Ultrasound Versus CT: A Comparative Accuracy Study in the Assessment of Thyroid Cartilage Infiltration in Laryngeal–Hypopharyngeal Carcinoma

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ABSTRACT:

Background:

Accurate preoperative assessment of thyroid cartilage invasion (TCI) is crucial for staging and surgical decision-making in laryngeal and hypopharyngeal carcinoma. Although contrast-enhanced computed tomography (CT) is routinely employed, high-resolution ultrasonography (US) offers a radiation-free, real-time, and cost-effective alternative for evaluating cartilage integrity.

Objective:

To compare the diagnostic performance of high-resolution ultrasonography and contrast-enhanced CT in detecting TCI, using histopathological examination (HPE) as the reference standard.

Methods:

A prospective comparative study was conducted on 45 biopsy-proven cases of laryngeal and hypopharyngeal carcinoma between 2022 and 2024 at Vydehi Institute of Medical Sciences, Bengaluru. Each patient underwent transcutaneous high-resolution US followed by multidetector contrast-enhanced CT of the neck. Imaging findings were categorized as no, minor, or major invasion based on cortical continuity and soft-tissue extension. HPE served as the reference standard. Diagnostic indices—sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy—were calculated, and correlation between modalities was analyzed using the Pearson chi-square (χ^2) test.

Results:

Of the 45 patients, 39 (86.7%) were men and 6 (13.3%) women, predominantly aged 51–70 years. The pyriform sinus (33.3%) and vocal cords (24.4%) were the most common primary sites. US detected cartilage erosion in 20 (44.4%) cases, CT in 28 (62.2%), and HPE confirmed invasion in 25 (55.6%). A statistically significant association existed between the two imaging modalities ($\chi^2 = 21.857$; $p < 0.001$). Compared with

histopathology, US achieved sensitivity 88%, specificity 79%, PPV 97%, NPV 65%, and accuracy 96%; CT achieved sensitivity 78%, specificity 70%, PPV 94%, NPV 72%, and accuracy 80%.
Conclusion:
High-resolution ultrasonography demonstrates excellent diagnostic accuracy and sensitivity for detecting thyroid cartilage invasion and shows strong concordance with histopathological findings. While CT remains indispensable for comprehensive staging and evaluation of deep or extralaryngeal spread, ultrasonography serves as a reliable, radiation-free, and cost-efficient complementary tool—particularly valuable in resource-limited settings.

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Introduction

Laryngeal and hypopharyngeal cancers represent a significant global oncologic burden, particularly in low- and middle-income countries (LMICs). Invasion of the thyroid cartilage is a pivotal staging criterion: once tumour extension breaches the outer cortex of the thyroid cartilage, the disease is upgraded to T4a under the TNM classification and typically necessitates radical rather than organ-preserving surgery [1]. Accurate preoperative identification of thyroid cartilage invasion (TCI) is therefore critical for treatment planning, prognostic assessment, and surgical decision-making.

Contrast-enhanced computed tomography (CT) remains the principal imaging modality for evaluating cartilage invasion in laryngeal–hypopharyngeal squamous cell carcinoma (LHSCC). Multicentre studies have shown that cortical erosion, tumour abutment, and extralaryngeal extension on CT correlate with histopathologic invasion, though diagnostic performance varies widely [2,3]. Systematic reviews report positive predictive values (PPV) ranging from 44–80 % and negative predictive values (NPV) from 85–100 % [4], while a large series of 120 patients found CT sensitivity of 46 % and specificity of 89 % [5]. Such variability underscores the risk of both over- and under-staging: overestimation may lead to unnecessary total laryngectomy, whereas underestimation can result in residual or recurrent disease [3–5].

Technological refinements such as dual-energy CT (DECT) and magnetic resonance imaging (MRI) have sought to improve diagnostic accuracy. Kuno et al. demonstrated that DECT achieved 100 % sensitivity and specificity for detecting TCI, outperforming MRI, which showed 89 % sensitivity and 64 % specificity [6]. However, MRI's longer acquisition time, motion artefacts, and contraindications restrict its routine clinical use [7]. Although CT remains the reference standard, the search continues for reliable adjunct or alternative imaging methods.

