26,27] as well as between subgroups of the Asian populations.[28,29] Other race was associated with lower likelihood of receiving dual-modality therapy in all models. However, the significance of this finding is also unclear given the heterogenous nature of this group. American Indian, Alaska Native, and racial categories that are not formally classified by the USCB are often classified as "other" in cancer databases. This highlights the importance of disaggregating traditional racial and racial categories when assessing disparities.

Our study has several strengths, including 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.[30] CCR data are representative of all cancer cases in California, since cancer reporting is mandated by California law. By linking CCR data to HCAI we were able to capture hospital and clinical information that is not usually available in cancer registry data. Another strength of this study is its use of a multifaceted approach to define HNC-specific hospital quality.

Our study has several limitations. The AJCC staging schema was not consistent throughout the study period. Consequently, year of diagnosis was included as a covariate, T classification was categorized as T1-3 versus T4, and nodal classification was categorized as N0 versus N1-3 in adjusted models, in order to reconcile differences in the staging schema of the 7^{th} and 8^{th} editions of the AJCC staging systems. Secondly, although we adjusted for many clinically-important variables such as sociodemographic variables, tumor-related variables, comorbidity, fragmented care, and neighborhood-level SES, we could not adjust for unmeasured variables such as individual-level SES, social support, access to transportation, tumor HPV status, tobacco and alcohol consumption, and rural/urban place of residence, which may also be related to access to care. To address this, we used sensitivity analysis to evaluate the potential effects of unobserved confounders. Finally, because this study was limited to patients treated in California, it is unclear if the findings are generalizable to the entire US.

Conclusion

Our study shows significant racial and ethnic disparities in quality of the treating hospital for patients with HNC in California. Black and Hispanic patients are less likely to receive care in top-quality hospitals, while Asian/Pacific Islander patients are more likely to receive care in top-quality hospitals. Black, Hispanic, and Asian/Pacific Islander patients are more likely to receive care in bottom-quality hospitals compared with White patients. These findings highlight the need for continued investigation into the drivers of racial disparities in HNC outcomes. Future studies are needed to further understand factors that affect racial differences in use of treatment facility and quality of care delivered.

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Figure Legend

Figure 1. Association of race/ethnicity with use of top-quality hospitals.

Adjusted 1: adjusted for demographic factors, clinical factors, and fragmented care. Adjusted 2: adjusted for demographic factors, clinical factors, fragmented care, and socioeconomic status. Adjusted 3: adjusted for demographic factors, clinical factors, fragmented care, socioeconomic status, and insurance status. API: Asian/Pacific Islander.

Figure 2. Association of race/ethnicity with use of bottom-quality hospitals.

Adjusted 1: adjusted for demographic factors, clinical factors, and fragmented care. Adjusted 2: adjusted for demographic factors, clinical factors, fragmented care, and socioeconomic status. Adjusted 3: adjusted for

demographic factors, clinical factors, fragmented care, socioeconomic status, and insurance status. API: Asian/Pacific Islander.

Figure 3. Association of race/ethnicity with use of top-quality hospitals and guideline-compliant care.

White is reference for all comparisons. Odds ratios for top quality hospital are adjusted for demographic factors, clinical factors, fragmented care, socioeconomic status, and insurance status. Odds ratios for dual modality therapy and adjuvant radiotherapy only include patients with T3, T4, and N2-3 disease, and are adjusted for demographic factors, clinical factors, fragmented care, socioeconomic status, insurance status, and hospital quality.

Table 1. Patient Characteristics.

Variable	Asian/ Pacific Islander (N=1882)	Black (N=1429)	Hispanic (N=3567)	Other (N=286)	White (N=16081)
Age (mean (SD))	64.7 (13.6)	62.9 (11.1)	62.8 (12.9)	62.8 (10.9)	65.4 (11.9)
Female	595 (31.6%)	335 (23.5%)	884 (24.8%)	74 (25.9%)	3882 (24.1%)
Male	1287 (68.4%)	1093 (76.5%)	2680 (75.2%)	212 (74.1%)	12194 (75.9%)
Single	532 (29.6%)	853 (63.7%)	1461 (43.5%)	108 (43.4%)	6545 (43.0%)
Married	1265 (70.4%)	486 (36.3%)	1901 (56.5%)	141 (56.6%)	8683 (57.0%)
Insurance: commercial	874 (46.4%)	543 (38.0%)	1466 (41.1%)	124 (43.4%)	7658 (47.6%)
Insurance: Medicare	677 (36.0%)	422 (29.5%)	1084 (30.4%)	96 (33.6%)	6150 (38.2%)

