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Pretreatment Upper Esophageal Sphincter Opening Diameter on Water-Soluble Contrast Esophagography: Differences by Tumor Site and Swallowing-Related Symptom Documentation

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Abstract

This study compared maximum upper esophageal sphincter (UES) opening diameter across tumor locations and pretreatment swallowing-related symptom-documentation categories to explore the clinical relevance of this measurement in routine pretreatment esophagography. Diameter was measured on pretreatment water-soluble iodinated contrast esophagrams from 168 patients with hypopharyngeal, laryngeal, or esophageal cancer. UES opening diameter differed across four primary tumor-site groups ($H = 38.12$, $P < 0.001$) and eight detailed locations ($H = 47.79$, $P < 0.001$), with the lowest median in patients with postcricoid tumors (7.29 mm). Symptom comparisons in the 80 patients with hypopharyngeal or laryngeal cancer showed differences among three pretreatment symptom-documentation categories: documented symptoms, explicit denial of symptoms, and no symptom documentation ($H = 18.87$, $P < 0.001$). Among 61 patients with either documented symptoms or explicit denial, those with documented symptoms had a smaller median diameter than those who explicitly denied symptoms (9.78 vs 12.84 mm; $P < 0.001$). Multivariable logistic regression in 55 patients with complete covariate data showed lower odds of documented symptoms with increasing diameter after adjustment for cancer type, age, and body mass index (*OR* = 0.602; 95% *CI* 0.415–0.876; $P = 0.008$). Intraobserver and interobserver intraclass correlation coefficients were 0.982 and 0.973, respectively. Maximum UES opening diameter can be measured reproducibly on routine pretreatment esophagrams and may provide supplementary quantitative information relevant to baseline swallowing assessment.

Introduction

Dysphagia is common in patients with upper aerodigestive tract cancer and can impair oral intake, nutritional status, and quality of life. Swallowing impairment may already be present at diagnosis and varies by tumor site [1, 2]. Pretreatment assessment documents baseline swallowing status before surgery or chemoradiotherapy alters swallowing anatomy and physiology, providing a reference for subsequent evaluation [3, 4]. Videofluoroscopic swallowing study (VFSS) and fiberoptic endoscopic evaluation of swallowing (FEES) are established methods for diagnosing oropharyngeal dysphagia and assessing swallowing safety and efficiency [3].

Swallowing-related information may also be obtained from imaging performed for other clinical indications. Contrast esophagography is commonly used to evaluate pharyngeal and esophageal disease and records the passage of swallowed contrast through the pharyngoesophageal segment. Opening of the upper esophageal sphincter (UES) is essential for bolus passage into the esophagus, and reduced opening may contribute to impaired bolus transit and swallowing difficulty [5, 6]. When the pharyngoesophageal segment is adequately recorded, maximum UES opening diameter can be measured on existing pretreatment water-soluble iodinated contrast esophagrams without additional imaging acquisition.

However, the clinical relevance of UES opening diameter measured in this routine imaging setting remains unclear. UES opening is influenced by local anatomy and the physiological mechanisms

involved in pharyngoesophageal passage [5–8]. Tumor location and local tissue involvement may therefore affect the extent of opening. Pretreatment swallowing-related symptom documentation provides an additional clinical perspective for examining whether differences in diameter correspond to recorded swallowing difficulties. Whether maximum UES opening diameter differs across tumor locations and symptom-documentation categories on routine pretreatment esophagrams has not been well characterized.

The present study compared maximum UES opening diameter across tumor locations in patients with untreated hypopharyngeal, laryngeal, or esophageal cancer using pretreatment water-soluble iodinated contrast esophagrams. Within the hypopharyngeal and laryngeal cancer subgroup, diameter was further compared across categories of pretreatment swallowing-related symptom documentation to explore the clinical relevance of this routinely obtainable measurement.

Materials and Methods

Study Design and Participants

This single-center, multicampus retrospective study screened records of patients admitted to one of three campuses of the same tertiary academic hospital between January 1, 2024, and December 31, 2025, with a diagnosis of laryngeal, hypopharyngeal, or esophageal cancer. Eligibility required pathologically confirmed cancer, water-soluble iodinated contrast esophagography performed before treatment, and a complete swallowing sequence that allowed maximum UES opening to be identified. For each patient, the first pretreatment esophagram was used; for surgically treated patients, this was the first preoperative examination. Records were excluded sequentially for (1) a known neurologic disorder affecting swallowing, (2) lack of a water-soluble iodinated contrast esophagram, (3) cancer treatment before imaging or prior surgery involving the pharynx, larynx, or esophagus, and (4) imaging insufficient to confirm maximum UES opening. Imaging was considered insufficient when the pharyngoesophageal segment was not visualized, the UES could not be localized reliably, or the opening sequence was incompletely recorded. A total of 168 patients were included: 32 with hypopharyngeal, 48 with laryngeal, and 88 with esophageal cancer (Online Resource 2, Fig. S1).

