CT of the Larynx: Is an Additional High-Resolution Acquisition Necessary for Diagnostic Accuracy?

Eva Chau, Katie S. Traylor and Barton F. Branstetter

AJNR Am J Neuroradiol published online 22 November 2023
http://www.ajnr.org/content/early/2023/11/22/ajnr.A8048

Published November 22, 2023 as 10.3174/ajnr.A8048

CT of the Larynx: Is an Additional High-Resolution Acquisition Necessary for Diagnostic Accuracy?

Eva Chau, Katie S. Traylor, and Barton F. Branstetter

ABSTRACT

BACKGROUND AND PURPOSE: Diagnostic CT of the larynx is historically performed with a protocol that combines a standard neck CT with dedicated imaging through the larynx. Multichannel CT scanners, however, allow high-resolution reformatted images of the larynx to be created directly from the initial neck acquisition data. The purpose of this study was to determine whether reformatted laryngeal images derived from a standard neck CT acquisition provide information comparable with that of separate dedicated high-resolution laryngeal images.

MATERIALS AND METHODS: The CT protocol for suspected laryngeal masses at our institution consists of a standard neck acquisition followed by a second acquisition focused on the larynx. We enrolled 200 patients who had undergone this protocol for a suspected laryngeal mass. Two head and neck radiologists independently reviewed each of the 200 scans twice. In one session, the entire scan was available, while in the other session, only images derived from the standard neck acquisition were available. The main outcome variable was the frequency of discrepant tumor staging between the interpretation sessions. No pathologic reference standard was used.

RESULTS: Radiologist A had discrepant staging in 45 of the 200 scans (23%; 95% CI, 17%–29%). Radiologist B had discrepant staging in 42 of the 200 scans (21%; 95% CI, 16%–27%). Fifty-three of the 87 discrepancies (61%) reflected improper downstaging of the laryngeal tumor on standard images alone, while the other 34 (39%) had improper upstaging on standard images alone.

CONCLUSIONS: Reformatted images from our institution's standard neck CT acquisition were less accurate than dedicated images of the larynx for analysis of laryngeal tumor extension. Focused images of the larynx were needed to optimize interpretation.

ABBREVIATION: AJCC = American Joint Committee on Cancer

Diagnostic CT of the larynx is historically performed using a protocol that combines a standard neck CT with additional, dedicated imaging through the larynx. Multidetector CT scanners, however, allow high-resolution multiplanar reformatted images of the larynx to be created directly from the initial neck acquisition. If the additional dedicated larynx acquisition is unnecessary, there are potential benefits to the patient (reduced radiation and reduced time in the scanner), the radiologist (fewer images resulting in reduced interpretation time), and the institution (improved scanner throughput and decreased contrast costs).

While there is literature comparing the use of CT versus MR imaging,[1-4] as well as the diagnostic accuracy of CT overall[2,5-7] in the staging of laryngeal carcinoma, there is limited literature regarding the use of dedicated imaging through the larynx in conjunction with a standard neck CT. One preliminary study in 2010 found no substantial difference in the comparison of standard neck CT with dedicated breath-maneuver laryngeal CT in 27 patients.[8] With the improvements in CT technology in the past decade, however, it is possible that standard high-resolution images are more useful now than before. Therefore, the purpose of this study was to determine whether reformatted laryngeal images derived from a standard neck CT acquisition can replace a separate dedicated high-resolution laryngeal acquisition.

MATERIALS AND METHODS

Patient Selection

Our institutional review board approved this retrospective study. Patients who had undergone neck CT using the larynx protocol for the evaluation of a suspected laryngeal mass were eligible. A power analysis was performed using a clinically significant threshold for a difference in the discrepancy rate of 5% and an α threshold of .05. This finding indicated that 200 patients were

Received July 26, 2023; accepted after revision October 3.

From the University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania.