Insurance: Medicaid	224 (11.9%)	297 (20.8%)	672 (18.8%)	28 (9.8%)	1127 (7.0%)
Insurance: uninsured	31 (1.6%)	25 (1.7%)	92 (2.6%)	2 (0.7%)	158 (1.0%)
Insurance: other	56 (3.0%)	121 (8.5%)	170 (4.8%)	15 (5.2%)	675 (4.2%)
Insurance: unknown	20 (1.1%)	21 (1.5%)	83 (2.3%)	21 (7.3%)	313 (1.9%)
SES Quintile 1	193 (10.3%)	458 (32.1%)	1097 (30.8%)	41 (14.3%)	1671 (10.4%)
SES Quintile 2	320 (17.0%)	357 (25.0%)	883 (24.8%)	63 (22.0%)	2736 (17.0%)
SES Quintile 3	401 (21.3%)	261 (18.3%)	709 (19.9%)	67 (23.4%)	3466 (21.6%)
SES Quintile 4	416 (22.1%)	225 (15.7%)	530 (14.9%)	69 (24.1%)	4025 (25.0%)
SES Quintile 5	552 (29.3%)	128 (9.0%)	348 (9.8%)	46 (16.1%)	4183 (26.0%)
Site: Hypopharynx	101 (5.4%)	67 (4.7%)	163 (4.6%)	11 (3.8%)	607 (3.8%)
Site: Larynx	372 (19.8%)	492 (34.4%)	1043 (29.2%)	74 (25.9%)	3400 (21.1%)
Site: Oral cavity	971 (51.6%)	333 (23.3%)	1163 (32.6%)	89 (31.1%)	4918 (30.6%)
Site: Oropharynx	438 (23.3%)	537 (37.6%)	1198 (33.6%)	112 (39.2%)	7156 (44.5%)
T Classification: T1	676 (35.9%)	343 (24.0%)	1131 (31.7%)	117 (40.9%)	5838 (36.3%)
T Classification: T2	540 (28.7%)	386 (27.0%)	977 (27.4%)	81 (28.3%)	4956 (30.8%)
T Classification: T3	316 (16.8%)	329 (23.0%)	634 (17.8%)	37 (12.9%)	2709 (16.8%)
T Classification: T4	350 (18.6%)	371 (26.0%)	825 (23.1%)	51 (17.8%)	2578 (16.0%)
N Classification: N0	1070 (56.9%)	641 (44.9%)	1744 (48.9%)	148 (51.7%)	7452 (46.3%)
N Classification: N1	241 (12.8%)	233 (16.3%)	560 (15.7%)	39 (13.6%)	2755 (17.1%)
N Classification: N2	493 (26.2%)	476 (33.3%)	1090 (30.6%)	89 (31.1%)	5299 (33.0%)
N Classification: N3	71 (3.8%)	71 (5.0%)	156 (4.4%)	9 (3.1%)	530 (3.3%)
N Classification: Unknown	7 (0.4%)	8 (0.6%)	17 (0.5%)	1 (0.3%)	45 (0.3%)
Charlson Score: 0	793 (42.1%)	517 (36.2%)	1427 (40.0%)	104 (36.4%)	7325 (45.6%)
Charlson Score: 1	373 (19.8%)	278 (19.5%)	674 (18.9%)	43 (15.0%)	3010 (18.7%)
Charlson Score: 2	132 (7.0%)	147 (10.3%)	287 (8.0%)	24 (8.4%)	1325 (8.2%)
Charlson Score: 3+	175 (9.3%)	249 (17.4%)	399 (11.2%)	24 (8.4%)	1575 (9.8%)
Charlson Score: Unknown	409 (21.7%)	238 (16.7%)	780 (21.9%)	91 (31.8%)	2846 (17.7%)

Table 2. Association of race/ethnicity with use of high-quality and low-quality hospitals.