Esophagography and UES Measurement

At all three campuses, patients stood in a 35°–40° right anterior oblique position while swallowing a water-soluble iodinated contrast agent (iodine concentration, 320 mg I/mL). Examinations were performed using a digital radiography/fluoroscopy system (SONIALVISION; Shimadzu Corporation, Kyoto, Japan), with the same equipment configuration across campuses. Image sequences used for UES measurements were acquired and stored at 6 frames/s. Digital Imaging and Communications in Medicine (DICOM) spatial calibration allowed measurements in millimeters within the picture archiving and communication system (PACS). The first swallow with an evaluable pharyngeal-phase sequence

was selected from each examination. The selected swallow was reviewed frame by frame to identify the image with the greatest visible UES opening. Maximum UES opening diameter was defined as the distance between opposing luminal margins at the narrowest pharyngoesophageal segment between C4 and C6 on this frame (Fig. 1). The diameter was measured three times on the selected frame, and the arithmetic mean, rounded to two decimal places, was used for analysis. Readers had access only to the original imaging sequences and no clinical records or other patient data.

For reproducibility, 50 randomly selected examinations from patients with hypopharyngeal or laryngeal cancer were remeasured on complete, de-identified sequences by the original observer after approximately 1 month to assess intraobserver agreement and independently by a second otolaryngology clinician to assess interobserver agreement. The same swallow-selection and triplicate-measurement procedure was used for each observer and measurement session.

Tumor Grouping and Clinical Variables

The anatomic comparisons used all 168 patients. Primary tumors were grouped as hypopharyngeal, laryngeal, upper/mid-upper esophageal, or middle/lower/mid-lower esophageal cancer. The esophageal groups distinguished the more proximal tumors, which lie closer to the UES, from more distal tumors. Group assignment followed the recorded tumor-segment labels. For the detailed comparison, hypopharyngeal tumors were subdivided into postcricoid, pyriform sinus, and posterior pharyngeal wall tumors; laryngeal tumors into supraglottic, transglottic, and glottic tumors. Esophageal cancers remained in the two segment-based groups, yielding eight detailed tumor-location categories.

Clinical covariates and pretreatment symptom documentation were available only for the 80 patients with hypopharyngeal or laryngeal cancer; the 88 patients with esophageal cancer contributed only to tumor-location comparisons. Age, sex, height, weight, TNM categories, serum albumin at the first admission before treatment, symptom documentation, and campus were recorded for this subgroup. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared; it was available for 74 of the 80 patients.

Stage was assigned according to the American Joint Committee on Cancer (AJCC) staging system, 8th edition: postoperative pathologic TNM (pTNM) was available for 70 surgically treated patients and clinical TNM (cTNM) for 10 nonsurgically treated patients. Early stage was defined as T1–2N0M0 and locoregionally advanced disease as T3–4 and/or node-positive disease without distant metastasis. The primary stage analyses were restricted to the 70 surgical patients with pTNM; sensitivity analyses added the 10 nonsurgical patients with cTNM. UES diameter and symptom documentation preceded treatment, whereas pTNM was determined after surgery.

Pretreatment Swallowing-Related Symptom Documentation

Pretreatment swallowing-related symptoms were abstracted from the chief complaint and history of present illness at the first visit for patients with hypopharyngeal or laryngeal cancer. Records were classified as an explicit denial of swallowing-related symptoms, no documentation of swallowing-related symptoms, or documented symptoms (odynophagia, a sensation of obstruction during swallowing, or dysphagia). “No documentation” meant that neither section recorded swallowing-related discomfort; it was not taken as an explicit denial. The initial comparison retained all three categories. The primary binary comparison and logistic models excluded undocumented cases and contrasted documented symptoms with explicit denial. In a sensitivity analysis, undocumented cases were combined with explicit denials and compared with documented symptoms.

Statistical Analysis

Continuous variables are reported as medians, interquartile ranges (IQRs), and ranges, and categorical variables as counts and percentages with stated denominators. To compare UES opening diameter across four primary tumor-site groups, eight detailed tumor locations, and three symptom-documentation categories, separate Kruskal–Wallis tests were used. When an overall comparison was statistically significant, pairwise Mann–Whitney tests were performed, with *P* values adjusted using the Bonferroni method separately within each set of pairwise comparisons. Adjusted pairwise *P* values are reported in the Results, figures, and Online Resource 1 (Tables S1–S3). Other comparisons of UES opening diameter between two groups were performed using Mann–Whitney tests, with standardized *Z* statistics reported.

Within the hypopharyngeal and laryngeal cancer subgroup, the distribution of the three symptom-documentation categories was compared between cancer types using Pearson’s chi-square test. The primary binary comparison included only patients with documented symptoms or an explicit denial. Logistic regression was used to estimate the odds ratio (*OR*) for documented symptoms per 1-mm increase in UES opening diameter. The main complete-case model included UES opening diameter, cancer type, age, and BMI. Reduced models were used to assess sensitivity to covariate selection; the combined "denied or undocumented" symptom definition was examined separately. Missing values were not imputed. Box–Tidwell terms were used to assess logit linearity for continuous predictors.

