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2-Year Prevalence of Dysphagia and Related Outcomes in Head and Neck Cancer Survivors: an Updated SEER-Medicare Analysis

Katherine Hutcheson, PhD[1], **Zhannat Nurgalieva, MD PhD**[1], **Hui Zhao, PhD**[2], **G. Brandon Gunn, MD**[3], **Sharon H. Giordano, MD, MPH**[2], **Mihir K. Bhayani, MD**[4], **Jan S. Lewin, PhD**[1], and **Carol M. Lewis, MD, MPH**[1]

[1]Department of Head and Neck Surgery, The University of Texas MD Anderson Cancer Center, Houston, Texas

[2]Department of Health Services Research, The University of Texas MD Anderson Cancer Center, Houston, Texas

[3]Department of Radiation Oncology, The University of Texas MD Anderson Cancer Center, Houston, Texas

[4]Northshore University Healthsystem, Evanston, Illinois

Abstract

Objective: Examine prevalence of dysphagia at the population level in head and neck cancer (HNC) survivors.

Methods: Surveillance, Epidemiology and End Results (SEER)-Medicare claims among 16,194 HNC patients (2002–2011) were analyzed to estimate 2-year prevalence of dysphagia, stricture, and aspiration pneumonia, and derive treatment- and site-specific estimates.

Results: Prevalence of dysphagia, stricture, pneumonia, and aspiration pneumonia was 45.3% (95% CI: 44.5–46.1), 10.2% (95% CI: 9.7–10.7), 26.3% (95% CI: 25.6–26.9), 8.6% (95% CI: 8.2–9.1), respectively. Dysphagia increased by 11.7% over the 10-year period ($p<0.001$). Prevalence was highest after chemoradiation and multimodality therapy.

Conclusions: Comparing to published rates using similar methodology the preceding decade (1992–1999), prevalence of dysphagia based on claims data was similar in 2002 to 2011 in this study. These results suggest persistence of dysphagia as a highly prevalent morbidity, even in the decade in which highly conformal radiotherapy and minimally invasive surgeries were popularized.

Keywords

SEER-Medicare; Dysphagia; Aspiration pneumonia; Stricture; Head and neck cancer

Corresponding author: Katherine A. Hutcheson, PhD, The University of Texas MD Anderson Cancer Center, P. O. Box 301402, Department of Head and Neck Surgery, Unit 1445, Houston, Texas 77030, U.S.A. Telephone: 713-792-6513, Fax: 713-794-4662, Karnold@mdanderson.org.

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INTRODUCTION

Dysphagia is a high impact morbidity of head and neck cancer (HNC). Swallowing difficulty can result from tumor or treatment and adversely impacts both the health[1,2] and quality of life[3,4] of survivors. Prevalence estimates for dysphagia vary widely in published literature and depend on tumor stage, subsite of disease, age, and treatment modality. Much of the published work in the area of dysphagia derives from single-institution, clinical datasets. While clinical data offer far superior detail about the nature of dysphagia, small numbers of patients and institutional biases may limit generalizability for inferences about the frequency of dysphagia in the broad population of HNC survivors as well as in clinically relevant subgroups of patients. Population-level data are critical to examine broad outcomes outside of academic institutions. Prior population-level analyses from the United States often use SEER-Medicare; these include analyses of feeding tube duration as a function of radiotherapy modality[5], case-control comparisons of aspiration pneumonia risk after chemoradiation[2], examination of dysphagia as a predictor of morbidity[6], as well as quality studies suggesting positive impact of early speech pathology utilization[7].

Perhaps the most comprehensive assessment of national HNC trends in dysphagia using the SEER-Medicare database was published by Francis and colleagues (2010)[8] reporting 3-year prevalence of dysphagia, stricture, and pneumonia of 40%, 7%, and 10%, respectively, among 8,002 patients treated between the years 1992 and 1999. Prevalence of all endpoints was higher among patients requiring multimodality therapy presumably for advanced stages of disease, and also among those with pharyngeal primary tumors relative to oral cavity or laryngeal sites. Among all modalities, prevalence of swallowing-related endpoints was highest in patients who received primary chemoradiation. This comprehensive analysis led to insights about higher risk subgroups of patients, and also suggested increasing prevalence of dysphagia-related events over the decade of study (1990's) in an era when organ preservation regimens were intensifying. Since the period of their analysis (1992–1999), the field of head and neck oncology has refined the delivery of surgery and radiotherapy by rapid adoption of both minimally invasive surgical methods (e.g., transoral robotic surgery) and highly conformal radiotherapy planning methods (e.g., IMRT). Refinements in treatment delivery and other notable shifts including more widespread adoption of proactive supportive care alongside shifting epidemiology of HNC (i.e., human papilloma virus associated HNC) could conceivably impact population level trends. Therefore, the purpose of this analysis was: 1) to re-examine prevalence of dysphagia-related endpoints in HNC survivors at the population-level in a more current decade (2002–2011), and 2) to compare prevalence by treatment modalities and site of disease.

MATERIALS AND METHODS

Data source

The Surveillance, Epidemiology, and End Results (SEER) data were linked to Medicare claims to allow HNC patients aged 65 or older to be followed longitudinally for information about both the initial diagnosis and downstream medical care. Our linked dataset includes cases diagnosed 2002 through 2011 with Medicare claims through 2013, allowing estimation of 2-year prevalence for all eligible cases.

Cohort selection

This retrospective cohort analysis of SEER-Medicare included patients with: 1) histologically confirmed carcinoma of the oral cavity, oropharynx, hypopharynx, nasopharynx, or larynx diagnosed between 2002 and 2011, 2) age equal to or greater than 66 years (allowing calculation of a comorbidity index), 3) enrollment in both Medicare A and B (to ensure inclusion of inpatient and outpatient medical utilization), 4) known diagnosis date, and 5) recorded initial treatment modality. The following Site Recode ICD-O-3 codes captured eligible disease sites: cancers of the lip (20010), tongue (20020), floor of mouth (20040), gum and other mouth (20050), nasopharynx (20060), tonsil (20070), oropharynx (20080), hypopharynx (20090), and larynx (22020). Patients were excluded for: 1) any prior cancer diagnosis; 2) synchronous HNCs; and/or 3) death within the first surveillance year. A total of 16,194 patients met these criteria.

Selection of Non-Cancer Controls

Non-cancer controls for the head and neck cancer cases were selected from the Medicare 5% sample by using 1:1 match based on cancer patients' age, gender, and race/ethnicity. For each matched control, we used the diagnosis date of its matched cases as its index date; each control was fully covered by Medicare Part A & B from the index date till 28 months after the index date or till the end of the study period if the control was followed up for less than 28 months. Prevalence was computed using the period of 4 months after the index date till 28 months or till the end of the study if the patient followed up less than 28 months. 15,439 controls with full Medicare coverage till the end of the 2-year study period were identified to match the 16,194 cases (95.3%).

Dysphagia-related Outcomes

Swallowing problems manifest in various ways with clinical observations including oral and/or pharyngeal dysfunction, pharyngoesophageal stenosis or stricture, aspiration, and/or aspiration pneumonia. To account for multiple (often co-existing) dysphagia presentations, 4 primary outcomes assessed in this study included dysphagia, stricture, pneumonia, and aspiration pneumonia over the two years following completion of treatment for HNC. Oropharyngeal dysphagia was identified by ICD-9-CM codes, 787.20 – 787.24. Similarly, pneumonia was defined on the basis of ICD-9- CM codes (481, 485–486, 482.0–482.9, 507.0–507.8) and aspiration pneumonia was coded only using the ICD-9 diagnosis code of 507.0. Stricture was defined on the basis of ICD-9-CM codes for pharyngeal and esophageal strictures (478.29, 530.3), ICD-9 procedure codes (29.91, 42.01, 42.92), and CPT-4 codes for esophageal dilation (43220, 43226, 43248, 43249, 43450, 43453, 43456, 74360).

Treatment

Four treatment categories were defined including: surgery alone, surgery with adjuvant therapy, radiation alone, and RT with chemotherapy. Only index treatment was considered (not salvage surgery or re-irradiation). Treatment groups were identified using Current Procedural Terminology (CPT)/Healthcare Common Procedure Coding System (HCPCS) and International Classification of Disease (ICD-9) codes for surgery, radiation, and chemotherapy occurring in the 4 months after cancer diagnosis (supplementary Table 1).

Covariates

Age at diagnosis, sex (male, female), race, stage at diagnosis, and sub-site of disease (oral cavity, oropharynx, hypopharynx, and larynx) were included as covariates in the analysis. Age was categorized into four groups (<69, 69–74, 74–79, >79). Race/ethnicity/origin was classified as non-Hispanic white, Spanish-Hispanic-Latino, black, or other (American Indian/AK Native, Asian/Pacific Islander). Stage at diagnosis was coded as available in SEER for the duration of the study period: in situ (no invasion of basement membrane)/ localized (confined to organ of origin), regional (extends beyond organ of origin, regional lymph nodes), distant (spread remote from primary tumor), and unstaged. Comorbidities (0 to 2) were coded by searching inpatient and outpatient claims for diagnostic billing codes for various conditions during the year prior to the diagnosis of cancer, as suggested by Klabunde[9], and by using the Deyo implementation of the Charlson comorbidity score[10]. Comorbidity index was categorized into none, one, and two or more.