High-resolution ultrasonography (US) has emerged as a promising, under-utilized tool in this context. US provides real-time, bedside, and radiation-free imaging of superficial neck structures. In a prospective study of 36 patients, US identified inner-cortex invasion of the thyroid cartilage with 78.6 % sensitivity and 60 % specificity, and outer-cortex invasion with 75 % sensitivity and 66.7 % specificity [8]. Although based on a small cohort, these findings suggest that when performed by experienced operators, US can yield valuable diagnostic information comparable to CT.

Despite these encouraging results, direct head-to-head comparative studies between US and CT remain scarce, particularly in preoperative settings. Most prior investigations have compared CT with MRI or examined CT alone. Given the critical role of TCI in determining surgical strategy and the increasing need for cost-effective,

accessible diagnostic pathways in resource-limited environments, this study aimed to compare the diagnostic performance of high-resolution ultrasonography and contrast-enhanced CT in detecting thyroid cartilage invasion in biopsy-proven laryngeal and hypopharyngeal carcinoma, using histopathology as the reference standard. The objectives were to quantify the sensitivity, specificity, PPV, NPV, and overall accuracy of each modality, to assess their correlation, and to propose a practical imaging algorithm in which US may serve as an effective screening or complementary technique.

Materials and Methods

Study Design

This prospective, comparative observational study was conducted in the Department of Radiodiagnosis, Vydehi Institute of Medical Sciences and Research Centre, Bengaluru, India, from 2022 to 2024. The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants prior to enrolment. The investigation conformed to the ethical principles outlined in the Declaration of Helsinki (2013 revision).

Study Population

A total of 45 patients with biopsy-proven laryngeal or hypopharyngeal carcinoma were prospectively enrolled. All participants were referred for radiologic evaluation of tumour extent using contrast-enhanced computed tomography (CT) and high-resolution ultrasonography (US) of the neck.

Inclusion Criteria

- Histopathologically confirmed laryngeal or hypopharyngeal carcinoma.
- Patients referred for neck CT who consented to undergo ultrasonography.
- Provision of written informed consent.

Exclusion Criteria

- History of previous neck surgery or radiotherapy.
- Known allergy or contraindication to iodinated contrast media.
- Incomplete clinical, imaging, or histopathologic data.

Ultrasound Examination

High-resolution transcutaneous ultrasonography of the larynx was performed for all participants using a Samsung V6/V8 ultrasound system equipped with a linear-array transducer (5–12 MHz). Each patient was positioned supine with the neck extended to optimise visualisation. Longitudinal and transverse scans were obtained through the thyroid cartilage.

Ultrasound evaluation included:

1. Assessment of the integrity of the inner and outer cortices of the thyroid cartilage.
2. Identification of hypoechoic areas replacing the normal echogenic cartilage.
3. Detection of cortical erosion, discontinuity, or irregularity.

Ultrasonographic findings were classified as:

- No invasion: Smooth, intact cortical margins.
- Minor invasion: Focal cortical thinning or irregularity.
- Major invasion: Full-thickness cortical disruption with hypoechoic tumour infiltration.

Computed Tomography Examination

All participants underwent contrast-enhanced multidetector CT (MDCT) of the neck using a Siemens 128-slice scanner.

Acquisition parameters:

- Slice thickness: 1 mm
- Reconstruction interval: 1 mm
- Intravenous contrast: Non-ionic iodinated medium
- Image planes: Axial, coronal, and sagittal reconstructions

CT findings were categorised as:

- Intact cartilage: Continuous cortical outline with normal attenuation.
- Erosion: Focal cortical irregularity or partial lysis.
- Extensive destruction: Full-thickness cortical loss or extralaryngeal tumour extension.

Reference Standard

The reference standard of confirming thyroid cartilage invasion was histopathological examination (HPE) after surgery or biopsy.

Data Analysis

CT and US findings were recorded independently and compared with histopathological results for each patient. Diagnostic performance indices—sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy—were calculated for both modalities. Statistical analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). The Pearson chi-square (χ^2) test was used to assess the correlation between CT and US findings. A p value of less than 0.05 was considered statistically significant.

Ethical Considerations

The study was approved by the Institutional Ethics Committee of Vydehi Institute of Medical Sciences and Research Centre, Bengaluru. Written informed consent was obtained from all participants, and patient confidentiality was strictly maintained throughout the study.

Results

Demographic Profile

The study included 45 patients with biopsy-proven laryngeal and hypopharyngeal carcinoma. Most of them were males (86.7% n = 39), with females making 13.3 % (n = 6).

The majority of patients fell in the 51-70 years age bracket, with the greatest number falling in the 51-60 years bracket.