Additional analyses in the hypopharyngeal and laryngeal cancer subgroup were exploratory. Spearman correlation was used to evaluate UES opening diameter in relation to age, BMI, and albumin. Multivariable linear regression was used to examine the relationship between cancer type and UES opening diameter after adjustment for age, BMI, and albumin, with stage group (early-stage vs locoregionally advanced disease) added in separate sensitivity models. The cancer-type coefficient represented the adjusted mean difference in diameter between hypopharyngeal and laryngeal cancer. Mann–Whitney tests were used to compare UES opening diameters between stage groups, and Fisher’s exact tests were used to compare symptom frequencies; a logistic model was used to estimate the odds of documented symptoms by stage group after adjustment for cancer type. Stage analyses were first restricted to surgical patients with pTNM and then repeated after adding nonsurgical patients with

cTNM. UES opening diameters were compared across campuses using Kruskal–Wallis tests and regression models adjusted for cancer type, then additionally for age, BMI, and albumin. Linear regression results are reported with model-based 95% confidence intervals (*CIs*) and *P* values. Exploratory *P* values were not corrected across all clinical-factor analyses.

Observer reproducibility was assessed using single-measure, absolute-agreement intraclass correlation coefficients (ICCs), with two-way mixed-effects models for intraobserver and two-way random-effects models for interobserver measurements. Each input value represented the mean of three repeated diameter measurements made by one observer in one measurement session. Percentile 95% *CIs* were obtained from 5,000 patient-level bootstrap resamples, with paired measurements resampled together.

Statistical analyses were performed using IBM SPSS Statistics, version 25.0 (IBM Corp., Armonk, NY, USA). Python 3.12.14 (Python Software Foundation) was used for regression diagnostics, bootstrap resampling, and ICC estimation. All tests were two-sided, and a P value < 0.05 was considered statistically significant.

Results

Study population and measurement reproducibility

Of 963 screened records, 168 met the eligibility criteria: 32 with hypopharyngeal, 48 with laryngeal, and 88 with esophageal cancer (Online Resource 2, Fig. S1). All 168 patients contributed to tumor-location comparisons. Clinical and symptom analyses were restricted to the 80 patients with hypopharyngeal or laryngeal cancer, for whom clinical covariates and symptom documentation were available.

Within the 80-patient clinical subgroup, excluding 19 patients with no symptom documentation left 61 for the primary binary symptom comparison. After exclusion of six patients with missing BMI, 55 entered the primary logistic model, including 28 with documented symptoms. These analysis populations overlap; their derivation and purpose, including those used in sensitivity and exploratory analyses, are summarized in Online Resource 2 (Table S4).

All 80 patients in the hypopharyngeal and laryngeal cancer subgroup were male, with a median age of 67.0 years (IQR 58.0–74.0). BMI was available for 74 patients. Baseline characteristics of this subgroup are presented in Table 1.

Table 1
Characteristics of the hypopharyngeal and laryngeal cancer subgroup

Characteristic	**Patients, No. (%)**		
	All patients (*n* = 80)	**Hypopharyngeal (*n* = 32)**	**Laryngeal (*n* = 48)**
Age, median (IQR), years	67.0 (58.0–74.0)	63.5 (59.5–71.0)	69.5 (58.0–75.0)
Male	80 (100.0)	32 (100.0)	48 (100.0)
BMI, median (IQR), kg/m²	21.7 (19.4–23.4)	21.2 (19.0–22.4)	22.3 (19.5–24.6)
BMI available, *n*	74	28	46
Albumin, median (IQR), g/L	40.2 (38.0–42.3)	38.8 (37.5–41.5)	41.1 (38.5–42.5)
Postoperative pTNM, n	**70**	**25**	**45**
pT1–2	33 (47.1)	8 (32.0)	25 (55.6)
pT3–4	37 (52.9)	17 (68.0)	20 (44.4)
pN0	43 (61.4)	9 (36.0)	34 (75.6)
pN1–2	27 (38.6)	16 (64.0)	11 (24.4)
Early stage	28 (40.0)	5 (20.0)	23 (51.1)
Locoregionally advanced	42 (60.0)	20 (80.0)	22 (48.9)
Nonsurgical cTNM, n	**10**	**7**	**3**
cT1–2	5 (50.0)	3 (42.9)	2 (66.7)
cT3–4	5 (50.0)	4 (57.1)	1 (33.3)
cN0	4 (40.0)	2 (28.6)	2 (66.7)
cN1–2	6 (60.0)	5 (71.4)	1 (33.3)
Early stage	2 (20.0)	1 (14.3)	1 (33.3)
Locoregionally advanced	8 (80.0)	6 (85.7)	2 (66.7)
Symptom documentation			
Explicitly denied symptoms	29 (36.3)	5 (15.6)	24 (50.0)
No symptom documentation	19 (23.8)	4 (12.5)	15 (31.3)

Note: Data are *n* (%) unless otherwise stated. Stage percentages use the subgroup *n* shown above them; other percentages use the column *n*. All patients were M0. Early stage: T1–2N0M0; locoregionally advanced: T3–4 and/or node-positive M0 (AJCC, 8th ed.). pTNM, pathologic TNM; cTNM, clinical TNM; BMI, body mass index; IQR, interquartile range. No symptom documentation is distinct from explicit denial. Campuses are anonymized.