Statistical Methods

Two-year period prevalence and 95% confidence intervals were first calculated for each dysphagia-related outcome (dysphagia, stricture, pneumonia, aspiration-pneumonia) among all patients. Prevalence of dysphagia, stricture, pneumonia and aspiration pneumonia was then estimated for subgroups of patients by tumor site, stage, and treatment modality and compared using the chi-square test. A full model including all HNC patients plus four treatment subgroup multivariable logistic regression models were then fit regressing treatment modality on each dysphagia endpoint to estimate independent impact of the following treatment scenarios after adjustment for clinicodemographic covariates using a theoretical model building approach retaining all a priori clinically relevant covariates regardless of statistical significance[11]. Acknowledging the diversity of HNC as a clinical population, treatment subgroup models were evaluated to derive the most clinically plausible effect estimates among more homogeneous groups of patients than the full model combining all HNC cases. Primary treatment modality comparisons from the four treatment subgroup multivariable regression models included: 1) single modality treatment options (RT alone versus surgery alone), 2) multimodality treatment options (chemoradiation versus surgery + RT), 3) adjuvant radiotherapy (surgery versus surgery + RT), and 4) adjuvant chemotherapy (RT alone versus RT with chemotherapy). Period estimates are reported as adjusted odds ratios (AORs) with 95% confidence intervals (CIs). Final models included treatment modality, race/ethnicity, age at diagnosis, disease sub-site, sex, comorbidity, and disease stage. All p values are two-sided (α=0.05). Statistical analyses were performed using SAS software (Version 9.3, SAS Institute, Cary, NC).

RESULTS

Cohort characteristics

16,194 patients were included in the analysis. The median age was 74 years, and 65.4% were male. The most common tumor subsites were oral cavity (39.3%) and laryngeal/ hypopharyngeal (34.1%) followed by oropharyngeal cancers (8%). Treatment modalities were fairly evenly distributed; approximately half (51.1%) underwent single modality

therapy (surgery or RT alone) and the remaining 48.9% underwent multimodality therapy (surgery + adjuvant or chemoradiation). Cohort characteristics are detailed in Table 1.

Prevalence of Dysphagia-Related Outcomes among All HNC Survivors

Dysphagia, stricture, and aspiration pneumonia were highly prevalent, occurring among 45.3% (95% CI: 44.5–46.1), 10.2% (95% CI: 9.7–10.7), 8.7% (95% CI: 8.2–9.1) of all patients, respectively. Prevalence of aspiration pneumonia and stricture remained stable over the decade, but dysphagia increased by 11.7% (Figure 1). Prevalence of all dysphagia-related endpoints was significantly higher in HNC cases relative to matched non-cancer controls: dysphagia (OR: 7.8, 95% CI: 7.2–8.3), stricture (OR: 4.6, 95% CI: 4.1–5.2), pneumonia (OR: 2.1, 95% CI: 2.0–2.2), and aspiration pneumonia (OR: 3.7, 95% CI: 3.3–4.1).

Prevalence of Dysphagia-Related Outcomes among All HNC Survivors by Site, Stage, and Treatment

Site of disease ($p \leq 0.0001$), stage ($p < 0.0001$), and treatment modality ($p < 0.0001$) significantly influenced prevalence of all endpoints in univariate analysis, as illustrated in Figure 2. Combining all sites of HNC, prevalence of all swallowing-related outcomes was highest among those treated with chemoradiation relative to all other treatment modalities. Combining all treatment modalities, prevalence of dysphagia and stricture was highest among patients treated for oropharyngeal cancers whereas pneumonia was most prevalent among laryngeal/hypopharyngeal and nasopharyngeal subgroups. Oral cavity cases had the lowest prevalence of all dysphagia-related endpoints. Site by treatment prevalence is detailed in Table 2. Treatment modality and stage retained statistical significant for all endpoints in full multivariate models among all patients, whereas site of disease remained significant for stricture, pneumonia, and aspiration pneumonia but not for dysphagia (Table 3).

Multivariable Models Comparing Prevalence of Dysphagia-Related Outcomes between Single Modality Treatments (n=8,277)

Results of multivariable regression models among the subgroup of 8,277 patients treated with single modality therapy (surgery or RT alone) are reported in supplementary Table 2 and in Figure 3. Adjusted odds of all dysphagia-related outcomes were higher with single modality RT relative to surgery. Relative to single modality surgery, single modality radiation was associated with 1.8 (95% CI: 1.5–2.1), 1.4 (95% CI: 1.0–1.9), and 1.3 (95% CI: 0.99–1.8) greater odds of dysphagia, stricture, and aspiration pneumonia respectively.

Multivariable Models Comparing Prevalence of Dysphagia-Related Outcomes between Multi-Modality Treatments (n=7,917)

Results of multivariable regression models among the subgroup of 7,917 patients treated with multi-modality therapy (surgery + adjuvant or chemoradiation) are reported in supplementary Table 3 and in Figure 3. Adjusted odds of all dysphagia-related outcomes were higher with chemoradiation relative to surgery + adjuvant therapy. Relative to multi-modality surgery+RT, CRT was associated with 1.9 (95% CI: 1.7–2.2), 1.3 (95% CI: 1.1–

1.6), and 1.3 (95% CI: 1.1–1.6) greater odds of dysphagia, stricture, and aspiration pneumonia respectively.

Multivariable Models Estimating Impact of Adjuvant Chemotherapy on Prevalence of Dysphagia-Related Outcomes in Nonsurgically Treated Patients (n=7,617)

Results of multivariable regression models among the subgroup of 7,617 patients treated with nonsurgical therapy (RT alone or chemoradiation) are reported in supplementary Table 4 and in Figure 3. Adjusted odds of all dysphagia-related outcomes were higher among patients who received adjuvant chemotherapy with RT relative to RT alone. Relative to single modality RT, CRT was associated with 3.1 (95% CI: 2.7–3.6), 2.3 (95% CI: 1.9–2.9), and 1.6 (95% CI: 1.2–2.0) greater odds of dysphagia, stricture, and aspiration pneumonia respectively.

Multivariable Models Estimating Impact of Adjuvant Treatment after Primary Surgery on Prevalence of Dysphagia-Related Outcomes (n=8,577)

Results of multivariable regression models among the subgroup of 8,577 patients treated with primary surgical therapy (surgery alone or surgery + adjuvant) are reported in supplementary Table 5 and in Figure 3. Adjusted odds of all dysphagia-related outcomes were higher among patients who received adjuvant therapy with surgery relative to surgery alone. Relative to single modality surgery, surgery + adjuvant therapy was associated with 2.8 (95% CI: 2.4–3.2), 2.0 (95% CI: 1.6–2.5), and 1.7 (95% CI: 1.4–2.2) greater odds of dysphagia, stricture, and aspiration pneumonia respectively.

DISCUSSION

Trends in population-level prevalence of dysphagia in HNC survivorship in the United States were last comprehensively explored in a cohort comprised of patients diagnosed in the 1990's (1992–1999)[8]. Using similar methodology and the SEER-Medicare administrative datasets, we report persistently high prevalence estimates for dysphagia (45%), stricture (10%), and pneumonia (9%) among patients diagnosed in the 2000's despite notable advancements in minimally invasive surgical technique and highly conformal radiotherapy in this decade. Using the adjacent boundary of the 95% CI of our estimates (2000's) against published prevalence by Francis et al[8] (1990's) as reference, prevalence of dysphagia increased by 4.7%, stricture increased by 2.6%, and pneumonia decreased by 0.9% in our SEER-Medicare cohort (2002–2011) relative to estimates published by Francis et al from the 1990's cohort. We present 2-year prevalence estimates whereas Francis et al reported 3-year prevalence. This methodological difference, if anything, would be expected to attenuate the magnitude of the differences in prevalence between these reports, suggesting that dysphagia and stricture are more commonly coded in administrative data in the 2000's than they were in the 1990's. It is not possible to know whether this reflects greater numbers of survivors affected by dysphagia, or greater reporting or coding of this outcome with growing awareness in the clinical community. Nonetheless, the persistently high prevalence of dysphagia at the population level in modern survivors is noteworthy as swallowing difficulty is a top driver of decisional regret[4] in survivorship and is a leading source of non-cancer mortality in survivorship[12].

These results confirm the excess burden of dysphagia and dysphagia-related conditions (e.g., pneumonia) in HNC survivors. Relative to non-cancer controls, HNC cases were 4.6- to 7.8-times more likely to have stricture or dysphagia related claims and 2.1- to 3.7-times more likely to have pneumonia or aspiration pneumonia related claims. These data suggest that the high prevalence of dysphagia observed in HNC cases in this sample do not simply reflect age- or comorbidity-related swallowing dysfunction, as controls were matched on these factors. Similar to comparisons to non-cancer controls previously reported by Xu et al in a SEER-Medicare analysis focused solely on aspiration pneumonia after chemoradiation for mixed sites of HNC[2], these estimates appear to largely reflect the impact of HNC and its treatment on dysphagia-related outcomes.

Frequency of dysphagia is influenced by many factors, most notably tumor site and treatment modality. In four treatment subgroups, multivariable regression models (adjusted for clinicodemographic confounders) were fit regressing each dysphagia outcome on treatment modality to examine two primary questions - first, the *impact of surgical versus nonsurgical* modalities (1: RT alone versus surgery alone, and 2: CRT versus Surgery + adjuvant), and second, the *impact of adjuvant therapy* (3: RT versus CRT, i.e., the added impact of chemotherapy; and 4: surgery alone versus surgery + adjuvant, i.e., the added impact of adjuvant RT or CRT). Two expected themes emerged exploring the results of treatment subgroup models. First, odds of dysphagia-related events were higher after primary nonsurgical methods when compared to primary surgery. This finding aligns with the trends observed in the similar 1990's SEER-Medicare analysis of these endpoints in dysphagia[8]. It is noteworthy that this trend persisted in the decade (2000s) when IMRT and other highly conformal methods of radiotherapy were popularized with the goal of toxicity reduction. Second, subgroup analyses confirmed that odds of dysphagia-related events were higher when adjuvant therapy was required (i.e., comparing single versus multi-modality strategies). That is, both the addition of chemotherapy to radiation and the addition of adjuvant therapy after primary surgery were associated with greater prevalence and odds of dysphagia. These trends align with clinical observations, and are supported by hosts of clinical and population data supporting excess burden of dysphagia with combined modality (compared to single modality) treatment[8,13].