Please address correspondence to Barton F. Branstetter, MD, University of Pittsburgh Medical Center, 200 Lothrop St, Pittsburgh, PA 15213; e-mail: BFB1@pitt.edu; @CharBranstetter

http://dx.doi.org/10.3174/ajnr.A8048

needed for the study, so consecutive patients were enrolled from 2017 to 2021. Inclusion was based on the clinical suspicion of a laryngeal mass, not the final diagnosis of a laryngeal mass, so some of the patients had CT examinations with negative findings. Patients were excluded if the 2 reviewers in consensus determined that motion artifacts rendered their scan nondiagnostic or if the larynx protocol was not performed correctly.

Image Acquisition

All imaging was performed on a LightSpeed 64-channel scanner (GE Healthcare). The neck acquisition was performed using Isovue 370 (Bracco), 75-mL IV, with an 80-second delay. Helical acquisition was performed with 120-kV(peak); milliampere automated; FOV = 25 cm; pitch = 0.97; matrix = 512 × 512. Axial reconstructions were performed as stacked 2.5-mm-thick slices. Coronal and sagittal reformats were performed as stacked 1-mm-thick slices.

The larynx acquisition was performed using an addition bolus of Isovue 370, 75 mL, again with an 80-second delay. The helical acquisition was performed with 120 kV(p); milliampere automated; FOV = 10 cm; pitch = 0.53; matrix = 512 × 512. Axial reconstructions were performed as stacked 1-mm-thick slices. Coronal and sagittal reformats were performed as stacked 1-mm-thick slices.

Patients were instructed to maintain shallow breathing and not swallow during the image acquisition.

Image Interpretation

Two Certificate of Added Qualification–certified neuroradiologists with head and neck imaging fellowship training with 20 and 3 years of post-training experience (radiologist A and radiologist B, respectively), working independently, retrospectively reviewed each of the 200 scans twice, in 2 separate sessions. In one session, the entire scan was available to the radiologist, while in the other session, only images derived from the standard neck acquisition were available. Half of the time, the full laryngeal protocol was presented in the first session, and half of the time, the limited scan was presented first. During the second session, the radiologists were blinded to their interpretations from their first session. The interpretation sessions were separated by at least 3 months to avoid recall bias, and the scans were presented in random order in each session. During both review sessions, the radiologists were blinded to all clinical data, including the results of endoscopy and the physical examination.

Involvement of laryngeal subsites was tabulated and used to calculate a radiologic stage based on the American Joint Committee on Cancer (AJCC) 8th edition schema.[9] The subsites that were evaluated included the epiglottis, epiglottic petiole, aryepiglottic fold, false vocal cords, true vocal cords, anterior commissure, paraglottic fat, pre-epiglottic fat, postcricoid hypopharynx, inner table of the thyroid cartilage, outer table of the thyroid cartilage, cricoid cartilage, and arytenoid cartilage. Some patients had no radiologic evidence of tumor because the selection criterion was based on clinical suspicion of a laryngeal mass. The main outcome variable was the frequency of discrepant staging between the interpretation of the complete scan and the interpretation of the single-acquisition scan for each radiologist. For a concordant interpretation, not every subsite had to be identically interpreted as long as the differences did not affect the overall staging. The staging was radiologic only. Clinical data such as vocal cord mobility were not incorporated into the staging.

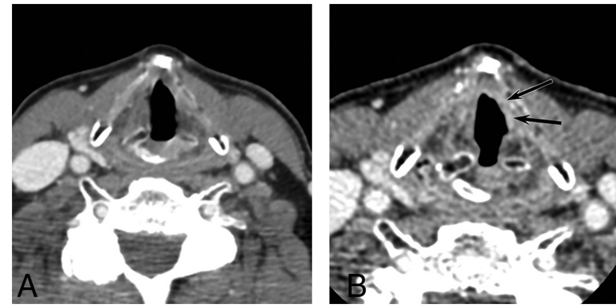

FIG 1. Axial CT images of a 65-year-old man with squamous cell carcinoma of the left true vocal cord. Standard 2.5-mm neck image (*A*) was interpreted as having normal findings. On a dedicated 1-mm larynx protocol image (*B*), the ulcerated enhancing tumor along the true vocal cord (*arrows*) was evident.