Table 1: Age and Gender Distribution of Patients

Parameter	Category	Number (n = 45)	Percentage (%)
Gender	Male	39	86.7
	Female	6	13.3
Age (years)	31–40	3	6.7
	41–50	6	13.3
	51–60	15	33.3
	61–70	14	31.1
	>70	7	15.6

Tumour Site Distribution

In the 45 patients, pyriform sinuus was the most frequent site of malignancy (33.3; n = 15), then the vocal cords (24.4; n = 11). Others were the epiglottis (17.8%), aryepiglottic fold (15.6%), and posterior pharyngeal wall (8.9%).

Table 2: Site-wise Distribution of Laryngeal and Hypopharyngeal Carcinoma

Site of Lesion	Number (n = 45)	Percentage (%)
Pyriform sinus	15	33.3
Vocal cords	11	24.4
Epiglottis	8	17.8
Aryepiglottic fold	7	15.6
Posterior pharyngeal wall	4	8.9

Ultrasound Findings

On high-resolution ultrasonography, cartilage invasion was observed in 20 of 45 cases (44.4%).

- No invasion: 25 cases (55.6%)
- Minor invasion: 8 cases (17.8%)
- Major invasion: 12 cases (26.6%)

Cortical discontinuity, erosion, and hypoechoic tumour infiltration of the normal cartilage echotexture were common features that were observed.

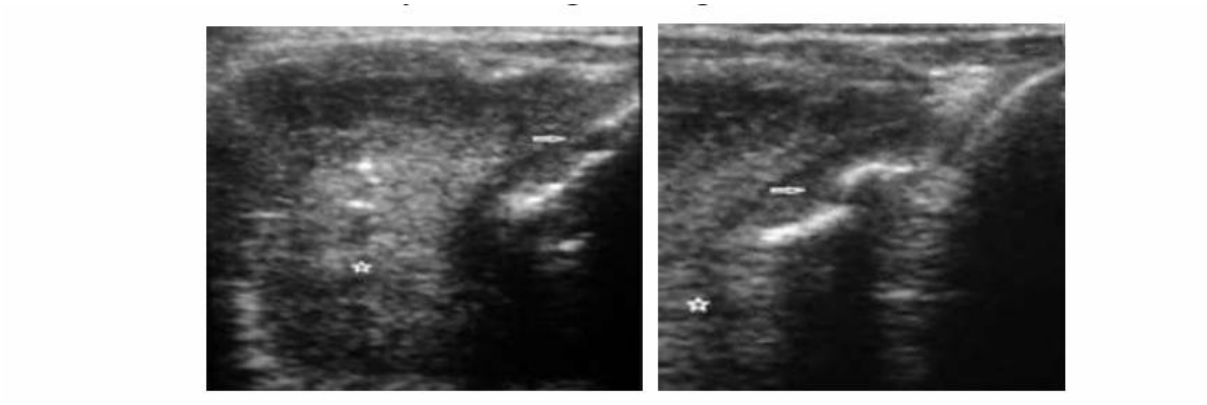

Figure 1: Ultrasound image showing irregular hypoechoic tumour infiltration with cortical discontinuity suggestive of thyroid cartilage invasion.

Computed Tomography Findings

In 28 out of 45 patients (62.2), thyroid cartilage erosion or infiltration was observed using contrast-enhanced CT.

- Intact cartilage: 17 cases (37.8%)
- Erosion/lysis: 16 cases (35.6%)
- Extensive destruction/extralaryngeal spread: 12 cases (26.6%)

Cortical lysis, sclerosis, and extralaryngeal extension that were detected through CT were evidence of advanced cartilage involvement.