Characteristic	Patients, No. (%)		
	All patients (*n* = 80)	**Hypopharyngeal (*n* = 32)**	**Laryngeal (*n* = 48)**
Documented symptoms	32 (40.0)	23 (71.9)	9 (18.8)
Campus			
Campus A	23 (28.8)	5 (15.6)	18 (37.5)
Campus B	51 (63.8)	23 (71.9)	28 (58.3)
Campus C	6 (7.5)	4 (12.5)	2 (4.2)

Note: Data are *n* (%) unless otherwise stated. Stage percentages use the subgroup *n* shown above them; other percentages use the column *n*. All patients were M0. Early stage: T1–2N0M0; locoregionally advanced: T3–4 and/or node-positive M0 (AJCC, 8th ed.). pTNM, pathologic TNM; cTNM, clinical TNM; BMI, body mass index; IQR, interquartile range. No symptom documentation is distinct from explicit denial. Campuses are anonymized.

Reproducibility was assessed in 50 examinations randomly selected from the 80-patient clinical subgroup. The intraobserver and interobserver ICCs were 0.982 (95% *CI* 0.966–0.990) and 0.973 (95% *CI* 0.948–0.985), respectively.

UES opening diameter by tumor site

UES opening diameter differed across the four primary tumor-site groups ($H = 38.12$, $P < 0.001$; Table 2 and Fig. 2). Patients with hypopharyngeal cancer had smaller openings than those in each of the other groups, and patients with laryngeal cancer had smaller openings than those in either esophageal group (all Bonferroni-adjusted $P \le 0.044$). No statistically significant difference was observed between the two esophageal groups ($P = 1.000$). Complete pairwise results, including standardized Z statistics and Bonferroni-adjusted P values, are provided in Online Resource 1 (Table S1).

Table 2
Upper esophageal sphincter opening diameter by primary tumor site

Primary tumor site	*n*	Median (IQR), mm	Range, mm
Hypopharyngeal cancer	32	10.25 (8.33–11.71)	5.59–15.22
Laryngeal cancer	48	11.61 (9.89–13.30)	7.54–19.50
Upper/mid-upper esophageal cancer	12	14.59 (12.85–17.19)	7.80–18.31
Middle/lower/mid-lower esophageal cancer	76	14.06 (11.93–15.75)	6.78–22.09

Note: IQR, interquartile range.

Diameter also differed across the eight detailed tumor locations ($H = 47.79$, $P < 0.001$; Table 3 and Fig. 3). Patients with postcricoid tumors ($n = 7$) had the lowest median diameter (7.29 mm), with smaller diameters than those with posterior pharyngeal wall, supraglottic, or glottic tumors and those in either esophageal group. Patients with pyriform sinus tumors had smaller diameters than those with middle/lower/mid-lower esophageal cancer, whereas patients with supraglottic tumors had smaller diameters than those in either esophageal group (all Bonferroni-adjusted $P < 0.05$). No other pairwise comparison was statistically significant. Figure 3 displays selected significant comparisons; complete pairwise results, including standardized Z statistics and Bonferroni-adjusted P values, are provided in Online Resource 1 (Table S2).

Table 3
Upper esophageal sphincter opening diameter by detailed tumor location

Detailed tumor location	*n*	Median (IQR), mm	Range, mm
Postcricoid region	7	7.29 (6.99–8.15)	5.72–8.83
Pyriform sinus	17	10.79 (9.05–12.80)	5.59–15.22
Posterior pharyngeal wall	8	11.22 (10.49–12.26)	9.55–12.91
Supraglottic larynx	21	10.81 (9.62–12.10)	7.54–15.43
Transglottic larynx	6	11.04 (9.28–12.81)	8.08–14.93
Glottic larynx	21	11.71 (11.02–14.84)	9.12–19.50
Upper/mid-upper esophagus	12	14.59 (12.85–17.19)	7.80–18.31
Middle/lower/mid-lower esophagus	76	14.06 (11.93–15.75)	6.78–22.09
Note: IQR, interquartile range.			

Within the hypopharyngeal and laryngeal cancer subgroup, exploratory multivariable linear regression in 74 complete cases showed smaller diameters in hypopharyngeal than laryngeal cancer after adjustment for age, BMI, and albumin ($B = -1.484$ mm, 95% CI −2.723 to −0.245, $P = 0.020$). Stage-adjusted estimates were similar, but the difference between cancer types did not reach statistical significance in the pTNM model ($n = 64$, $P = 0.057$). Correlations (Table S6), linear regression estimates (Table S7), and campus comparisons (Table S8) are provided in Online Resource 3.

