Supplementary sensitivity and exploratory analyses

Details of the primary symptom model are provided in Table S5. Clinical-factor, campus, and stage analyses in the hypopharyngeal and laryngeal cancer subgroup are exploratory and are reported in Tables S6–S11. UES opening distributions by primary tumor site, detailed location, and symptom documentation are presented in main Tables 2–4; complete pairwise comparisons are provided in Online Resource 1.

These analyses included the 80 patients with hypopharyngeal or laryngeal cancer. Analyses requiring BMI used complete cases; missing values were not imputed. Binary symptom analyses excluded patients with no symptom documentation, except for the alternative-definition analysis, which combined these patients with explicit denials. All tests were two-sided. *P* values were not adjusted across the exploratory clinical-factor analyses.

Symptom model details

Table S5 Analysis population and logit-linearity diagnostic for the primary symptom model

Measure	Result
Patients with complete covariate data, *n*	55
Documented symptom events, *n*	28
Joint Box–Tidwell test, *P*	0.409

The primary model compared documented symptoms with explicit denial and included UES opening diameter, cancer type, age, and BMI. The joint Box–Tidwell test assessed logit linearity for the continuous predictors. Estimates from the primary model, reduced models, and alternative symptom definition are reported in main Table 5. The alternative definition combined patients with no symptom documentation and those who explicitly denied symptoms. BMI, body mass index; UES, upper esophageal sphincter.

Clinical factors and adjusted tumor-site comparisons

Table S6 Correlations between UES opening diameter and clinical factors

Clinical factor	*n*	Spearman ρ	*P* value
Age, years	80	–0.070	0.534
BMI, kg/m^2	74	0.266	0.022
Albumin, g/L	80	0.170	0.132

Two-sided Spearman rank correlations. Each analysis used patients with available data for the corresponding factor.

Adjusted tumor-site and campus analyses

Among the 74 complete cases, patients with hypopharyngeal cancer had smaller diameters than those with laryngeal cancer in an unadjusted comparison ($Z = –2.61$, $P = 0.009$). Selected adjusted coefficients are presented in Table S7. Stage-adjusted models differed in both staging source and the number of complete cases.

Table S7 Selected linear regression coefficients for UES opening diameter

Predictor and model	*n*	*B*, mm	95% *CI*	*P* value
Cancer type: base model	74	−1.484	−2.723 to −0.245	0.020
Cancer type: stage-adjusted, pTNM	64	−1.407	−2.858 to 0.044	0.057
Cancer type: stage-adjusted, pTNM/cTNM	74	−1.379	−2.667 to −0.091	0.036
BMI: base model	74	0.147	–0.036 to 0.330	0.114

The base model included cancer type, age, BMI, and albumin. Stage-adjusted models additionally included stage group (early-stage vs locoregionally advanced disease). The pTNM/cTNM model combined surgical patients staged by pTNM with nonsurgical patients staged by cTNM. Cancer-type coefficients compare hypopharyngeal with laryngeal cancer. The BMI coefficient is per 1-kg/m^2 increase. Model-based *CIs* and *P* values are reported.

Campus comparisons

Table S8 UES opening diameter by campus

Campus	*n*	Median (IQR), mm
Campus A	23	11.02 (9.57–12.64)
Campus B	51	10.83 (9.31–12.92)
Campus C	6	10.83 (10.19–11.43)

Unadjusted comparison: $n = 80$; Kruskal–Wallis $H = 0.36$, $P = 0.833$. Adjusted for cancer type: $n = 80$; partial $F = 0.14$, $P = 0.867$. Adjusted for cancer type, age, BMI, and albumin: $n = 74$; partial $F = 0.04$, $P = 0.957$. Campuses are anonymized.

Stage analyses

Stage was assigned using the AJCC staging system, 8th edition. Early-stage disease was defined as T1–2*N*0M0, and locoregionally advanced disease as T3–4 and/or node-positive disease without distant metastasis. Primary stage analyses used postoperative pTNM in 70 surgically treated patients. Sensitivity analyses added the 10 nonsurgically treated patients staged by cTNM, forming a combined pTNM/cTNM sample of 80 patients. The cTNM subgroup included 2 early-stage and 8 locoregionally advanced cases.

Table S9 Stage groups and analysis populations

Staging source	All patients, *n*	Early stage, *n*	Locoregionally advanced, *n*	Explicit symptom documentation, *n*
Postoperative pTNM	70	28	42	52
Combined pTNM/cTNM	80	30	50	61

Explicit symptom documentation comprised documented symptoms or explicit denial. Patients without symptom documentation were excluded from symptom comparisons (18 in the pTNM analysis and 19 in the combined pTNM/cTNM analysis). UES diameter comparisons included all patients with the relevant staging source.

UES opening diameter

No statistically significant difference in diameter was detected between stage groups in either analysis population (Table S10).

Table S10 UES opening diameter by stage group

Staging source	*n* Early / advanced	Early stage Median (IQR), mm	Locoregionally advanced Median (IQR), mm	*Z*	*P* value
Postoperative pTNM	28/42	11.60 (9.60–13.37)	10.78 (9.26–12.78)	0.83	0.408
Combined pTNM/cTNM	30/50	11.60 (9.70–13.50)	10.78 (9.26–12.65)	1.26	0.207

Two-sided Mann–Whitney tests; standardized *Z* statistics are reported.

Swallowing-related symptom documentation

Among patients with explicit symptom documentation, symptoms were documented more frequently in locoregionally advanced than early-stage disease in both analysis populations (Table S11). In the combined pTNM/cTNM sample, the association between stage group and documented symptoms did not reach statistical significance after adjustment for cancer type ($P = 0.073$).

Table S11 Documented symptoms by stage and adjusted logistic estimates

Staging source	Early stage *n*/*N* (%)	Locoregionally advanced *n*/*N* (%)	Fisher's exact *P*	Adjusted *OR* (95% *CI*)	Logistic *P*
Postoperative pTNM	4/20 (20.0)	20/32 (62.5)	0.004	4.64 (1.03–20.84)	0.045
Combined pTNM/cTNM	6/22 (27.3)	26/39 (66.7)	0.004	3.30 (0.89–12.22)	0.073

Symptom frequencies are shown as documented symptoms / patients with explicit symptom documentation (%). Logistic models compared locoregionally advanced with early-stage disease and adjusted for cancer type. The pTNM model included 52 patients and 24 symptom events; the model for the combined pTNM/cTNM sample included 61 patients and 32 events.

UES measurements and symptom documentation preceded treatment, whereas pTNM was determined after surgery. These exploratory stage comparisons describe associations and do not establish preoperative predictive performance.

Abbreviations: AJCC, American Joint Committee on Cancer; BMI, body mass index; *CI*, confidence interval; cTNM, clinical TNM; IQR, interquartile range; *OR*, odds ratio; pTNM, pathologic TNM; UES, upper esophageal sphincter.