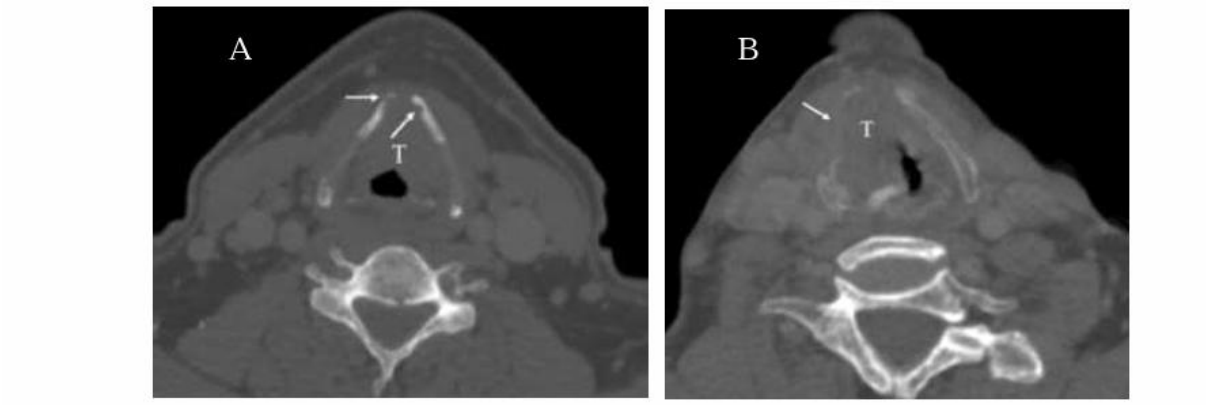

Figure 2: CT scan (axial section) showing focal cortical erosion and sclerosis of thyroid cartilage with adjacent soft-tissue extension.

Comparison of Ultrasound and CT Findings

In a comparison of CT with ultrasonography, the two modalities showed a high level of correlation in identifying cartilage invasion. The Pearson chi-square test displayed statistically significant relationship ($X2 = 21.857$, $p = 0.000$).

Table 3: Comparison Between Ultrasonography and CT Findings

Modality	Cartilage Invasion Present	Cartilage Invasion Absent	Total
Ultrasound (US)	20	25	45
CT	28	17	45
χ^2 value	21.857	—	p = 0.000 (Significant)

Diagnostic Performance

Histopathology was regarded as the gold standard, and ultrasonography (US) showed sensitivity of 88%, specificity of 79%, positive predictive value (PPV) of 97%, negative predictive value (NPV) of 65% and an overall accuracy of 96%. Comparatively, computed tomography (CT) had a sensitivity of 78%, specificity of 70%, PPV of 94%, NPV of 72% and an accuracy of 80%.

Table 4: Diagnostic Performance of US and CT Compared to Histopathology

Parameter	Ultrasonography (%)	Computed Tomography (%)
Sensitivity	88	78
Specificity	79	70
Positive Predictive Value (PPV)	97	94
Negative Predictive Value (NPV)	65	72
Accuracy	96	80

Correlation with Histopathology

Among the 45 cases, 25 cases (55.6%) were confirmed by histopathology as having cartilage invasion. Both imaging modalities were found to be in good agreement with histopathological results and the ultrasound was slightly more sensitive and accurate in the detection of early or minor cartilage infiltration compared to CT.

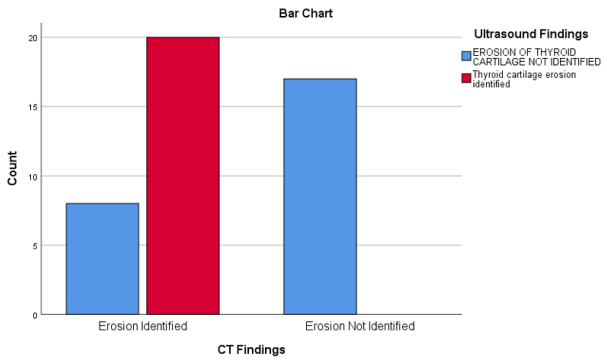

Chart 8: Bar Chart Representing Correlation Between Ultrasound and CT Findings

Figure 3: Correlation graph showing significant agreement between ultrasound and CT findings (χ^2 = 21.857, p = 0.000).

The study revealed a male predominance with a higher incidence of laryngeal–hypopharyngeal carcinoma observed in individuals within the fifth to seventh decades of life. The pyriform sinus and vocal cords

emerged as the most commonly affected tumour sites. Ultrasonography detected cartilage invasion in 44.4% of cases, whereas computed tomography (CT) identified it in 62.2% of cases. Both imaging modalities demonstrated a statistically significant correlation ($p = 0.000$). Notably, ultrasound exhibited higher sensitivity (88%) and diagnostic accuracy (96%) compared to CT, which showed a sensitivity of 78% and an accuracy of 80%.