UES opening diameter by swallowing-related symptom documentation

Symptoms were classified from the chief complaint and history of present illness. Among the 80 patients with hypopharyngeal or laryngeal cancer, 29 explicitly denied swallowing-related symptoms, 19 had no symptom documentation, and 32 had documented symptoms. Records with no symptom documentation were analyzed separately from explicit denials. The distribution of these categories

differed between cancer types (χ^2 = 22.65, P < 0.001; Table 1). UES opening diameter differed across the three categories (H = 18.87, P < 0.001; Table 4 and Fig. 4). Bonferroni-adjusted comparisons showed larger diameters in patients who explicitly denied symptoms than in those with no symptom documentation (P = 0.034) or documented symptoms (P < 0.001). No statistically significant difference was observed between the latter two categories (P = 0.197). Complete pairwise results, including standardized Z statistics and Bonferroni-adjusted P values, are provided in Online Resource 1 (Table S3).

After exclusion of the 19 patients with no symptom documentation, the primary binary comparison included 61 patients: 32 with documented symptoms and 29 who explicitly denied symptoms. Median diameter was 9.78 mm (IQR 8.40–11.06) in patients with documented symptoms and 12.84 mm (IQR 10.77–14.82) in those who explicitly denied symptoms (Z = − 4.10, P < 0.001). Six patients had missing BMI, leaving 55 for the primary multivariable logistic regression, including 28 with documented symptoms. Each 1-mm increase in diameter was associated with lower odds of documented symptoms after adjustment for cancer type, age, and BMI (OR = 0.602, 95% CI 0.415–0.876, P = 0.008; Table 5).

Reduced models retained all 61 patients with explicit symptom documentation. The alternative-definition model combined undocumented records with explicit denials and included 74 complete cases, adjusting for cancer type, age, and BMI. These sensitivity analyses yielded estimates in the same direction as the primary model (Table 5). Additional model details are provided in Online Resource 3 (Table S5).

Table 4
Upper esophageal sphincter opening diameter by pretreatment symptom documentation

Pretreatment symptom documentation	***n***	**Median (IQR), mm**	**Range, mm**
Explicitly denied symptoms	29	12.84 (10.77–14.82)	9.12–19.50
No symptom documentation	19	11.02 (9.86–12.05)	7.54–14.93
Documented symptoms	32	9.78 (8.40–11.06)	5.59–15.43
Note: IQR, interquartile range.			

Table 5
Logistic regression for documented swallowing-related symptoms

Analysis	*n*	Symptom events	Adjusted *OR* per 1-mm increase in UES diameter	95% *CI*	*P* value
Primary model: cancer type, age, BMI	55	28	0.602	0.415–0.876	0.008
Reduced model: cancer type	61	32	0.613	0.438–0.857	0.004
Reduced model: cancer type, age	61	32	0.620	0.443–0.868	0.005
Alternative symptom definition: cancer type, age, BMI	74	28	0.691	0.510–0.936	0.017

Note: BMI, body mass index; *CI*, confidence interval; *OR*, odds ratio; UES, upper esophageal sphincter.

Exploratory stage analyses found no statistically significant difference in UES opening diameter between early-stage and locoregionally advanced disease. Documented symptoms were more frequent in advanced disease, although adjusted estimates were imprecise in both staging populations. Analysis populations and full results are provided in Online Resource 3 (Tables S9–S11).

Discussion

Maximum UES opening diameter varied by tumor location, with the lowest median in patients with postcricoid tumors. In patients with hypopharyngeal or laryngeal cancer, smaller diameters were associated with documented swallowing-related symptoms, and the association persisted after adjustment for cancer type, age, and BMI. Excellent intraobserver and interobserver agreement supports reproducible measurement under the study protocol. These findings show that routine pretreatment water-soluble contrast esophagrams provide quantitative information on pharyngoesophageal opening that relates to both tumor location and symptom documentation.

The differences by tumor location are consistent with an anatomical contribution to pharyngoesophageal opening. Cheng et al. reported more frequent aspiration in hypopharyngeal than laryngeal cancer [2], providing context for the present site-related differences in a distinct component of swallowing. The low median diameter in postcricoid tumors is anatomically plausible given their proximity to the pharyngoesophageal segment. Local tumor involvement may restrict tissue displacement or distension during bolus passage. Exploratory linear regression also showed smaller diameters in hypopharyngeal than laryngeal cancer after adjustment for age, BMI, and albumin. Stage-adjusted estimates were similar in magnitude but less precise.

The association with documented symptoms places the imaging differences in a clinical context. Swallowing difficulties are already present in some patients at diagnosis [1], and pretreatment dysphagia

has been linked to subsequent swallowing dysfunction after chemoradiation [9]. In the present study, the diameter–symptom association persisted after covariate adjustment and was assessed before treatment could alter anatomy or function. Studies combining imaging and patient-reported outcomes illustrate the value of assessing complementary dimensions of swallowing [10, 11]. Cui et al. found no significant difference in UES diameter across qualitative VFSS severity categories in patients with neurological dysphagia [12]. That study examined a different population and a broader outcome; UES diameter describes a focal aspect of bolus passage, whereas swallowing assessment also encompasses airway protection, residue, and other physiological deficits [3, 13–15].

Distinguishing undocumented symptoms from explicit symptom denial was important to interpreting these findings. Patients with no symptom documentation had smaller openings than those who explicitly denied symptoms. Retaining this category separately in the descriptive analysis, and restricting the primary binary comparison to patients with explicit documentation, avoided classifying missing information as symptom absence. The alternative analysis, which combined undocumented records with explicit denials, yielded an association in the same direction.

