2 Laryngeal Exam Indications and Techniques

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Abstract

Postoperative voice changes are one of the most common and feared complications of thyroid surgery. In most cases, postoperative hoarseness is due to recurrent laryngeal nerve (RLN) injury, although injury to the external branch of the superior laryngeal nerve (EBSLN) can also result in significant vocal issues, including diminished vocal projection and inability to attain higher vocal registers. Voice complaints can also occur in the absence of neural dysfunction and may be present prior to any surgery being performed. Thus, timely and accurate evaluation of laryngeal function optimizes ongoing management efforts and provides important prognostic and outcome information.

Only recently has increased awareness of the importance of voice outcomes in thyroid surgery led to the publication of a number of important papers on this topic, with several professional organizations starting to make reference to voice and laryngeal function in their guidelines for best practice. However, recommendations in these guidelines vary, especially with regard to laryngeal examination for patients without voice impairments, with many surgeons using voice symptoms alone to guide the need for laryngeal examination. True laryngeal function may be inaccurately

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predicted by voice symptoms, and thus controversy remains regarding need for routine laryngeal examination, timing of any such examination, and optimal examination technique(s). This chapter will discuss indications for laryngeal examination in thyroid surgery and current techniques available for voice and laryngeal examination.

Keywords
Laryngeal examination • Laryngoscopy • Vocal fold paralysis • Vocal cord paralysis • Recurrent laryngeal nerve • Superior laryngeal nerve • Thyroidectomy • Dysphonia • Larynx

Introduction

Postoperative voice changes are one of the most common and feared complications of thyroid surgery. In most cases, postoperative hoarseness is due to recurrent laryngeal nerve (RLN) injury, although injury to the external branch of the superior laryngeal nerve (EBSLN) can also result in significant vocal issues, including diminished vocal projection and inability to attain higher vocal registers. Voice complaints can also occur in the absence of neural dysfunction and may be present prior to any surgery being performed. Thus, timely and accurate evaluation of laryngeal function optimizes ongoing management efforts and provides important prognostic and outcome information.

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Indications for Laryngeal Examination in Thyroid Surgery

Preoperative Indications

It has been estimated that up to 33 % of individuals undergoing thyroid surgery may exhibit voice impairment preoperatively [1, 2]. However, preoperative subtle voice changes are not easily volunteered by patients and may be difficult for clinicians to detect. Also, there is a significant divergence between voice symptoms and objective vocal fold function. Indeed, the sensitivity of voice change in predicting vocal fold paralysis ranged from 33 to 68 % in two recent studies [3, 4]. Similarly, another study reported that one-third of 98 patients with postoperative vocal fold paralysis were ultimately judged to be asymptomatic in terms of vocal symptoms [5]. Thus, vocal fold paralysis may be present without significant vocal symptoms. This discrepancy between voice symptoms and vocal fold function on laryngeal examination may be due to a number of factors including residual fold function, variability in the position of the affected vocal fold, and variability in contralateral vocal fold compensation. This discrepancy provides a rationale for the inclusion of a glottic examination in all patients, both preoperatively and postoperatively. However, many surgeons use voice symptoms alone to screen for RLN injury and, at present, only 6.1–54 % of thyroidectomy patients undergo a preoperative laryngeal exam [6].

A number of professional thyroid organizations have begun to make reference to laryngeal examination in their guideline statements. The