		Top Quality Hospital			Bottom Quality Hospital		
	Variable	**Odds Ratio**	**95% CI (lower)**	**95% CI (upper)**	**Odds Ratio**	**95% CI (lower)**	**95% CI (upper)**
Unadjusted	White	1.00	Reference	Reference	1.00	Reference	Reference
	Black	0.73	0.65	0.81	1.63	1.40	1.90
	Hispanic	0.70	0.65	0.75	1.33	1.19	1.49
	Asian/Pacific Islander	1.23	1.12	1.35	1.18	1.02	1.37
	Other	0.97	0.76	1.22	1.24	0.86	1.77
Adjusted for demographic factors, clinical factors, and fragmented care	White	1.00	Reference	Reference	1.00	Reference	Reference
	Black	0.76	0.67	0.85	1.60	1.36	1.88
	Hispanic	0.68	0.63	0.74	1.39	1.24	1.57
	Asian/Pacific Islander	1.12	1.02	1.24	1.30	1.11	1.52
	Other	0.99	0.77	1.28	1.17	0.77	1.77
Adjusted for demographic factors, clinical factors, fragmented care, and socioeconomic status	White	1.00	Reference	Reference	1.00	Reference	Reference
	Black	0.89	0.79	1.00	1.43	1.21	1.69
	Hispanic	0.81	0.75	0.88	1.23	1.09	1.38
	Asian/Pacific Islander	1.13	1.02	1.25	1.29	1.10	1.51
	Other	1.06	0.82	1.37	1.10	0.73	1.67
Final Model: adjusted for demographic factors, clinical factors, fragmented care, socioeconomic status, and insurance status	White	1.00	Reference	Reference	1.00	Reference	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
	Insurance: commercial	1.00	Reference	Reference	1.00	Reference	Reference
	Insurance: Medicare	0.78	0.73	0.84	1.29	1.15	1.43
	Insurance: Medicaid	0.59	0.54	0.66	1.27	1.09	1.48
	Insurance: uninsured	0.38	0.29	0.49	0.95	0.63	1.41
	Insurance: other	0.81	0.70	0.93	0.86	0.68	1.10
	Insurance: unknown	0.89	0.73	1.10	1.30	0.95	1.77

	Age (per 1-year increment)	0.99	0.99	1.00	1.01	1.01	1.01
	Female	1.00	Reference	Reference	1.00	Reference	Reference
	Male	0.99	0.93	1.06	1.01	0.91	1.12
	Single	1.00	Reference	Reference	1.00	Reference	Reference
	Married	1.11	1.04	1.17	1.00	0.92	1.10
	SES Quintile 1	1.00	Reference	Reference	1.00	Reference	Reference
	SES Quintile 2	1.24	1.12	1.36	1.04	0.90	1.19
	SES Quintile 3	1.39	1.26	1.53	0.99	0.86	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	Reference	Reference	1.00	Reference	Reference
	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	0.82	1.41	1.25	1.60
	T1-3 disease	1.00	Reference	Reference	1.00	Reference	Reference
	T4 disease	1.10	1.02	1.19	0.93	0.83	1.05
	Nodal metastasis: No	1.00	Reference	Reference	1.00	Reference	Reference
	Nodal metastasis: Yes	1.05	0.99	1.12	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	Reference	Reference	1.00	Reference	Reference
	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
	Non-fragmented care	1.00	Reference	Reference	1.00	Reference	Reference
	Fragmented care	1.09	1.03	1.16	0.95	0.86	1.04

The adjusted model was adjusted for year of diagnosis.

Table 3. Association of race/ethnicity with dual-modality therapy for T3, T4, and N2-3 disease.

	Variable	Odds Ratio	95% CI (lower)	95% CI (upper)
Unadjusted	White	1.00	Reference	Reference
	Black	0.82	0.70	0.96
	Hispanic	1.25	1.13	1.39
	Asian/Pacific Islander	1.74	1.52	2.00
	Other	0.61	0.40	0.94
Adjusted for demographic factors, clinical factors, fragmented care, and socioeconomic status	White	1.00	Reference	Reference
	Black	0.86	0.71	1.03
	Hispanic	1.20	1.06	1.36
	Asian/Pacific Islander	1.25	1.06	1.46
	Other	0.58	0.36	0.93
Adjusted for demographic factors, clinical factors, fragmented care, socioeconomic status, and insurance status	White	1.00	Reference	Reference
	Black	0.88	0.73	1.05
	Hispanic	1.25	1.10	1.41
	Asian/Pacific Islander	1.28	1.09	1.51
	Other	0.58	0.36	0.93
Final Model: adjusted for demographic factors, clinical factors, fragmented care,	White	1.00	Reference	Reference
	Black	0.89	0.74	1.06
	Hispanic	1.27	1.13	1.44