χ^2 analysis was used to identify differences in discordance rates between the 2 radiologists and in their propensity to upstage or downstage tumor with the addition of the dedicated larynx acquisition. A Cohen κ statistic with linear rating for ordinal categoric variables was used to evaluate the interreader variability between radiologists in the interpretation of the full laryngeal protocol. No pathologic reference standard was used because this study was designed to evaluate the consistency of radiologic interpretations.

RESULTS

Two hundred patients were included in the study. One hundred thirty-eight (69%) were men, and sixty-two (31%) were women. The average patient age was 65 years, with a range of 20–100 years. One hundred thirty-five of the 200 patients (68%) were eventually diagnosed with squamous cell carcinoma of the larynx.

Radiologist A had discrepant staging in 45 of the 200 scans (23%; 95% CI, 17%–29%). Radiologist B had discrepant staging in 42 of the 200 scans (21%; 95% CI, 16%–27%). For radiologist A, 27 of the 45 discordant scans (60%) were upstaged by the additional dedicated imaging through the larynx. The remaining 18 of the 45 discordant scans (40%) were downstaged by the additional images. Similarly, for radiologist B, 28 of the 42 discordant scans (67%) were upstaged by the additional dedicated imaging through the larynx. The remaining 14 of the 42 discordant scans (33%) were downstaged by the additional images.

Overall, 53 of the 87 discrepancies (61%) resulted in upstaging of the tumor with the dedicated acquisition, while the other 34 (39%) reflected downstaging of the tumor. Most of the discordant interpretations involved distinguishing between true and false cord involvement, accounting for 33 of the total 87 discordances, approximately 38% (Fig 1). Determining thyroid cartilage invasion accounted for 31 of the total 87 discordant reads, approximately 36% (Fig 2).

Motion artifacts on one of the acquisitions contributed to some of the discrepant interpretations. Motion artifacts degraded the quality of standard neck images in 20 of the 200 patients

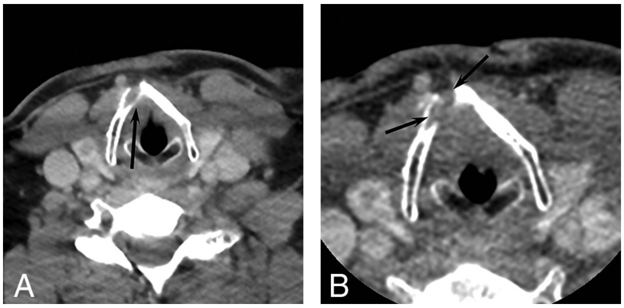

FIG 2. Axial images of a 58-year-old man with squamous cell carcinoma of the right true vocal cord. The thyroid cartilage was interpreted as intact on standard 2.5-mm neck imaging (*A*) because of a visible inner table (*arrow*). On a 1-mm larynx protocol image (*B*), tumor extension into the thyroid cartilage was identified (*arrows*).

(10%) and in 8 of the dedicated laryngeal sequences (4%). The 95% CI for the difference of proportions is 0.01–0.11, indicating statistical significance.

Abducted vocal cords (closed glottis) on one of the acquisitions also contributed to some of the discrepant interpretations. Abducted cords degraded the quality of standard neck images in 20 of the 200 patients (10%) and in 17 of the dedicated laryngeal sequences (9%). This difference was not statistically significant.

χ^2 analysis revealed no difference between observers in the overall concordance rate ($P = .72$) or in the propensity to upstage versus downstage ($P = .52$). The Cohen κ statistic for interrater variability was 0.67, which is considered "good" agreement between raters.

DISCUSSION

Reformatted images based on standard neck CT are often presumed to convey adequate diagnostic information for staging of laryngeal squamous cell carcinoma. In comparing interpretations made from standard neck CTs with those that included a dedicated laryngeal acquisition, however, this study found a discrepancy in nearly one-quarter of the interpretations. This discrepancy rate was consistent between head and neck radiologists with varying experience levels.