German Association of Endocrine Surgeons [7] and a recent consensus statement of the British Association of Endocrine and Thyroid Surgeons (BAETS) [8] recommend that all patients undergoing thyroid surgery should have preoperative and postoperative laryngeal examinations. The International Neural Monitoring Study Group (INMSG) recommends pre- and postoperative laryngoscopy in all patients undergoing thyroid surgery with use of intraoperative neural monitoring (IONM) [9]. The recent clinical practice guidelines published by the American Academy of Otolaryngology Head and Neck Surgery (AAOHNS) recommend that the surgeon should document assessment of the patient's voice once a decision has been made to proceed with thyroid surgery [6]. At a minimum, this should involve subjective assessment of voice by the surgeon, patient, and family, with documentation in the patient chart as to whether these parties consider the patient's voice to be abnormal, impaired, or less than satisfactory. If there is any detectable voice impairment, or when there is a past history of voice disorder, more thorough voice investigation is indicated, which may include a validated quality of life measure, referral to an otolaryngologist, and/or assessment by a speech and language pathologist. In addition, preoperative laryngeal examination should be performed on all patients undergoing thyroid surgery when the voice is abnormal or, in the case of normal voice, if there is preoperative suggestion of thyroid cancer with suspected extrathyroidal extension or a past history of surgery in which the vagus or recurrent laryngeal nerves were at risk. Similarly, the British Thyroid Association recommends the larynx be examined in patients with preoperative voice changes and for those undergoing thyroid cancer surgery, and the National Comprehensive Cancer Network (NCCN) guidelines suggests preoperative laryngeal exam for all patients with thyroid cancers [10]. The American Thyroid Association (ATA) 2009 clinical guidelines on thyroid nodules and differentiated thyroid cancer make no reference to laryngeal examination; however, their guidelines for anaplastic thyroid carcinoma strongly recommend every patient undergo initial evaluation of the vocal folds [11, 12]. However, the most recent ATA 2015 clinical guidelines on thyroid nodules in differentiated thyroid cancer recommend voice evaluation on all patients preoperatively and laryngeal exam to be performed on patients in accordance with the American Academy of Otolaryngology recent guidelines noted above [13].

There are many reasons as to why laryngeal examination prior to thyroid surgery is important. Firstly, vocal fold paralysis, as noted earlier, can be present without significant vocal symptoms, and preoperative voice symptoms or lack of such symptoms are not reliable indicators of RLN function. Secondly, preoperative recognition of vocal fold paralysis is essential in planning a thyroid procedure. Total thyroidectomy, whether for benign or malignant disease, imparts a risk of bilateral vocal fold palsy due to both RLNs being at risk. Preoperative laryngoscopy may identify those individuals, with or without an impaired voice, who have preexisting vocal fold weakness and who would be at increased risk for bilateral vocal fold paralysis with its resultant airway obstruction, respiratory distress, and possibly the need for urgent interventions such as tracheotomy. Thus, the potential for significant postoperative morbidity is minimized and patients can be counseled appropriately about the risks of surgery. With regard to thyroid malignancy, a finding of vocal fold paralysis on preoperative examination strongly suggests the presence of invasive disease and help guide the surgical approach, as RLN invasion identified at surgery is managed based on knowledge of its preoperative function [14]. Third, identification of preoperative neural palsy may facilitate optimization of long-term voice outcomes. One study demonstrated that individuals identified with presurgical RLN impairment due to tumor invasion exhibited improved voice function outcomes after a subsequent voice surgery compared to those who were not so identified [15]. Additionally, from a medicolegal viewpoint, preoperative assessment of vocal fold function is necessary before assuming responsibility for any vocal fold dysfunction found postoperatively. Finally, with surgical outcome measures assuming increasing importance in day-to-day surgical practice, accurate interpretation of postoperative thyroidectomy laryngeal outcomes can only be accomplished if preoperative function is known.

Postoperative Indications

RLN injury with resultant dysphonia (and possibly dysphagia) is one of the main concerns for patients undergoing thyroid surgery. Incidence rates for RLN injury during thyroid surgery vary and are dependent on the pathology, involvement of the nerve with tumor, or need to resect or transect the nerve. Estimates of RLN injury can approach 13 % for thyroid cancer operations and as high as 30 % for revision thyroid surgery [16]. In patients where the nerve is spared, the traditionally low rates of reported vocal fold paralysis (1 %) are likely significantly underestimated. A recent analysis of 27 articles reviewing over 25,000 patients undergoing thyroidectomy found an average temporary vocal fold paralysis rate of 9.8 % [17]. In addition, recent quality registers of European and UK endocrine surgeons focusing on thyroid surgery have quoted rates between 2.5 and 4.3 % and administrators of these databases deemed their rates of temporary and permanent vocal fold paralysis to be severely underestimated [6]. Postoperative voice complaints can also occur in the absence of neural dysfunction, possibly due to direct cricothyroid muscle (CTM) dysfunction, strap muscle injury, peri-laryngeal scarring, or regional soft tissue changes, with a number of recent large series quoting subjective postoperative voice complaints in 30–87 % of patients [18–21]. Nonsurgical causes of postoperative voice change may include laryngeal irritation, edema, or injury from airway management [22]. In a prospective nonrandomized study of 100 patients, subjective voice changes occurred in one-third of patients with preserved vocal fold movement [23]. Another prospective single-arm study of 395 patients reported that 50 % of patients had early subjective voice changes, with voice symptoms improving within 6 months in 85 % of patients and within 1 year in 98 % [24].