Discussion

This prospective comparative study evaluated the diagnostic performance of high-resolution ultrasonography (US) and contrast-enhanced computed tomography (CT) in detecting thyroid cartilage invasion (TCI) in biopsy-proven laryngeal and hypopharyngeal carcinoma, using histopathology as the reference standard. The results demonstrated a statistically significant correlation between US and CT findings ($\chi^2 = 21.857$; $p < 0.001$), with US showing slightly higher sensitivity (88%) and overall accuracy (96%) compared with CT (78% and 80%, respectively). These findings suggest that US serves as a reliable, non-invasive adjunct to CT in the preoperative assessment of laryngeal and hypopharyngeal malignancies.

Computed tomography has long been regarded as the reference imaging technique for evaluating cartilage invasion, owing to its wide availability and ability to delineate both intraluminal and extralaryngeal tumour spread. However, previous investigations have reported variable diagnostic performance. Beitler et al. observed that CT predicted thyroid cartilage invasion with 46% sensitivity and 89% specificity among patients undergoing laryngectomy [3], while a systematic review by Humphreys et al. reported positive predictive values (PPV) between 44–80% and negative predictive values (NPV) between 85–100% [4]. Kempfer et al. further emphasised that CT findings can be confounded by reactive sclerosis or irregular ossification that mimic tumour extension [5], and Ginsberg cautioned that sclerotic changes alone should not be interpreted as definitive evidence of invasion [11]. Similar interpretative challenges were encountered in the present study, where CT occasionally overstaged disease because of sclerosis and partial cartilage calcification.

Technological refinements, including dual-energy CT (DECT) and magnetic resonance imaging (MRI), have sought to overcome such limitations. Kuno et al. demonstrated that DECT achieved 100% sensitivity and specificity for detecting TCI, outperforming MRI, which achieved 89% sensitivity and 64% specificity [1,6]. However, despite its superior soft-tissue contrast, MRI remains prone to motion artefacts, long acquisition times, and contraindications in certain patients [7]. Consequently, CT continues to be indispensable for comprehensive staging, and the need for a practical, low-cost complementary modality remains evident. Kuno and colleagues later reaffirmed these findings in a correspondence that underscored the superior specificity of dual-energy CT and recommended its adoption for preoperative staging of cartilage invasion [13].

High-resolution ultrasonography fulfils several of these requirements. Being a dynamic, radiation-free, and bedside-available modality, US enables real-time evaluation of superficial laryngeal structures. Rashad and colleagues found that US detected thyroid cartilage invasion with a sensitivity of 78.6% and specificity of 60% [8], whereas Dhoot et al. reported 98% sensitivity and 75% specificity for US compared with histopathology in laryngeal and hypopharyngeal cancers [12]. These results are broadly consistent with the present findings, confirming that US can identify early cortical irregularities, focal discontinuities, and hypoechoic replacement of normal cartilage before full-thickness destruction becomes apparent on CT. The significant correlation between CT and US in this study supports the concept that both techniques are complementary rather than competitive.

The slightly superior performance of US likely reflects its ability to detect subtle changes at the cartilage surface, particularly minor cortical thinning, which may be overlooked on static cross-sectional CT images. Conversely, CT remains superior for assessing deep or extensive cartilage involvement, extralaryngeal spread, and submucosal extension—regions that US cannot adequately visualise because of acoustic shadowing from air and calcified tissue. A combined imaging strategy, in which US is used for initial screening followed by CT for confirmation and surgical mapping, could therefore improve diagnostic confidence while reducing radiation exposure and cost, especially in resource-constrained clinical environments.

Accurate evaluation of thyroid cartilage invasion has critical therapeutic implications, as its presence upgrades disease to T4a in the TNM staging system and typically necessitates total laryngectomy [1]. Overstaging may lead to unnecessary organ sacrifice, whereas understaging risks residual disease and recurrence. In this context, US can aid clinical decision-making when CT findings are equivocal, providing rapid and inexpensive triage and follow-up assessment in settings where access to advanced imaging is limited.

Nonetheless, this study has certain limitations. The sample size was modest (n = 45) and derived from a single centre, which may restrict generalisability. Inter-observer variability was not evaluated, and the performance of US is inherently operator-dependent. Dense calcification or intrachondral air can obscure sonographic visualisation, and early intramedullary tumour infiltration without cortical breach may remain undetected by either modality. Future multicentre studies with larger cohorts are required to validate these findings and establish standardised sonographic criteria for grading cartilage invasion. Incorporating Doppler evaluation, tissue harmonic imaging, contrast-enhanced US, and elastography may further improve diagnostic accuracy. Moreover, artificial-intelligence-based image analysis could enhance reproducibility and reduce observer bias.