Staging errors made with our standard neck CT protocol alone were a mix of false-positive and false-negative findings. A slight majority of the errors were downstaging errors, but about one-third of cases were erroneously upstaged when only the conventional sequences were used. The errors were made in predictable locations, such as determining thyroid cartilage invasion or tumor spread across the laryngeal ventricle, but these determinations are critical in defining the optimal therapeutic approach. The AJCC staging guidelines outline how the radiologic extent of tumor spread may impact tumor staging and, therefore, treatment choice.[9] For example, T3 lesions have extension into the pre-epiglottic space or the inner cortex of the thyroid cartilage. These patients can opt for organ-preservation surgery without compromising overall survival. For selected patients with extensive T3 or large T4a lesions that erode the outer cortex of the thyroid cartilage, however, better survival rates and quality of life are achieved with total laryngectomy.[10] Thus, accurate T categorization may directly impact therapeutic decision-making and prognosis.

Our results differ from those of the preliminary study by Gilbert et al,[8] which found no significant difference in accuracy between the interpretations of the standard neck CT and the additional laryngeal CT in 27 patients. Their study appears to be the only study comparing similar imaging protocols, to our knowledge, and it may be underpowered to detect substantial differences between protocols.

When evaluating the overall literature regarding the propensity for CT imaging to upstage-versus-downstage tumors, our results are consistent with the audit by Agada et al[11] comparing the accuracy of CT staging of advanced laryngeal tumor evaluated against the pathologic examination. Of their audit of 38 patients with laryngeal carcinoma, 11 had discordant staging, with 9 patients erroneously upstaged by CT imaging, while 2 were erroneously downstaged.[11] In this study, only thick axial slices, 5 mm through the neck and 3 mm through the larynx, were used. Similarly, Contrera et al[12] reported that clinical staging, using a combination of clinical examination, endoscopy, and imaging, can downstage or upstage a patient with laryngeal cancer nearly one-third of the time after pathologic confirmation in their cohort of 265 patients.

Concerns regarding additional radiation and contrast use with a dedicated larynx protocol require that we determine whether these images are necessary. As the American College of Radiology 2007 white paper on radiation dose in medicine recommends, the additional cases of cancer resulting directly from the radiation exposure from CT scans can likely be minimized by optimizing studies that are performed to obtain the best image quality with the lowest radiation dose.[13] Furthermore, given the adverse effects of contrast media[14] and the ongoing iodinated contrast media shortage,[15] minimizing individual doses to reduce waste continues to be important. Nevertheless, dedicated images through the larynx may still be of benefit in the imaging for suspected laryngeal carcinoma.

Using a smaller FOV for dedicated laryngeal images has both potential benefits and potential drawbacks. A larger FOV gives us better contrast resolution by decreasing noise. As the FOV decreases, the pixel size decreases, resulting in a higher spatial resolution but an increase in noise.[16] Given the small size of the larynx, this higher spatial resolution allows radiologists to better appreciate smaller structures that are located in close proximity to each other. While it is not immediately obvious which FOV is preferable, our results suggest that the increased spatial resolution is advantageous. Additionally, we found that 1 acquisition often contained a great deal of motion artifacts. The additional set of images provided by the dedicated larynx acquisition allowed better diagnostic interpretation in these situations despite the increase in noise.

Our study has several limitations. Our larynx protocol includes a second bolus of contrast for the high-resolution acquisition. It is unclear whether the benefits of the larynx protocol derive exclusively from the higher spatial resolution and thinner slices or whether having 2 contrast boluses given at different times played a role. We did not use dual-energy or perfusion techniques in our protocol; such advanced imaging might further improve diagnostic accuracy. Furthermore, we did not incorporate clinical data into staging. Given that not all patients undergo laryngectomies to allow pathologic staging confirmation, this study also did not confirm which of the discrepant interpretations were ultimately concordant with pathologic staging. Future studies involving biopsy-confirmed subsite involvement and staging of laryngeal carcinoma will likely shed more light on these issues.