Differences in observed effects sizes are perhaps the most notable results from treatment subgroup multivariable analyses. Specifically, as depicted in Figure 3, effect sizes were largest for addition adjuvant therapy (CRT versus RT alone *or* surgery + adjuvant versus surgery alone) suggesting 2- to 3-fold increased odds of dysphagia and stricture associated with addition of adjuvant therapy to either surgery or RT. Effect sizes were much smaller when comparing primary surgical or nonsurgical options for single modality (RT v surgery alone) or multimodality therapy (CRT v surgery + adjuvant) suggesting 30% to 90% increased odds (<2-fold) of dysphagia or stricture when primary nonsurgical therapy was delivered relative to primary surgical options (adjusted odds ratios: 1.27 to 1.94, see Figure 3). These observations suggest, at least with treatment practices in the 2000's, greater impact of the number of modalities rather than selection of the primary treatment strategy (surgery or radiation) on the prevalence of dysphagia-related outcomes after treatment. This is particularly important when considering strategies to reduce dysphagia burden among patients with low- or intermediate risk disease, as these population-level data support the

notion that the largest impact may be seen with de-escalation strategies that promote a single treatment modality when possible rather than those that simply trade one form of multimodality therapy for another.

Herein, we report updated trends in population-level prevalence of dysphagia in more than 16,000 patients treated for HNC in the U.S. between 2002 and 2011. Strengths of this analysis include large numbers offering the ability to yield narrow confidence intervals from estimates of multivariable models derived from clinically relevant subgroups of patients. We must acknowledge a number of caveats inherent to use of the SEER-Medicare database for these analyses. First, prevalence estimates may be inflated because we analyzed an older cohort of Medicare beneficiaries (age >65) as clinical series report age as the most discriminant demographic factor predicting poor swallowing outcomes[14]. Rising prevalence as shown in Figure 1 occurred in an era where treatment optimization (such as more conformal RT planning like IMRT and rising utilization of minimally invasive surgery). This is counter-intuitive and may in part reflect better coding over the study period rather than true rise in prevalence.

Use of administrative claims to code binary dysphagia outcomes over a 2-year period of observation (i.e., ever/never present) also lacks specificity with regard to the nature, severity, or duration of dysphagia events. Likewise, events must be coded on a claim to be coded in the analysis and claims data likely are not sensitive to milder toxicity events. Finally, cancer stage is a major driver of dysphagia outcomes, particularly primary tumor stage (or T-classification) but analysis of stage as a relevant covariate is limited using SEER-Medicare as their cancer staging (localized, regional, distant) is not compatible with the clinical standard of the AJCC system. Limiting the sample to 2004 onward (when full staging is available in SEER) would have allowed more relevant analysis of this covariate, but would also have limited sufficient sample size to examine all subgroup trends. This should be considered in future work.

It is also noteworthy that inferences regarding effect sizes, statistical significance, and direction of effects were most consistent between related endpoints of dysphagia and stricture. Pneumonia and aspiration pneumonia performed less consistently, and subgroup trends were not always compatible between these outcomes. As an outcome, aspiration pneumonia trended more similarly with stricture and dysphagia whereas general pneumonia diverged in subgroup analyses both by tumor site and treatment modality. These observations support the use of the aspiration pneumonia codes as most specific to dysphagia-related endpoints.

CONCLUSION

Updated population-level analysis using SEER-Medicare data find that prevalence of dysphagia, stricture, and aspiration pneumonia remains high in the decade studied (2002 to 2011) when comparing to published rates using similar methodology in an earlier decade (1992–1999). These results suggest persistence of this morbidity in the decade in which highly conformal radiotherapy methods and minimally invasive surgery were popularized. Prevalence of each dysphagia related endpoints was highest among those treated with

combined modality RT with chemotherapy. As expected, multivariable models also indicated that odds of dysphagia related endpoints were higher among patients treated with multimodality therapy compared to single modality whether primary treatment was surgical or nonsurgical. Finally, larger effect sizes for the impact of adjuvant therapy (i.e., single versus multi-modality regimens) rather than modality (non-surgical versus surgical modalities) supports the notion that de-escalation strategies that promote a single treatment modality rather than those that simply trade one form of multimodality therapy for another could have largest impact on toxicity reduction for swallowing.

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Appendix

Appendix Table 1.

Medicare claims codes.

Variable	Codes
Radiotherapy	ICD-9 procedure codes: 92.21–92.27, 92.29. ICD-9 diagnosis codes: V58.0, V66.1-V67.1. CPT/HCPCS codes: 77401–77525, 77761–77799. Revenue Center codes: 0330, 0333.
Surgery	ICD-9 procedure codes: 24.31, 25.1–25.4, 27.3, 27.32, 27.4, 27.42–43, 27.49, 27.72, 28.92, 29.33, 29.39, 30.0, 30.09, 30.1, 30.21–30.22, 30.29, 30.3–30.5, 76.2, 76.31, 76.39–76.42, 76.44–45. CPT/HCPCS codes: 21044–21045, 31365, 31367–31368, 31370, 31375, 31380, 31382, 31390, 31395, 31420, 38700, 38720, 38724, 40810, 40812, 40814, 40816, 40819, 41110, 41112–41116, 41120, 41130, 41135, 41140, 41145, 41150, 41153, 41155, 42104, 42106–42107, 42120, 42140, 42842, 42844–42845, 42890.
Chemotherapy	ICD-9 procedure code: 99.25. ICD-9 diagnosis codes: V58.1, V58.11, V58.12, V66.2, or V67.2. CPT/HCPCS codes: 96400 to 96599, J8999 to J9999, J8520, J8521, or Q0083 to Q0085. Revenue Center codes: 0331, 0332, or 0335.

Abbreviations: CPT, Current Procedural Terminology; ICD, International Classification of Diseases; HCPCS, Healthcare Common Procedure Coding System.

Appendix Table 2.

Dysphagia, pneumonia, and stricture regressed on single modality treatments in multivariable models.

	Dysphagia No. pts (%), OR (95% CI)		Stricture No. pts (%), OR (95% CI)		Pneumonia No. pts (%), OR (95% CI)		Aspiration pneumonia No. pts (%), OR (95% CI)	
Treatment Modality								
Radiation alone	1,666/4,130 (40.3)	1.81 (1.54–2.13)	335/4,130 (8.1)	1.42 (1.03–1.94)	1,118/4,130 (27.1)	1.27 (1.05–1.53)	335/4,130 (8.1)	1.34 (0.99–1.81)
Surgery alone	1,109/4,147 (26.7)	-Ref-	193/4,147 (4.7)	-Ref-	800/4,147 (19.3)	-Ref-	208/4,147 (5.0)	-Ref-
Race/Ethnicity								
Other	111/365 (30.4)	1.25 (0.93–1.68)	NR	1.20 (0.87–1.67)	83/365 (22.7)	1.10 (0.79–1.55)	22/365 (6.0)	1.20 (0.69–2.09)
Hispanic	124/361 (34.4)	1.21 (0.87–1.67)	NR	1.41 (1.05–1.91)	92/361 (25.5)	1.03 (0.71–1.50)	31/361 (8.6)	1.58 (0.93–2.68)
Black	197/435 (45.3)	1.47 (1.11–1.95)	NR	1.21 (0.94–1.56)	117/435 (26.9)	1.22 (0.89–1.67)	37/435 (8.5)	1.24 (0.75–2.07)
Caucasian	2,343/7,116 (32.9)	-Ref-	NR	-Ref-	1,626/7,116 (22.9)	-Ref-	453/7,116 (6.4)	-Ref-