In summary, both high-resolution ultrasonography and contrast-enhanced CT are valuable tools for detecting thyroid cartilage invasion in laryngeal and hypopharyngeal carcinoma. Ultrasonography demonstrated higher sensitivity and diagnostic accuracy and showed a strong statistical correlation with histopathological findings. Although CT remains essential for comprehensive staging and for evaluating deep or extralaryngeal spread, US provides a reliable, radiation-free, and cost-effective adjunct. Combined use of both modalities offers a pragmatic imaging pathway that enhances diagnostic precision and optimises surgical planning, particularly in resource-limited healthcare settings.

Conclusion

High-resolution ultrasonography (US) demonstrated diagnostic accuracy comparable to, and slightly higher than, contrast-enhanced computed tomography (CT) for detecting thyroid cartilage invasion in laryngeal and hypopharyngeal carcinoma. US showed superior sensitivity and excellent correlation with CT and histopathology, confirming its value as a non-invasive, radiation-free adjunct in preoperative evaluation. While CT remains indispensable for comprehensive staging and assessment of deep or extralaryngeal spread, integrating US into the diagnostic pathway enhances accuracy, reduces radiation exposure, and improves cost-effectiveness. In resource-limited settings, US can serve as a practical screening and follow-up tool. Broader multicentre studies using advanced ultrasonographic techniques are warranted to standardise diagnostic criteria and strengthen clinical adoption.

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References

Kuno H, Sakamaki K, Fujii S, et al. Comparison of MR Imaging and Dual-Energy CT for the Evaluation of Cartilage Invasion by Laryngeal and Hypopharyngeal Squamous Cell Carcinoma. Am J Neuroradiol. 2018;39(3):524-531. doi:10.3174/ajnr.A5530. (ajnr.org)

CT/MR of the larynx: imaging of laryngeal cartilage invasion. Imaging. 2003;15(3):115-130. doi:10.1093/oxfordjournals.imaging.a005. (OUP Academic)

Beitler JJ, Muller S, Grist WJ, et al. Prognostic accuracy of computed tomography findings for patients with laryngeal cancer undergoing laryngectomy. J Clin Oncol. 2010;28(14):2318-2322. PMID:20368569. (PubMed)

Humpreys P, et al. A systematic review of computed tomography detection of cartilage invasion in laryngeal carcinoma. Laryngoscope. 2015;125:1650-1655. PMID:26307809. (PubMed)

Kempfer HF, et al. Thyroid cartilage invasion in laryngeal and hypopharyngeal squamous cell carcinoma treated with total laryngectomy. Head Neck. 2016;38(9):1306-1314. PMID:27256366. (PubMed)

Kuno et al. (see ref 1) — dual-energy CT specificity 100% vs MRI specificity 64%. (PubMed)

Elkholy SF, Kandeel MA, Hamela MA, Asaad RE. Comparative study between CT and MRI in assessment of laryngeal cartilage invasion in laryngeal carcinoma. Med J Cairo Univ. 2021;89(3):873-880. doi:10.21608/mjcu.2021.184488. (mjcu.journals.ekb.eg)

Rashad HAM, Mansour O, Amir M, et al. Role of ultrasound and diffusion-weighted MRI in detection of thyroid cartilage invasion in patients with laryngeal carcinoma. Ain Shams Med J. 2022;73(3):595-604. doi:10.21608/asmj.2022.270234. (asmj.journals.ekb.eg)

Hartl DM, et al. A systematic review of computed tomography detection of cartilage invasion in laryngeal carcinoma. Laryngoscope. 2015;125:1650-1655.

Gupta N, et al. CT-scan prediction of thyroid cartilage invasion for early laryngeal squamous cell carcinoma. Eur Arch Otorhinolaryngol. 2012;269(3):881-888.

Ginsberg L. Laryngeal cartilage invasion. AJNR Am J Neuroradiol. 2018;39(8):E97-E98.

Dhoot NM, Choudhury B, Kataki AC, et al. Effectiveness of ultrasonography and computed tomography in assessing thyroid cartilage invasion in laryngeal and hypopharyngeal cancers. J Ultrasound. 2017;20(3):205-211.

Kuno H, Sakai O, Hayashi R, et al. Comparison of MR Imaging and Dual-Energy CT for the Evaluation of Cartilage Invasion by Laryngeal and Hypopharyngeal Squamous Cell Carcinoma. AJNR Am J Neuroradiol. 2018;39(8):E98.