The practical contribution is the use of existing esophagrams to add quantitative information to pretreatment assessment. Kerrison et al. showed that quantitative VFSS measurements improved observer agreement and influenced rehabilitation recommendations [16]. UES diameter was measured with high observer agreement using a standardized procedure for image selection and repeated measurements. Steele et al. derived UES reference intervals from standardized lateral VFSS and emphasized the importance of acquisition and bolus conditions [17]. The present measurements characterize variation within a right anterior oblique, water-soluble contrast protocol. For patients whose examinations adequately record the pharyngoesophageal sequence, this approach may supplement baseline swallowing assessment without additional imaging acquisition.

Limitations

Imaging was acquired for routine clinical care, with nonstandardized bolus administration and volume. Recording at 6 frames/s may have missed peak UES distension and underestimated maximum opening. Smaller boluses selected by patients with greater swallowing difficulty could partly account for the symptom-related difference. DICOM spatial calibration does not remove projection or potential magnification effects, so lateral VFSS reference values cannot be applied directly. Symptoms were abstracted from routine records and included odynophagia, a sensation of obstruction, and dysphagia, without a validated measure of symptom severity. The observed association therefore concerns recorded symptoms rather than a standardized measure of overall swallowing impairment.

Selection and sample size also affect interpretation. Only 168 of 963 screened records met the eligibility criteria, and requiring an evaluable pharyngeal-phase sequence may have introduced selection bias. Clinical covariates were available only for the hypopharyngeal and laryngeal cancer subgroup, which comprised male patients exclusively. Several anatomical subgroups were small, including seven

postcricoid tumors. The primary logistic model included 55 complete cases and 28 symptom events, limiting precision and increasing the risk of overfitting; reproducibility was assessed in 50 examinations from patients with hypopharyngeal or laryngeal cancer. Primary stage analyses were restricted to surgical patients with postoperative pTNM, while sensitivity analyses added nonsurgical patients with cTNM, introducing differences in patient selection and stage ascertainment. Healthy controls and concurrent standardized swallowing assessments were unavailable, so abnormal thresholds and diagnostic performance were not evaluated. Prospective studies using standardized acquisition and bolus administration should compare UES diameter with validated physiological and patient-reported outcomes to determine its added value in pretreatment swallowing assessment.

Conclusion

Maximum UES opening diameter can be measured reproducibly from routine pretreatment water-soluble contrast esophagrams. It differed across tumor-site groups, with the lowest median in patients with postcricoid tumors. Among patients with hypopharyngeal or laryngeal cancer, larger diameter remained associated with lower odds of documented swallowing-related symptoms after adjustment for cancer type, age, and BMI. These findings suggest that this measurement may provide supplementary quantitative information relevant to pretreatment swallowing assessment, although its clinical utility warrants further evaluation.

Declarations

Author Contribution

L.Z. curated the data, performed the statistical analyses, prepared the figures, and drafted and revised the manuscript.J.J.Z. and Y.B.Z. conducted the investigation, curated the data, and validated the results. Y.Z. curated the data, validated the results, and revised the manuscript. Y.F.Z. developed the methodology, performed the statistical analyses, validated the results, and revised the manuscript. B.S.T. developed the methodology, supervised the study, validated the results, and revised the manuscript. Q.W. conceived the study, administered the project, supervised the study, and revised the manuscript. All authors reviewed and approved the final manuscript.

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Figures



Figure 1

Selection of the frame for UES diameter measurement. Consecutive frames from the same swallow show early opening (a), maximum visible opening (b), and continued bolus passage after maximum opening (c). Diameter was measured on frame b. UES, upper esophageal sphincter