	Dysphagia No. pts (%), OR (95% CI)		Stricture No. pts (%), OR (95% CI)		Pneumonia No. pts (%), OR (95% CI)		Aspiration pneumonia No. pts (%), OR (95% CI)	
Age quartiles								
>79	1,006/2,887 (34.9)	1.12 (0.92–1.35)	158/2,887 (5.5)	0.66 (0.47–0.94)	796/2,887 (27.6)	1.87 (1.49–2.35)	245/2,887 (8.5)	2.23 (1.48–3.35)
74–79	637/1,919 (33.2)	1.05 (0.86–1.29)	138/1,919 (7.2)	0.72 (0.50–1.04)	430/1,919 (22.4)	1.36 (1.06–1.73)	127/1,919 (6.6)	1.41 (0.90–2.20)
69–74	694/2,141 (32.4)	1.05 (0.86–1.28)	125/2,141 (5.8)	0.76 (0.53–1.08)	454/2,141 (21.2)	1.30 (1.02–1.65)	117/2,141 (5.5)	1.54 (1.00–2.38)
<69	438/1,330 (32.9)	-Ref-	107/1,330 (8.1)	-Ref-	238/1,330 (17.9)	-Ref-	54/1,330 (4.1)	-Ref-
Disease sub-site								
Nasopharynx	35/81 (43.2)	0.96 (0.46–1.97)	NR	1.10 (0.25–4.76)	18/81 (22.2)	0.70 (0.28–1.74)	NR	1.28 (0.37–4.41)
Oropharynx	170/336 (50.6)	1.46 (1.13–1.88)	NR	1.82 (1.18–2.80)	77/336 (22.9)	0.90 (0.66–1.21)	NR	1.00 (0.62–1.61)
Larynx	1,283/3,333 (38.5)	1.08 (0.90–1.30)	NR	1.59 (1.13–2.24)	897/3,333 (26.9)	1.38 (1.12–1.70)	NR	1.14 (0.82–1.60)
Oral cavity	1,110/3,622 (30.7)	-Ref-	NR	-Ref-	720/3,622 (19.9)	-Ref-	NR	-Ref-
Missing	177		NR		206		NR	
Sex								
Female	1,002/3,103 (32.3)	1.16 (1.02–1.33)	181/3,103 (5.8)	1.07 (0.93–1.23)	624/3,103 (20.1)	0.80 (0.68–0.92)	155/3,103 (5.0)	0.70 (0.54–0.91)
Male	1,773/5,174 (34.3)	-Ref-	347/5,174 (6.7)	-Ref-	1,294/5,174 (25.0)	-Ref-	388/5,174 (7.5)	-Ref-
Comorbidity								
2	599/1,475 (40.6)	1.51 (1.27–1.79)	99/1,475 (6.7)	0.97 (0.69–1.36)	525/1,475 (35.6)	2.26 (1.88–2.71)	144/1,475 (9.8)	1.77 (1.31–2.39)
1	804/2,152 (37.4)	1.31 (1.13–1.52)	160/2,152 (7.4)	1.09 (0.82–1.45)	582/2,152 (27.0)	1.64 (1.39–1.93)	173/2,152 (8.0)	1.52 (1.15–2.01)
0	1,372/4,650 (29.5)	-Ref-	269/4,650 (5.8)	-Ref-	811/4,650 (17.4)	-Ref-	226/4,650 (4.9)	-Ref-
SEER stage								
Distant	173/434 (39.9)	1.97 (1.71–2.27)	26/434 (6.00)	2.00 (1.62–2.48)	124/434 (28.6)	1.55 (1.33–1.82)	29/434 (6.7)	2.13 (1.65–2.75)
Regional	677/1,541 (43.9)	1.46 (1.15–1.84)	109/1,541 (7.1)	1.66 (1.44–1.92)	433/1,541 (28.1)	1.46 (1.12–1.89)	152/1,541 (9.9)	1.24 (0.78–1.96)
In situ/Localized	955/3,587 (26.6)	-Ref-	173/3,587 (4.8)	-Ref-	687/3,587 (19.2)	-Ref-	160/3,587 (4.5)	-Ref-
Unstaged/Missing	970		220		674		202	
Total	2,775/8277 (33.5)		528/8277 (6.4)		1,918/8,277 (23.2)		543/8,277 (6.6)	

NR, numbers of patients not reported for cells in which n≤11 observations contributed to the estimate.

Appendix Table 3.

Dysphagia, pneumonia, and stricture regressed on multi-modality treatments in multivariable models.

	Dysphagia No. pts (%), OR (95% CI)		Stricture No. pts (%), OR (95% CI)		Pneumonia No. pts (%), OR (95% CI)		Aspiration pneumonia No. pts (%), OR (95% CI)	
Treatment Modality								
Chemoradiation	2,486/3,487 (71.3)	1.94 (1.7–2.22)	641/3,487 (18.4)	1.32 (1.11–1.56)	1,267/3,487 (36.3)	1.38 (1.21–1.58)	493/3,487 (14.1)	1.34 (1.11–1.63)
Surgery + Adjuvant	2,074/4,430 (46.8)	-Ref-	480/4,430 (10.8)	-Ref-	1,067/4,430 (24.1)	-Ref-	364/4,430 (8.2)	-Ref-
Race/Ethnicity								
Other	218/356 (61.2)	0.32 (0.12–0.86)	29/356 (8.2)	0.49 (0.29–0.84)	120/356 (33.7)	1.15 (0.83–1.59)	49/356 (13.7)	1.30 (0.85–2.00)
Hispanic	253/402 (62.9)	1.03 (0.55–1.93)	74/402 (18.4)	1.32 (0.93–1.85)	138/402 (34.3)	1.02 (0.76–1.37)	43/402 (10.7)	0.69 (0.43–1.11)
Black	372/566 (65.7)	0.93 (0.55–1.59)	97/566 (17.1)	1.08 (0.80–1.46)	185/566 (32.7)	1.12 (0.88–1.43)	64/566 (11.3)	0.99 (0.70–1.42)
Caucasian	3,717/6,593 (56.4)	-Ref-	921/6,593 (14.0)	-Ref-	1,891/6,593 (28.7)	-Ref-	701/6,593 (10.6)	-Ref-
Age quartiles								
>79	913/1,800 (50.7)	0.89 (0.73–1.07)	186/1,800 (10.3)	0.82 (0.64–1.06)	551/1,800 (30.6)	1.32 (1.09–1.61)	210/1,800 (11.7)	1.42 (1.07–1.88)
74–79	1,058/1,803 (58.7)	1.11 (0.92–1.34)	242/1,803 (13.4)	0.94 (0.75–1.20)	563/1,803 (31.2)	1.36 (1.13–1.64)	218/1,803 (12.1)	1.63 (1.25–2.12)
69–74	1,533/2,533 (60.5)	1.02 (0.86–1.20)	417/2,533 (16.5)	0.97 (0.79–1.20)	709/2,533 (28.0)	1.05 (0.88–1.24)	246/2,533 (9.7)	1.04 (0.80–1.35)
<69	1,056/1,781 (59.3)	-Ref-	276/1,781 (15.5)	-Ref-	511/1,781 (28.7)	-Ref-	183/1,781 (10.3)	-Ref-
Disease sub-site								
Nasopharynx	175/279 (62.7)	0.64 (0.38–1.08)	42/279 (15.1)	1.35 (0.67–2.71)	94/279 (33.7)	1.08 (0.63–1.85)	31/279 (11.1)	0.74 (0.31–1.75)

	Dysphagia No. pts (%), OR (95% CI)		Stricture No. pts (%), OR (95% CI)		Pneumonia No. pts (%), OR (95% CI)		Aspiration pneumonia No. pts (%), OR (95% CI)	
Oropharynx	667/972 (68.6)	0.84 (0.71–0.99)	169/972 (17.4)	1.38 (1.12–1.71)	282/972 (29.0)	0.88 (0.74–1.04)	118/972 (12.1)	0.94 (0.74–1.20)
Larynx	1,429/2,188 (65.3)	0.84 (0.72–0.98)	487/2,188 (22.3)	1.93 (1.59–2.35)	837/2,188 (38.3)	1.39 (1.18–1.62)	303/2,188 (13.9)	0.98 (0.77–1.23)
Oral cavity	1,830/2,749 (66.6)	-Ref-	333/2,749 (12.1)	-Ref-	806/2,749 (29.3)	-Ref-	318/2,749 (11.6)	-Ref-
Missing	101		90		315		87	
Sex								
Female	1,399/2,503 (55.9)	1.12 (0.86–1.45)	322/2,503 (12.9)	0.90 (0.75–1.08)	682/2,503 (27.3)	1.02 (0.88–1.17)	227/2,503 (9.1)	0.82 (0.67–1.01)
Male	3,161/5,414 (58.4)	-Ref-	799/5,414 (14.8)	-Ref-	1,652/5,414 (30.5)	-Ref-	630/5,414 (11.6)	-Ref-
Comorbidity								
2	790/1,256 (62.9)	1.41 (1.17–1.69)	191/1,256 (15.2)	1.04 (0.83–1.32)	522/1,256 (41.6)	2.06 (1.74–2.45)	193/1,256 (15.4)	1.77 (1.40–2.22)
1	1,206/1,971 (61.2)	1.25 (1.08–1.46)	309/1,971 (15.7)	1.21 (1.00–1.47)	670/1,971 (34.0)	1.41 (1.21–1.64)	237/1,971 (12.0)	1.17 (0.94–1.46)
0	2,564/4,690 (54.7)	-Ref-	621/4,690 (13.2)	-Ref-	1,142/4,690 (24.4)	-Ref-	27/4,690 (9.1)	-Ref-
SEER stage								
Distant	774/1,762 (43.9)	0.98 (0.62–1.56)	132/938 (14.1)	1.45 (1.11–1.89)	335/938 (35.7)	1.98 (1.61–2.43)	116/938 (12.4)	1.82 (1.35–2.47)
Regional	2,153/3,590 (60.0)	1.37 (1.05–1.79)	491/3,590 (13.7)	1.42 (1.15–1.74)	1,007/3,590 (28.1)	1.35 (1.15–1.58)	383/3,590 (10.7)	1.54 (1.21–1.96
In situ/Localized	580/938 (61.8)	-Ref-	172/1,762 (9.8)	-Ref-	392/1,762 (22.3)	-Ref-	118/1,762 (6.7)	-Ref-
Unstaged/missing	1,053		326		600		240	
Total	4,560/7,917 (57.6)		1,121/7,917 (14.2)		2,334/7,917 (29.5)		857/7,917 (10.8)	

Appendix Table 4.

Dysphagia, pneumonia, and stricture regressed on non-surgical treatments in multivariable models.