socioeconomic status, insurance status, and hospital quality	Asian/Pacific Islander	1.27	1.08	1.49
	Other	0.57	0.35	0.92
	Insurance: commercial	1.00	Reference	Reference
	Insurance: Medicare	1.04	0.93	1.17
	Insurance: Medicaid	0.72	0.62	0.83
	Insurance: uninsured	0.64	0.44	0.93
	Insurance: other	1.05	0.86	1.29
	Insurance: unknown	0.78	0.56	1.09
	Age	0.97	0.96	0.97
	Female	1.00	Reference	Reference
	Male	0.98	0.88	1.09
	Single	1.00	Reference	Reference
	Married	1.26	1.15	1.38
	SES Quintile 1	1.00	Reference	Reference
	SES Quintile 2	1.02	0.88	1.18
	SES Quintile 3	1.14	0.98	1.31
	SES Quintile 4	1.10	0.95	1.28
	SES Quintile 5	1.21	1.04	1.41
	Site: Oral cavity	1.00	Reference	Reference
	Site: Larynx	0.27	0.24	0.31
	Site: Hypopharynx	0.10	0.07	0.12
	Site: Oropharynx	0.16	0.14	0.18
	T1-3 disease	1.00	Reference	Reference
	T4 disease	0.86	0.78	0.95
	Nodal metastasis: No	1.00	Reference	Reference
	Nodal metastasis: Yes	1.07	0.96	1.20
	Nodal metastasis: Unknown	0.33	0.13	0.83
	Charlson Score: 0	1.00	Reference	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
	Non-fragmented care	1.00	Reference	Reference
	Fragmented care	1.77	1.62	1.94
	Low-quality Hospital	1.00	Reference	Reference
	Mid-quality Hospital	1.18	1.00	1.38
	High-quality Hospital	1.62	1.39	1.90

The adjusted models were adjusted for year of diagnosis.

Table 4. Association of race/ethnicity with adjuvant radiotherapy for surgically-resected T3, T4, and N2-3 disease.

	Variable	Odds Ratio	95% CI (lower)	95% CI (upper)
Unadjusted	White	1.00	Reference	Reference
	Black	0.86	0.66	1.12
	Hispanic	0.94	0.79	1.12
	Asian/Pacific Islander	1.02	0.82	1.28
	Other	0.93	0.44	1.99
Adjusted for demographic factors, clinical factors,	White	1.00	Reference	Reference

fragmented care, and socioeconomic status	Black	1.09	0.80	1.47
	Hispanic	1.16	0.95	1.42
	Asian/Pacific Islander	1.13	0.89	1.45
	Other	1.00	0.45	2.25
Adjusted for demographic factors, clinical factors, fragmented care, socioeconomic status, and insurance status	White	1.00	Reference	Reference
	Black	1.10	0.82	1.49
	Hispanic	1.21	0.99	1.48
	Asian/Pacific Islander	1.17	0.91	1.50
	Other	0.96	0.43	2.16
Final Model: adjusted for demographic factors, clinical factors, fragmented care, socioeconomic status, insurance status, and hospital quality	White	1.00	Reference	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
	Insurance: commercial	1.00	Reference	Reference
	Insurance: Medicare	0.95	0.79	1.15
	Insurance: Medicaid	0.73	0.58	0.93
	Insurance: uninsured	0.96	0.51	1.81
	Insurance: other	1.18	0.82	1.71
	Insurance: unknown	1.32	0.72	2.42
	Age	0.98	0.97	0.98
	Female	1.00	Reference	Reference
	Male	1.18	1.00	1.40
	Single	1.00	Reference	Reference
	Married	1.18	1.01	1.37
	SES Quintile 1	1.00	Reference	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	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	Reference
	T4 disease	0.96	0.82	1.13
	Nodal metastasis: No	1.00	Reference	Reference
	Nodal metastasis: Yes	2.27	1.93	2.67
	Nodal metastasis: Unknown	0.53	0.15	1.92
	Charlson Score: 0	1.00	Reference	Reference
	Charlson Score: 1	0.94	0.77	1.14

	Charlson Score: 2	0.95	0.73	1.25
	Charlson Score: 3+	0.65	0.51	0.82
	Charlson Score: Unknown	0.82	0.65	1.04
	Non-fragmented care	1.00	Reference	Reference
	Fragmented care	2.56	2.16	3.02
	Low-quality Hospital	1.00	Reference	Reference
	Mid-quality Hospital	2.20	1.74	2.77
	High-quality Hospital	3.56	2.83	4.48

The adjusted models were adjusted for year of diagnosis.

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