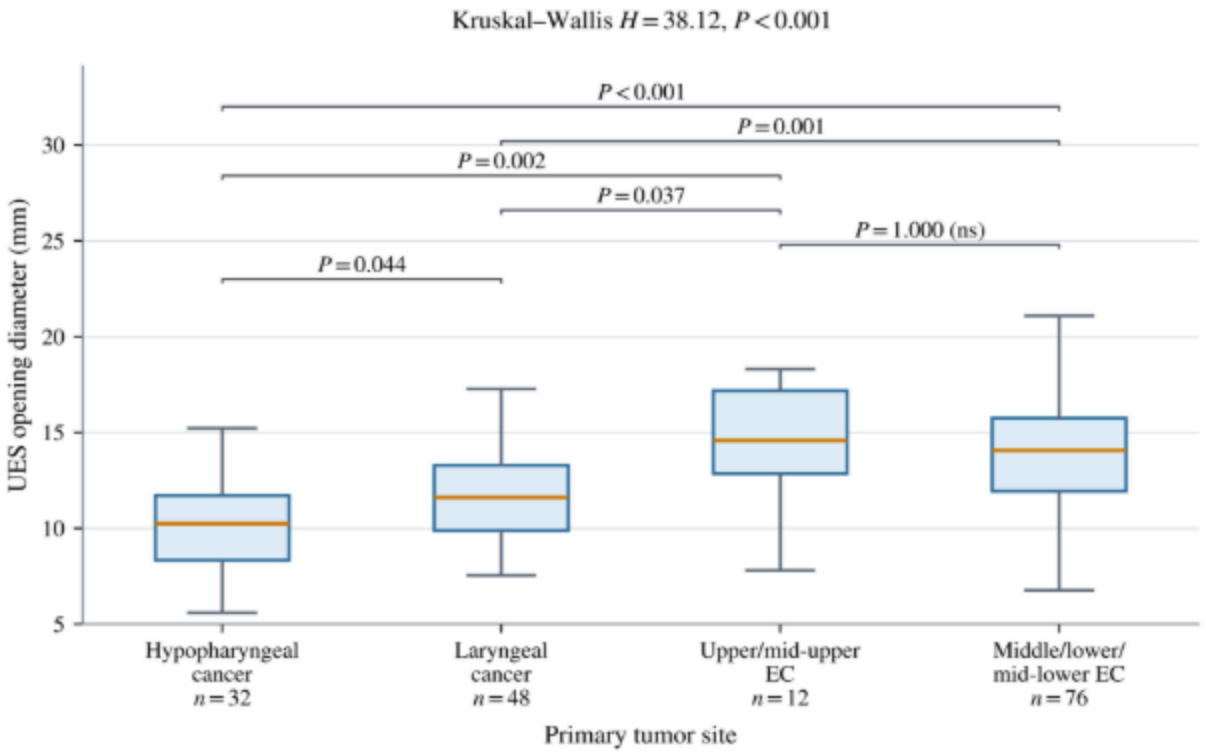


Figure 2

UES opening diameter by primary tumor site (*n* = 168). Boxes show interquartile ranges (IQRs), center lines indicate medians, and whiskers extend to the most extreme values within 1.5 × IQR of the box limits. Values beyond the whiskers are not shown but are included in analyses. Brackets show Bonferroni-adjusted pairwise *P*values (Online Resource 1, Table S1). UES, upper esophageal sphincter; EC, esophageal cancer; *H*, Kruskal–Wallis statistic; *n*, number of patients; ns, not statistically significant ($P \geq 0.05$)