	Dysphagia No. pts (%), OR (95% CI)		Stricture No. pts (%), OR (95% CI)		Pneumonia No. pts (%), OR (95% CI)		Aspiration pneumonia No. pts (%), OR (95% CI)	
Treatment Modality								
Chemoradiation	2,486/3,487 (71.3)	3.08 (2.65–3.58)	641/3,487 (18.4)	2.31 (1.85–2.88)	1,267/3,487 (36.3)	1.47 (1.26–1.72)	493/3,487 (14.1)	1.55 (1.23–1.95)
Radiation alone	1,666/4,130 (40.3)	-Ref-	335/4,130 (8.1)	-Ref-	1,118/4,130 (27.1)	-Ref-	335/4,130 (8.1)	-Ref-
Race/Ethnicity								
Other	181/332(54.5)	1.10 (0.79–1.55)	23/332 (6.9)	1.15 (0.83–1.59)	111/332 (33.4)	1.24 (0.86–1.80)	38/332 (11.5)	1.31 (0.79–2.16)
Hispanic	207/364 (56.9)	1.03 (0.71–1.50)	56/364 (15.4)	1.02 (0.76–1.37)	140/364 (38.5)	1.26 (0.90–1.76)	47/364 (12.9)	0.95 (0.58–1.57)
Black	388/611 (63.5)	1.22 (0.89–1.67)	79/611 (12.9)	1.12 (0.88–1.43)	206/611 (33.7)	1.21 (0.94–1.55)	73/611 (12.0)	1.12 (0.78–1.61)
Caucasian	3,376/6,310 (53.5)	-Ref-	818/6,310 (13.0)	-Ref-	1,928/6,310 (30.6)	-Ref-	670/6,310 (10.6)	-Ref-
Age quartiles								
>79	1,005/1,982 (50.7)	1.04 (0.85–1.28)	192/1,982 (9.7)	0.85 (0.64–1.12)	674/1,982 (34.0)	1.49 (1.21–1.83)	255/1,982 (12.9)	1.90 (1.39–2.59)
74–79	953/1,737 (54.9)	1.10 (0.90–1.35)	229/1,737 (13.2)	0.87 (0.67–1.14)	574/1,737 (33.1)	1.45 (1.18–1.78)	215/1,737 (12.4)	1.77 (1.30–2.41)
69–74	1,294/2,309 (56.1)	1.05 (0.87–1.28)	326/2,307 (14.1)	0.89 (0.70–1.14)	690/2,307 (29.9)	1.11 (0.91–1.35)	226/2,307 (9.8)	1.24 (0.92–1.67)
<69	900/1,591 (56.6)	-Ref-	229/1,591 (14.4)	-Ref-	447/1,591 (28.1)	-Ref-	132/1,591 (8.3)	-Ref-
Disease sub-site								
Nasopharynx	183/307 (59.6)	0.63 (0.39–1.03)	41/307 (13.4)	0.96 (0.46–1.97)	94/279 (33.7)	0.81 (0.48–1.36)	35/307 (11.4)	0.54 (0.21–1.36)
Oropharynx	600/911 (65.9)	0.89 (0.74–1.07)	145/911 (15.9)	1.23 (0.97–1.56)	282/972 (29.0)	0.86 (0.71–1.04)	112/911 (12.3)	1.00 (0.77–1.30)
Larynx	2,115/4,304 (49.1)	0.95 (0.81–1.12)	546/4,304 (12.7)	1.44 (1.15–1.79)	837/2,188 (38.3)	1.38 (1.17–1.62)	451/4,304 (10.5)	1.09 (0.86–1.39)
Oral cavity	1,091/1,645 (66.3)	-Ref-	214/1,645 (13.0)	-Ref-	806/2,749 (29.3)	-Ref-	196/1,645 (11.9)	-Ref-
Missing	163		30		366		34	
Sex								
Female	1,118/1,930 (57.9)	0.80 (0.68–0.92)	249/1,930 (12.9)	1.02 (0.88–1.17)	597/1,930 (30.9)	0.99 (0.84–1.15)	191/1,930 (9.9)	0.88 (0.70–1.11)
Male	3,034/5,687 (53.4)	-Ref-	727/5,687 (12.8)	-Ref-	1,788/5,687 (31.4)	-Ref-	637/5,687 (11.2)	-Ref-

	Dysphagia No. pts (%), OR (95% CI)		Stricture No. pts (%), OR (95% CI)		Pneumonia No. pts (%), OR (95% CI)		Aspiration pneumonia No. pts (%), OR (95% CI)	
Comorbidity								
2	858/1,450 (59.2)	1.65 (1.37–2.00)	177/1,450 (12.2)	0.95 (0.74–1.23)	614/1,450 (42.3)	2.03 (1.69–2.43)	205/1,450 (14.1)	1.73 (1.34–2.22)
1	1,194/2,056 (58.1)	1.32 (1.12–1.56)	294/2,056 (14.3)	1.15 (0.93–1.42)	732/2,056 (35.6)	1.48 (1.26–1.74)	258/2,056 (12.6)	1.31 (1.04–1.67)
0	2,100/4,111 (51.1)	-Ref-	505/4,111 (12.3)	-Ref-	1,039/4,111 (25.3)	-Ref-	365/4,111 (8.9)	-Ref-
SEER stage								
Distant	458/712 (64.3)	1.55 (1.33–1.82)	108/712 (15.2)	1.98 (1.61–2.43)	273/712 (38.3)	1.68 (1.36–2.09)	92/712 (12.9)	1.97 (1.50–2.58)
Regional	1,477/2,262 (65.3)	1.46 (1.12–1.89)	332/2,262 (14.7)	1.35 (1.15–1.58)	752/2,262 (33.2)	1.42 (1.20–1.69)	297/2,262 (13.1)	1.88 (1.35–2.62)
In situ/Localized	654/1,331 (49.1)	-Ref-	140/1,331 (10.5)	-Ref-	365/1,331 (27.4)	-Ref-	90/1,331 (6.8)	-Ref-
Unstaged/missing	1,563		396		995		349	
Total	4,152/7,617 (54.5)		976/7,617 (12.8)		2,385/7,617 (31.3)		828/7,617 (10.9)	

Appendix Table 5.

Dysphagia, pneumonia, and stricture regressed on surgical treatments in multivariable models.

	Dysphagia No. pts (%), OR (95% CI)		Stricture No. pts (%), OR (95% CI)		Pneumonia No. pts (%), OR (95% CI)		Aspiration pneumonia No. pts (%), OR (95% CI)	
Treatment Modality								
Surgery + adjuvant therapy	2,074/4,430 (46.8)	2.77 (2.44–3.15)	480/4,430 (10.8)	1.97 (1.56–2.49)	1,067/4,430 (24.1)	1.36 (1.17–1.58)	364/4,430 (8.2)	1.73 (1.36–2.20)
Surgery alone	1,109/4,147 (26.7)	-Ref-	193/4,147 (4.7)	-Ref-	800/4,147 (19.3)	-Ref-	208/4,147 (5.0)	-Ref-
Race/Ethnicity								
Other	148/389 (38.1)	1.20 (0.69–2.09)	15/389 (3.9)	1.30 (0.85–2.00)	92/389(23.7)	1.05 (0.77–1.43)	33/389 (8.5)	1.22 (0.77–1.93)
Hispanic	170/399 (42.6)	1.58 (0.93–2.68)	39/399 (9.8)	0.69 (0.43–1.11)	90/399 (22.6)	0.86 (0.62–1.18)	27/399 (6.8)	0.93 (0.56–1.53)
Black	181/390 (46.4)	1.24 (0.75–2.07)	52/390 (13.3)	0.99 (0.70–1.42)	96/390 (24.6)	1.10 (0.81–1.50)	28/390 (7.2)	0.99 (0.60–1.64)
Caucasian	2,684/7,399 (36.3)	-Ref-	567/7,399 (7.7)	-Ref-	1,589/7,399 (21.5)	-Ref-	484/7,399 (6.5)	-Ref-
Age quartiles								
>79	914/2,705 (33.8)	1.01 (0.85–1.20)	152/2,705 (5.6)	0.73 (0.54–0.99)	673/2,705 (24.9)	1.59 (1.30–1.95)	200/2,705 (7.4)	1.45 (1.05–1.99)
74–79	742/1,985 (37.4)	1.06 (0.88–1.27)	151/1,985 (7.6)	0.90 (0.67–1.22)	419/1,985 (21.1)	1.23 (0.99–1.52)	130/1,985 (6.6)	1.25 (0.89–1.74)
69–74	933/2,367 (39.4)	1.01 (0.85–1.20)	216/2,367 (9.1)	0.95 (0.72–1.25)	473/2,367 (19.9)	1.13 (0.93–1.39)	137/2,367 (5.8)	1.04 (0.75–1.44)
<69	594/1,520 (39.1)	-Ref-	154/1,520 (10.1)	-Ref-	302/1,520 (19.9)	-Ref-	105/1,520 (6.9)	-Ref-
Disease sub-site								
Nasopharynx	27/53 (50.9)	0.94 (0.35–2.51)	NR	2.55 (0.72–9.12)	99/307 (32.3)	1.71 (0.62–4.71)	NR	3.23 (1.03–10.15)
Oropharynx	237/397 (59.7)	1.19 (0.95–1.50)	NR	1.76 (1.28–2.43)	269/911 (29.5)	0.88 (0.68–1.15)	NR	0.81 (0.54–1.21)
Larynx	597/1,217 (49.1)	0.82 (0.69–0.98)	NR	2.42 (1.88–3.12)	1,361/4,304 (31.6)	1.36 (1.12–1.66)	NR	0.93 (0.68–1.27)
Oral cavity	1,849/4,726 (39.1)	-Ref-	NR	-Ref-	522/1,645 (31.7)	-Ref-	NR	-Ref-
Missing	473				387			
Sex								
Female	1,283/3,676 (34.9)	0.70 (0.54–0.91)	254/3,676 (6.9)	0.82 (0.67–1.01)	709/3,676 (19.3)	0.85 (0.75–0.98)	191/3,676 (5.2)	0.68 (0.54–0.85)
Male	1,900/4,901 (38.8)	-Ref-	419/4,901 (8.6)	-Ref-	1,158/4,901 (23.6)	-Ref-	381/4,901 (7.8)	-Ref-
Comorbidity								
2	531/1,281 (41.5)	1.34 (1.14–1.58)	113/1,281 (8.8)	1.11 (0.83–1.47)	433/1,281 (33.8)	2.28 (1.92–2.70)	132/1,281 (10.3)	1.84 (1.42–2.40)
1	816/2,067 (39.5)	1.26 (1.09–1.44)	175/2,067 (8.5)	1.20 (0.95–1.52)	520/2,067 (25.2)	1.54 (1.32–1.79)	152/2,067 (7.4)	1.26 (0.98–1.63)
0	1,836/5,229 (35.1)	-Ref-	385/5,229 (7.4)	-Ref-	914/5,229 (17.5)	-Ref-	288/5,229 (5.5)	-Ref-
SEER stage								
Distant	295/660 (44.7)	2.13 (1.65–2.75)	50/660 (7.6)	1.82 (1.35–2.47)	186/660 (28.2)	2.00 (1.57–2.54)	53/660 (8.0)	1.69 (1.16–2.46)