CONCLUSIONS

Radiologic staging of laryngeal tumors may be improved with the addition of focused images of the larynx produced with a second contrast bolus and a second acquisition sequence.

Disclosure forms provided by the authors are available with the full text and PDF of this article at www.ajnr.org.

REFERENCES

1. Cho SJ, Lee JH, Suh CH, et al. **Comparison of diagnostic performance between CT and MRI for detection of cartilage invasion for primary tumor staging in patients with laryngo-hypopharyngeal cancer: a systematic review and meta-analysis.** *Eur Radiol* 2020;30:3803–12 CrossRef Medline
2. Han MW, Kim SA, Cho KJ, et al. **Diagnostic accuracy of computed tomography findings for patients undergoing salvage total laryngectomy.** *Acta Otolaryngol* 2013;133:620–25 CrossRef Medline
3. 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.** *AJNR Am J Neuroradiol* 2018;39:524–31 CrossRef Medline
4. Wu JH, Zhao J, Li ZH, et al. **Comparison of CT and MRI in diagnosis of laryngeal carcinoma with anterior vocal commissure involvement.** *Sci Rep* 2016;6:30353 CrossRef Medline
5. Li L, Krantz ID, Deng Y, et al. **Alagille syndrome is caused by mutations in human Jagged1, which encodes a ligand for Notch1.** *Nat Genet* 1997;16:243–51 CrossRef Medline
6. Imre A, Pinar E, Erdoğan N, et al. **Prevertebral space invasion in head and neck cancer: negative predictive value of imaging techniques**. *Ann Otol Rhinol Laryngol* 2015;124:378–83 CrossRef Medline
7. Ryu IS, Lee JH, Roh JL, et al. **Clinical implication of computed tomography findings in patients with locally advanced squamous cell carcinoma of the larynx and hypopharynx.** *Eur Arch Otorhinolaryngol* 2015;272:2939–45 CrossRef Medline
8. Gilbert K, Dalley RW, Maronian N, et al. **Staging of laryngeal cancer using 64-channel multidetector row CT: comparison of standard neck CT with dedicated breath-maneuver laryngeal CT.** *AJNR Am J Neuroradiol* 2010;31:251–56 CrossRef Medline
9. Amin MB, Edge SB, Greene FL, et. al. *AJCC Cancer Staging Manual.* 8th ed. Springer-Verlag; 2017
10. Forastiere AA, Ismaila N, Lewin JS, et al. **Use of larynx-preservation strategies in the treatment of laryngeal cancer: American Society of Clinical Oncology Clinical Practice Guideline Update.** *J Clin Oncol* 2018;36:1143–69 CrossRef Medline
11. Agada FO, Nix PA, Salvage D, et al. **Computerised tomography vs. pathological staging of laryngeal cancer: a 6-year completed audit cycle.** *Int J Clin Pract* 2004;58:714–16 CrossRef Medline
12. Contrera KJ, Hair BB, Prendes B, et al. **Clinical versus pathologic laryngeal cancer staging and the impact of stage change on outcomes.** *Laryngoscope* 2021;131:559–65 CrossRef Medline
13. Amis ES Jr, Butler PF, Applegate KE, et al; American College of Radiology. **American College of Radiology white paper on radiation dose in medicine.** *J Am Coll Radiol* 2007;4:272–84 CrossRef Medline
14. Andreucci M, Solomon R, Tasanarong A. **Side effects of radiographic contrast media: pathogenesis, risk factors, and prevention.** *Biomed Res Int* 2014;2014:741018 CrossRef Medline
15. Eibschutz LS, Gholamrezanezhad A. **How low can we go? Strategies and recommendations to combat the iodinated contrast shortage.** *Emerg Radiol* 2022;29:925–28 CrossRef Medline
16. Seeram E. *Computed Tomography-E-Book: Physical Principles, Clinical Applications, and Quality Control.* 4th ed. Elsevier; 2015