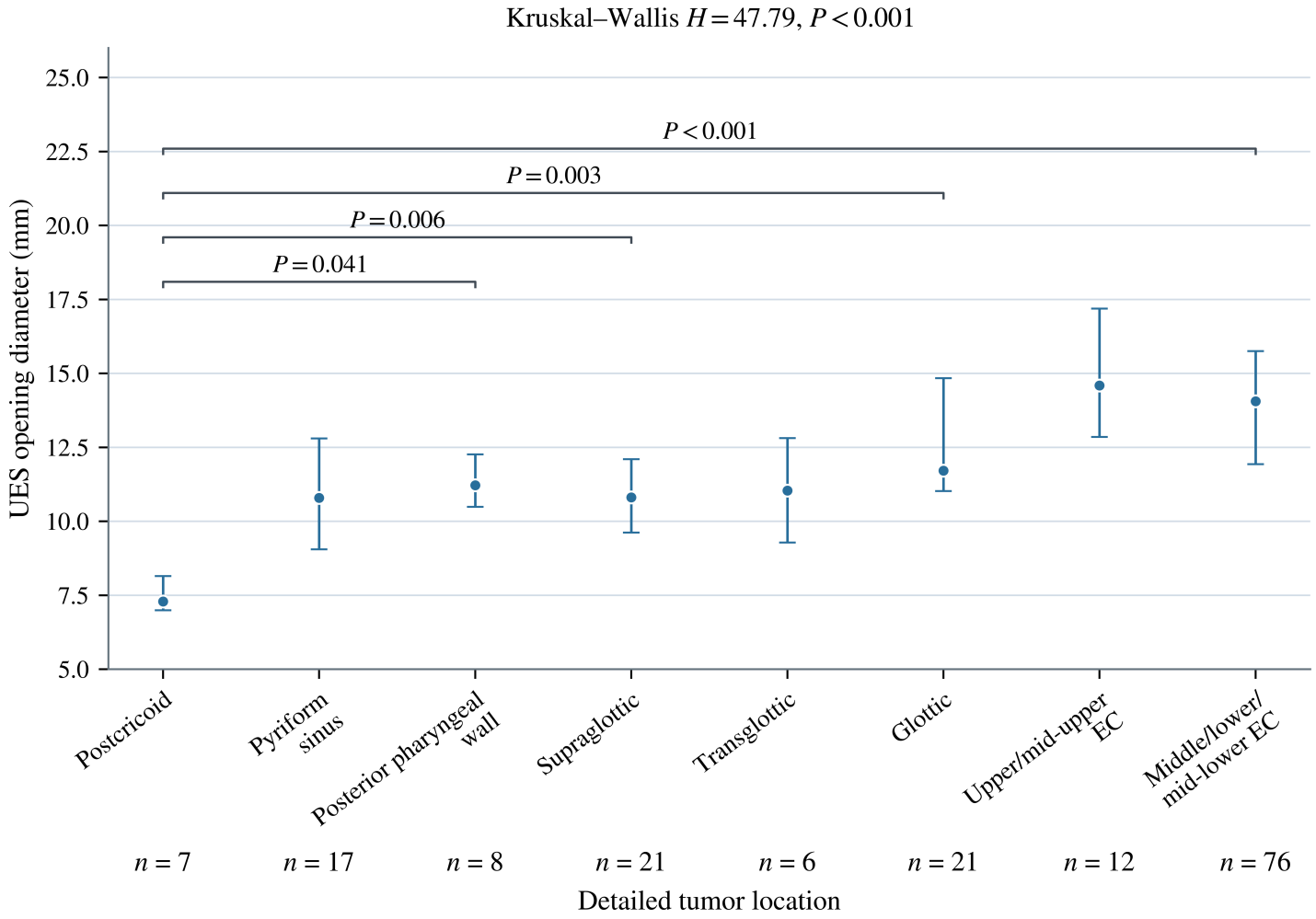


Figure 3

UES opening diameter by detailed tumor location (*n* = 168). Points show medians and error bars indicate interquartile ranges. Brackets show Bonferroni-adjusted *P*values for selected significant comparisons; all 28 pairwise comparisons are provided in Online Resource 1 (Table S2). UES, upper esophageal sphincter; EC, esophageal cancer; *H*, Kruskal–Wallis statistic; *n*, number of patients

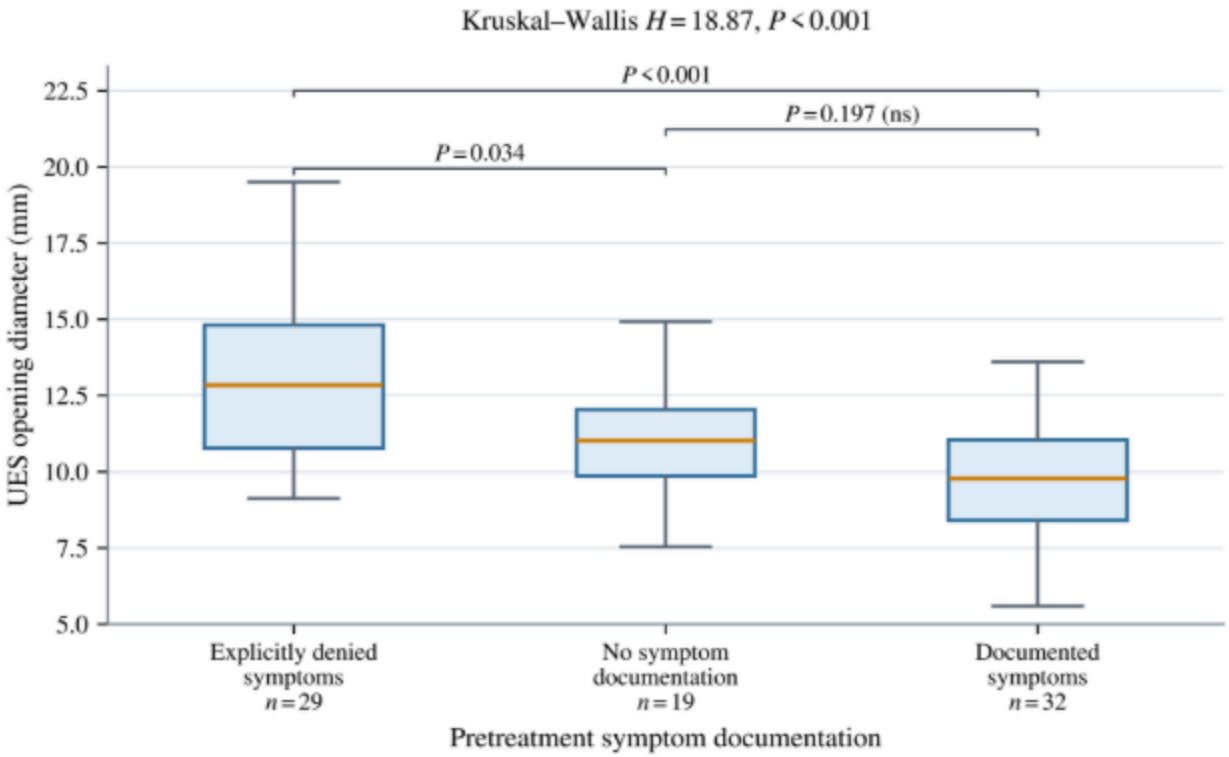


Figure 4

UES opening diameter by swallowing-related symptom documentation. The analysis included 80 patients with hypopharyngeal or laryngeal cancer. Boxes show interquartile ranges (IQRs), center lines indicate medians, and whiskers extend to the most extreme values within 1.5 × IQR of the box limits. Values beyond the whiskers are not shown but are included in analyses. Brackets show Bonferroni-adjusted pairwise *P* values (Online Resource 1, Table S3). UES, upper esophageal sphincter; *H*, Kruskal–Wallis statistic; *n*, number of patients; ns, not statistically significant ($P \geq 0.05$)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- ESM1.pdf
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