	Dysphagia No. pts (%), OR (95% CI)		Stricture No. pts (%), OR (95% CI)		Pneumonia No. pts (%), OR (95% CI)		Aspiration pneumonia No. pts (%), OR (95% CI)	
Regional	1,353/2,869 (47.2)	1.24 (0.78–1.96)	268/2,869 (9.3)	1.54 (1.21–1.96)	688/2,869 (24.0)	1.42 (1.22–1.65)	238/2,869 (8.3)	1.61 (1.27–2.05)
In situ/Localized	1,075/4,018 (26.8)	-Ref-	205/4,018 (5.1)	-Ref-	714/4,018 (17.8)	-Ref-	188/4,018 (4.7)	-Ref-
Unstaged/missing	460		82		279		93	
Total	3,183/8,577 (37.1)		673/8,577 (7.9)		1,867/8,577 (21.8)		572/8,577 (6.7)	

NR, numbers of patients not reported for cells in which n≤11 observations contributed to the estimate.

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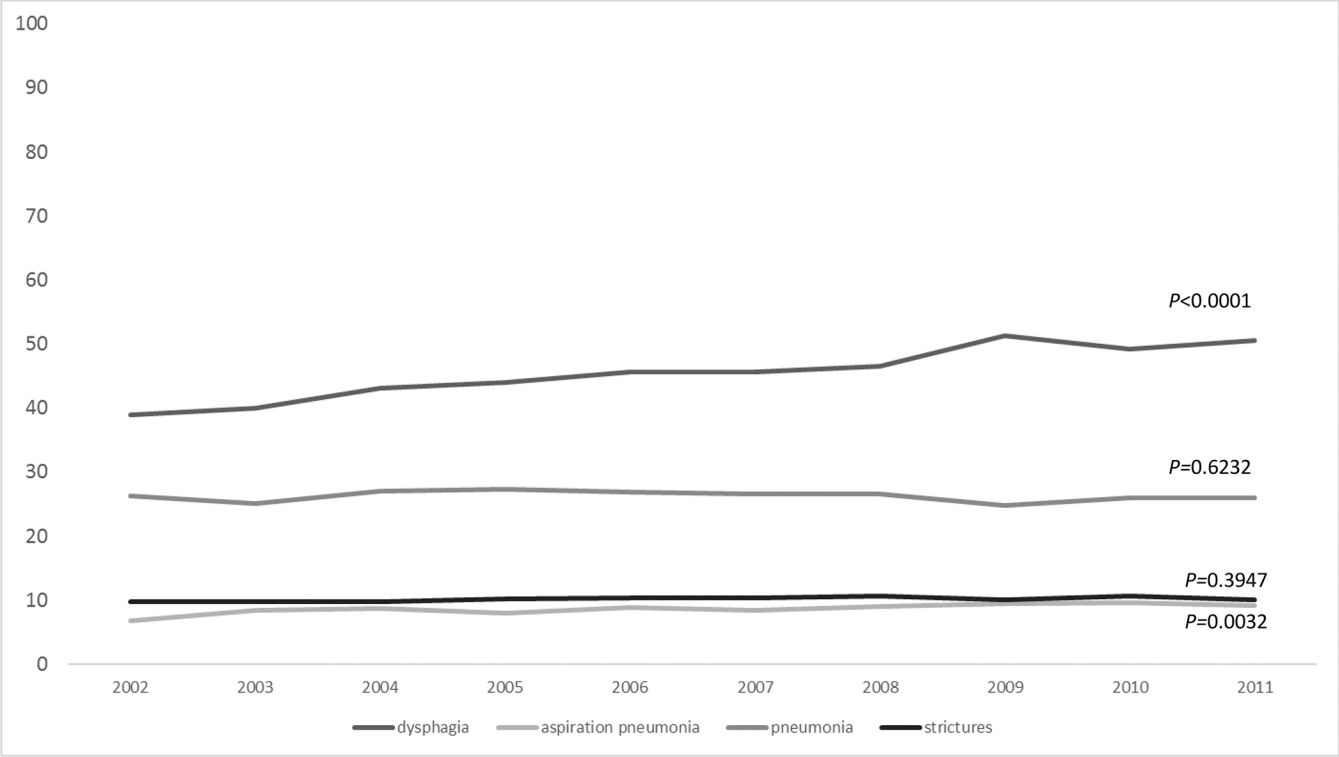
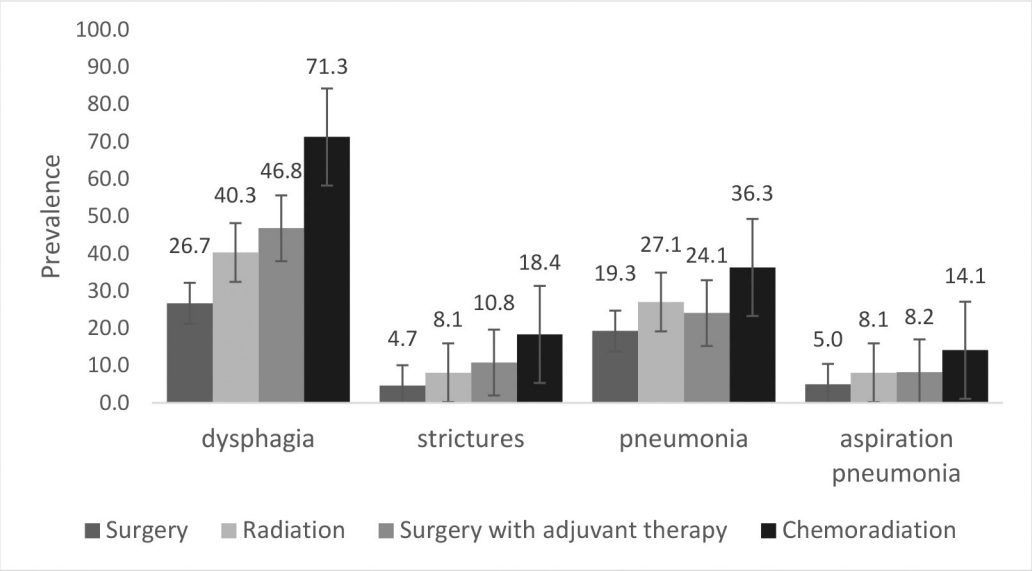
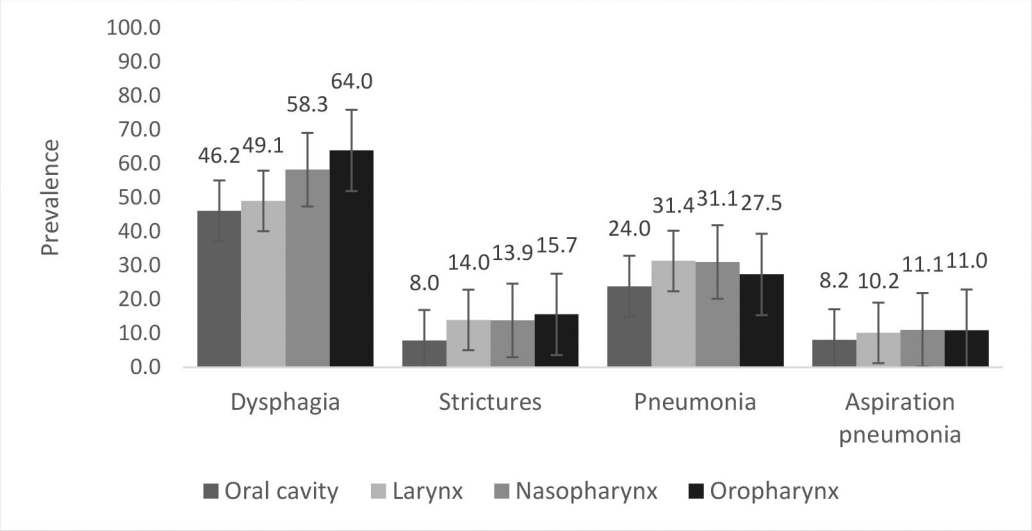


FIGURE 1.

Two year prevalence of swallowing-related events by treatment modality (top) and disease sub-site (bottom), n=16,194.





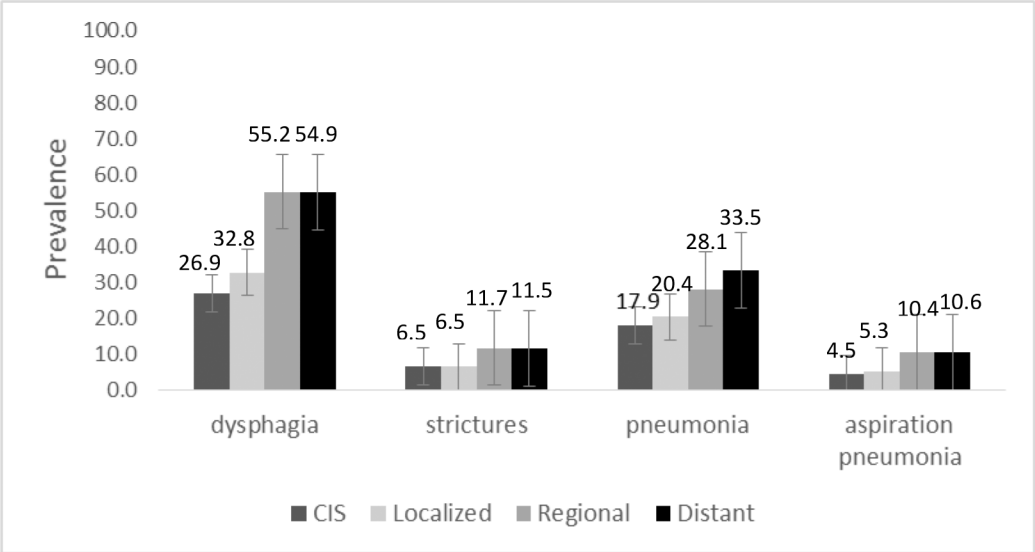


FIGURE 2.

Adjusted odds of 2-year swallowing-related events by treatment modality, n=16,194. Adjusted for age, sex, race/ethnicity, tumor site, comorbidity stage, SEER stage. CRT: chemoradiation

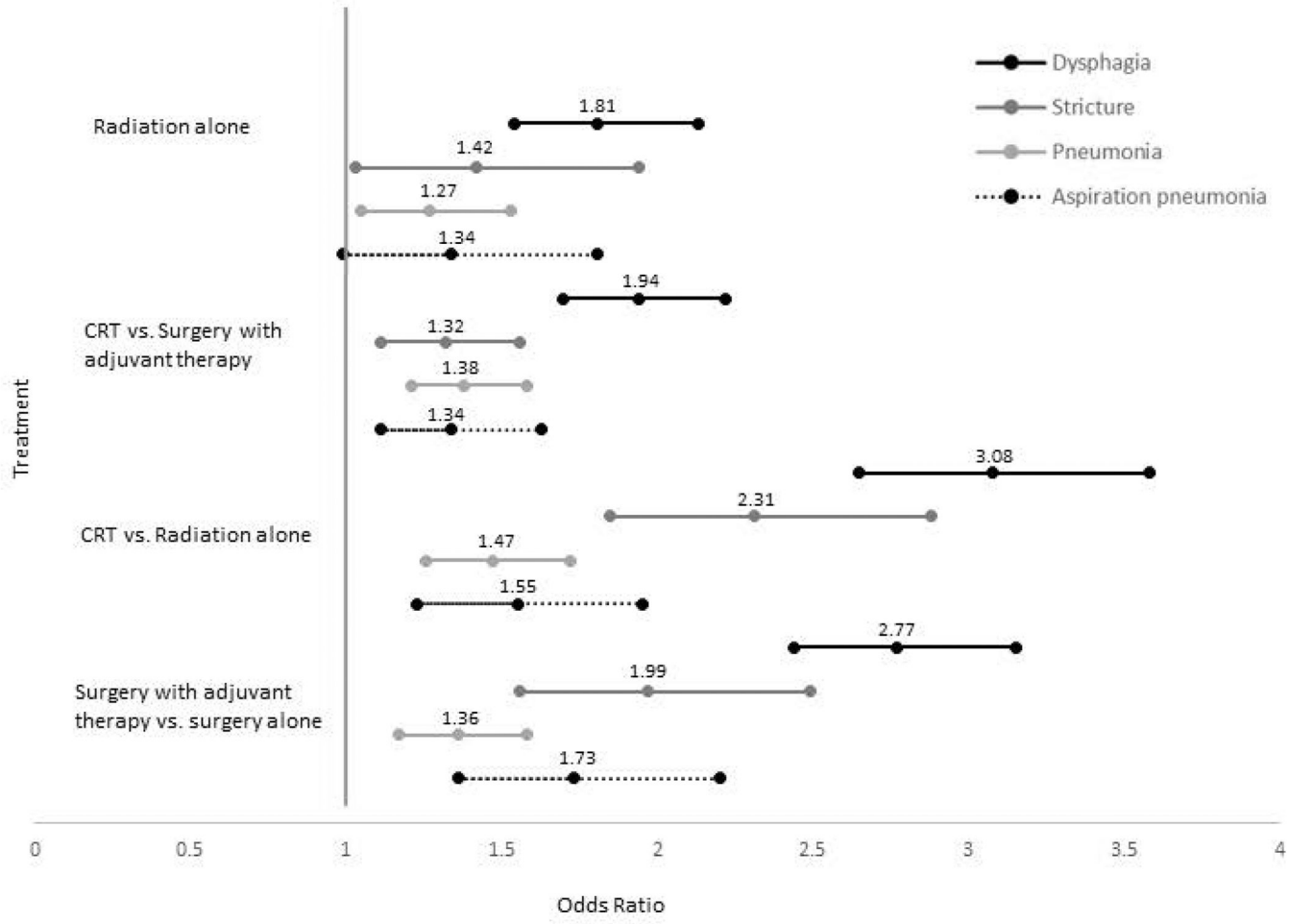


FIGURE 3.

Adjusted odds of dysphagia, stricture, pneumonia and aspiration pneumonia by treatment modality.

Table 1.

Patient characteristics (n=16,194)

	No (%)
Sex	
Female	5,606 (34.62)
Male	10,588 (65.38)
Race/Ethnicity	
Caucasian	13,709 (84.65)
Black	1,001 (6.18)
Hispanic	763 (4.71)
Other	721 (4.45)
Age quartiles	
<69	3,111 (19.21)
69–74	4,674 (28.86)
74–79	3,722 (22.98)
>79	4,687 (28.94)
Disease sub-site	
Oral cavity	6,371 (39.34)
Larynx	5,521 (34.09)
Oropharynx	1,308 (8.08)
Nasopharynx	360 (2.22)
Missing	2,634 (16.27)
SEER stage	
In situ/Localized	5,349 (33.03)
Regional	5,131 (31.68)
Distant	1,372 (8.47)
Unstaged/Missing	4,342 (26.81)
Comorbidity	
0	9,340 (57.68)
1	4,123 (25.46)
2	2,731 (16.86)
Treatment Modality	
Surgery alone	4,147 (25.61)
Surgery + adjuvant therapy	4,430 (27.36)
Radiation alone	4,130 (25.50)
Chemoradiation	3,487 (21.53)
2-Year Prevalence (95% CI)	
Dysphagia	7,335 (45.29)
Stricture	1,649 (10.18)
Pneumonia	4,252 (26.26)

	No (%)
Aspiration pneumonia	1,400 (8.65)
Total	**16,194**

Table 2.

Two year prevalence of swallowing-related events by site and treatment modality, n=16,194

	Single modality No. pts (%)	Multimodality No. pts (%)	*p* value	Surgery alone No. pts (%)	Surgery + adjuvant No. pts (%)	RT alone No. pts (%)	CRT No. pts (%)	*p* value
NPC								
Dysphagia	35/81 (43.2)	175/279 (62.7)	**0.002**	NR	26/46 (56.5)	34/74 (46.0)	149/233 (64.0)	**0.004**
Stricture	NR	42/279 (15.1)	0.236	NR	NR	NR	33/233 (14.2)	0.472
Pneumonia	18/81 (22.2)	94/279 (33.7)	**0.050**	NR	12/46 (26.1)	17/74 (23.0)	82/233 (35.2)	0.157
Asp Pneumonia	NR	31/279 (11.1)	1.0	NR	NR	NR	26/233 (11.2)	0.986
OPC								
Dysphagia	170/336 (50.6)	667/972 (68.6)	**<0.001**	39/87 (44.8)	198/310 (63.9)	131/249 (52.6)	469/662 (70.9)	**<0.001**
Stricture	36/336 (10.7)	169/972 (17.4)	**0.004**	NR	49/310 (15.9)	25/249 (10.0)	120/662 (18.1)	**0.022**
Pneumonia	77/336 (22.9)	282/972 (29.0)	**0.031**	13/87 (14.9)	77/310 (24.8)	64/249 (25.7)	205/662 (31.0)	**0.006**
Asp Pneumonia	26/336 (7.7)	118/972 (12.1)	**0.026**	NR	29/310 (9.4	23/249 (9.2)	89/662 (13.4)	**0.013**
Laryngeal cancer								
Dysphagia	1,283/3,333 (38.5)	1,429/2,188 (65.3)	**<0.001**	148/362 (40.9)	449/855 (52.5)	1135/2,971 (38.2)	980/1,333 (73.5)	**<0.001**
Stricture	288/3,333 (8.6)	487/2,188 (22.3)	**<0.001**	37/362 (10.2)	192/855 (22.5)	251/2,971 (8.5)	295/1,333 (22.1)	**<0.001**
Pneumonia	897/3,333 (26.9)	837/2,188 (38.3)	**<0.001**	100/362 (27.6)	273/855 (31.9)	797/2,971 (26.8)	564/1,333 (42.3)	**<0.001**
Asp Pneumonia	261/3,333 (7.8)	303/2,188 (13.9)	**<0.001**	26/362 (7.2)	87/855 (10.2)	235/2,971 (7.9)	216/1,333 (16.2)	**<0.001**
Oral cavity cancer								
Dysphagia	1,110/3,622 (30.7)	1,830/2,749 (66.6)	**<0.001**	822/3,047 (27.0)	1027/1,679 (61.2)	288/575 (50.1)	803/1,070 (75.1)	**<0.001**
Stricture	174/3,622 (4.8)	333/2,749 (12.1)	**<0.001**	131/3,047 (4.3)	162/1,679 (9.7)	43/575 (7.5)	171/1,070 (16.0)	**<0.001**
Pneumonia	720/3,622 (19.9)	806/2,749 (29.3)	**<0.001**	565/3,047 (18.5)	439/1,679 (26.2)	155/575 (27.0)	367/1,070 (34.3)	**<0.001**
Asp Pneumonia	203/3,622 (5.6)	318/2,749 (11.6)	**<0.001**	155/3,047 (5.1)	170/1,679 (10.1)	48/575 (8.4)	148/1,070 (13.8)	**<0.001**
Missing								
Dysphagia	177/905 (19.6)	459/1,729 (26.6)	**<0.001**	99/644 (15.4)	374/1,540 (24.3)	78/261 (29.9)	85/189 (45.0)	**<0.001**
Stricture	22/905 (2.4)	90/1,729 (5.2)	**<0.001**	14/644 (2.2)	68/1,540 (4.4)	NR	22/189 (11.6)	**<0.001**
Pneumonia	206/905 (22.8)	315/1,729 (18.2)	**0.005**	121/644 (18.8)	266/1,540 (17.3)	85/261 (32.6)	49/189 (25.9)	**<0.001**
Asp Pneumonia	44/905 (4.9)	87/1,729 (5.0)	0.849	24/644 (3.7)	73/1,540 (4.7)	20/261 (7.7)	14/189 (7.4)	**<0.034**
All sites								

	Single modality No. pts (%)	Multimodality No. pts (%)	*p* value	Surgery alone No. pts (%)	Surgery + adjuvant No. pts (%)	RT alone No. pts (%)	CRT No. pts (%)	*p* value
Dysphagia	2775/8277 (33.5)	4560/7917 (57.6)	**<0.001**	1109/4147 (26.7)	2074/4430 (46.8)	1666/4130 (40.3)	2486/3487 (71.3)	**<0.001**
Stricture	528/8277 (6.4)	1121/7917 (14.2)	**<0.001**	193/4147 (4.7)	480/4430 (10.8)	335/4130 (8.1)	641/3487 (18.4)	**<0.001**
Pneumonia	1918/8277 (23.2)	2334/7917 (29.5)	**<0.001**	800/4147 (19.3)	1067/4430 (24.1)	1118/4130 (27.1)	1267/3487 (36.3)	**<0.001**
Asp Pneumonia	543/8277 (6.6)	857/7917 (10.8)	**<0.001**	208/4147 (5.0)	364/4430 (8.2)	335/4130 (8.1)	493/3487 (14.1)	**<0.001**
All patients	8,277 (51.11)	7,917 (48.89)		4,147 (25.61)	4,430 (27.36)	4,130 (25.50)	3,487 (21.53)	

NR, numbers of patients not reported for cells in which n≤11 observations contributed to the estimate.

Table 3.

Dysphagia, pneumonia, and stricture regressed in multivariable models in full sample (n=16,194)

	Dysphagia No. pts (%), OR (95% CI)		**Stricture No. pts (%), OR (95% CI)**		**Pneumonia No. pts (%), OR (95% CI)**		**Aspiration pneumonia No. pts (%), OR (95% CI)**	
Treatment Modality								
Chemoradiation	2,486/3,487 (71.3)	**5.58 (4.84–6.44)**	641/3,487 (18.4)	**2.95 (2.35–3.72)**	1,267/3,487 (36.3)	**1.90 (1.63–2.21)**	493/3,487 (14.1)	**2.24 (1.77–2.84)**
Surgery + Adjuvant	2,074/4,430 (46.8)	**2.01 (1.74–2.32)**	480/4,430 (10.8)	1.29 (0.99–1.67)	1,067/4,430 (24.1)	**1.28 (1.09–1.51)**	364/4,430 (8.2)	**1.44 (1.11–1.87)**
Radiation	1,666/4,130 (40.3)	**2.93 (2.59–3.31)**	335/4,130 (8.1)	**2.22 (1.78–2.76)**	1,118/4,130 (27.1)	**1.36 (1.18–1.56)**	335/4,130 (8.1)	**1.67 (1.33–2.09)**
Surgery	1,109/4,147 (26.7)	-Ref-	193/4,147 (4.7)	-Ref-	800/4,147 (19.3)	-Ref-	208/4,147 (5.0)	-Ref-
Race/Ethnicity								
Other	329/721 (45.6)	1.21 (0.97–1.51)	38/721 (5.3)	0.44 (0.27–0.70)	203/721 (28.2)	1.12 (0.88–1.41)	71/721 (9.9)	1.25 (0.89–1.75)
Hispanic	377/763 (49.4)	**1.30 (1.05–1.62)**	95/763 (12.5)	1.23 (0.91–1.66)	230/763 (30.1)	1.02 (0.81–1.28)	74/763 (9.7)	0.94 (0.66–1.33)
Black	569/1,001 (56.8)	**1.33 (1.10–1.61)**	131/1,001 (13.1)	1.04 (0.80–1.35)	302/1,001 (30.2)	1.17 (0.96–1.42)	101/1,001 (10.1)	1.08 (0.81–1.45)
Caucasian	6,060/13,709 (44.2)	-Ref-	1,385/13,709 (10.1)	-Ref-	3,517/13,709 (25.7)	-Ref-	1,154/13,709 (8.4)	-Ref-
Age quartiles								
>79	1,494/3,111 (48.0)	1.02 (0.89–1.16)	383/3,111 (12.3)	0.78 (0.64–0.96)	749/3,111 (24.1)	**1.58 (1.37–1.82)**	237/3,111 (7.6)	**1.69 (1.35–2.12)**
74–79	2,227/4,674 (47.7)	1.08 (0.94–1.23)	542/4,674 (11.6)	0.88 (0.72–1.08)	1,163/4,674 (24.9)	**1.35 (1.16–1.56)**	363/4,674 (7.8)	**1.53 (1.22–1.91)**
69–74	1,695/3,722 (45.5)	1.03 (0.90–1.17)	380/3,722 (10.2)	0.91 (0.76–1.09)	993/3,722 (26.7)	1.13 (0.98–1.30)	345/3,722 (9.3)	1.16 (0.93–1.44)
<69	1,919/4,687 (40.9)	-Ref-	344/4,687 (7.3)	-Ref-	1,387/4,687 (28.7)	-Ref-	455/4,687 (9.7)	-Ref-
Disease sub-site								
Nasopharynx	210/360 (58.3)	0.74 (0.48–1.13)	50/360 (13.9)	1.29 (0.69–2.41)	112/360 (31.1)	0.95 (0.60–1.52)	40/360 (11.1)	0.85 (0.42–1.72)
Oropharynx	837/1,308 (64.0)	0.99 (0.86–1.14)	205/1,308 (15.7)	**1.45 (1.20–1.75)**	359/1,308 (27.5)	0.88 (0.76–1.02)	144/1,308 (11.0)	0.95 (0.77–1.18)
Larynx	2,712/5,521 (49.1)	0.92 (0.81–1.04)	775/5,521 (14.0)	**1.81 (1.53–2.15)**	1,734/5,521 (31.4)	**1.39 (1.23–1.58)**	564/5,521 (10.2)	**1.03 (0.86–1.25)**
Oral cavity	2,940/6,371 (46.2)	-Ref-	507/6,371 (8.0)	-Ref-	1,526/6,371 (23.9)	-Ref-	521/6,371 (8.2)	-Ref-
Missing	101		90		315		87	
Sex								
Female	2,401/5,606 (42.8)	**1.11 (1.01–1.22)**	503/5,606 (9.0)	1.03 (0.88–1.19)	1306/5,606 (23.3)	0.90 (0.82–1.00)	382/5,606 (6.8)	0.77 (0.65–0.90)
Male	4,934/10,588 (46.6)	-Ref-	1,146/10,588 (10.8)	-Ref-	2,946/10,588 (27.8)	-Ref-	1,018/10,588 (9.6)	-Ref-
Comorbidity								
2	844/1,653 (51.1)	**1.46 (1.25–1.69)**	166/1,653 (10.0)	0.96 (0.76–1.22)	665/1,653 (40.2)	**2.32(2.01–2.69)**	226/1,653 (13.7)	**1.96 (1.59–2.41)**

	Dysphagia No. pts (%), OR (95% CI)		**Stricture No. pts (%), OR (95% CI)**		**Pneumonia No. pts (%), OR (95% CI)**		**Aspiration pneumonia No. pts (%), OR (95% CI)**	
1	1,746/3,469 (50.3)	**1.35 (1.21–1.51)**	406/3,469 (11.7)	**1.21 (1.03–1.42)**	1,114/3,469 (32.1)	**1.49 (1.33–1.68)**	367/3,469 (10.6)	**1.37 (1.15–1.63)**
0	4,745/11,072 (42.9)	-Ref-	1,077/11,072 (9.7)	-Ref-	2,473/11,072 (22.3)	-Ref-	807/11,072 (7.3)	-Ref-
SEER stage								
Distant	774/1,762 (43.9)	**1.81 (1.56–2.11)**	132/938 (14.1)	**1.31 (1.05–1.64)**	335/938 (35.7)	**1.81 (1.54–2.11)**	116/938 (12.4)	**1.75 (1.37–2.23)**
Regional	2,153/3,590 (60.0)	**1.81 (1.63–2.00)**	491/3,590 (13.7)	**1.37 (1.17–1.61)**	1,007/3,590 (28.1)	**1.42 (1.27–1.58)**	383/3,590 (10.7)	**1.76 (1.47–2.10)**
In situ/Localized	580/938 (61.8)	-Ref-	172/1,762 (9.8)	-Ref-	392/1,762 (22.3)	-Ref-	118/1,762 (6.7)	-Ref-
Unstaged/missing	1,053		326		600		240	
Total	7335/16,194 (45.3)		1,649/16,194 (10.2)		4252/16,194 (26.3)		1400/16,194 (8.7)	

Bold cells denote statistically significant ($p<0.05$) adjusted odds ratios.