As previously mentioned, subjective voice findings are a poor predictor of vocal fold paralysis and, even if the goal of the surgeon is only to identify the presence of vocal fold immobility, relying on a change in voice may not capture all patients. The Scandinavian quality register reported a vocal fold paralysis rate of 4.3 % nerves at risk, based on 3660 thyroid operations performed in 2008 in 26 endocrine surgical units from Sweden and Denmark [25]. Detection of vocal fold paralysis doubled when patients were submitted to routine laryngeal exam after surgery as compared to laryngoscopy performed only in patients with persistent and severe voice changes. In another recent study of 98 patients with vocal fold paralysis, voice was judged to be normal in 20 % and improved to normal in an additional 8 %. Thus, overall, nearly one-third of patients with vocal fold paralysis were or became asymptomatic [26].

Examination of vocal fold motion after thyroid surgery is appropriate in patients with postoperative dysphonia to assess the cause of the dysphonia, establish prognosis, and facilitate the design of treatment options to be instituted as necessary in a timely fashion.

Recent evidence suggests that early identification of vocal fold paralysis with surgical intervention via injection laryngoplasty within 3 months of injury can significantly improve long-term prognosis for functional recovery with minimal morbidity with less likely need for open formal thyroplasty surgery [27, 28]. These studies postulate that early medialization of the vocal fold creates a more favorable vocal fold position for phonation that can be maintained by synkinetic reinnervation. Referral of patients with vocal fold palsy to a speech language therapist for voice therapy can also improve glottal closure and minimize maladaptive compensatory strategies such as supraglottic hyperfunction. However, none of these strategies can be implemented unless the larynx is examined and thus all patients with dysphonia following thyroid surgery should have an examination of vocal fold mobility.

In patients with minimal voice disruption after thyroid surgery, a strong case for laryngeal examination can still be made. Laryngeal examination in this situation may identify asymptomatic vocal fold motion abnormalities and, in doing so, mitigate the risks of injury to the contralateral nerve for patients requiring subsequent surgery, such as other neck procedures, revision thyroid or parathyroid surgery, carotid endarterectomy, anterior cervical approaches to the spine, or other neck or major chest surgery. Asymptomatic undiagnosed vocal fold paralysis can also have significant impact on swallowing safety and aspiration risk, particularly in elderly patients. In addition, given that postoperative vocal symptoms are not necessarily predictive of objective vocal fold function, postoperative laryngeal examination is an important consideration as part of a surgical quality assessment evaluation.

Timing of postoperative laryngeal examination is controversial. In the first 7–14 days after surgery, symptoms of vocal fold paralysis may be offset by early postoperative vocal fold intubation-related edema and, during later phases of the postoperative period, vocal fold paralysis can become asymptomatic due to a variety of mechanisms including remaining partial neural function, variability in paralytic vocal fold position, and variability in contralateral vocal fold compensation. Thus assessing voice too early postoperatively may result in excessive false positive referrals for speech/voice assessment whereas assessing too late may preclude the utility of early forms of intervention and negatively impact eventual functional recovery. Given this, the surgeon should document whether there has been a change in voice between 2 weeks and 2 months following thyroid surgery as stated in the recent AAOHNS guidelines [6].

Techniques of Laryngeal Examination

Modern laryngoscopy began in the early to mid-1800s, when physicians began employing various devices designed to channel candlelight or sunlight along a series of mirrors to illuminate and visualize the laryngeal structures [29]. Examination of the larynx was initially performed on awake patients in the office setting, but operative laryngoscopy was increasingly common in the early 1900s, as anesthesia became safer and endoscopic equipment improved. However, by the late twentieth century many operative laryngeal procedures had migrated back to office setting [29]. This shift was made possible by improvements in instrumentation and topical anesthesia, high intensity illumination sources, advanced rigid and fiberoptic imaging technology, and flexible laser delivery systems. In addition to being more efficient than operative laryngoscopy, office-based examination allows for better assessment of laryngeal motion and function because patients can respire, phonate, and swallow during their procedure.

The ideal laryngeal examination technique would provide information on the neurologic integrity of both the recurrent and superior laryngeal nerves, and would assess the function of each intrinsic laryngeal muscle and the mobility of the cricoarytenoid joint. It would also evaluate the phonotory function of the larynx by providing detailed imaging of the true vocal fold mucosal wave, and would allow for visualization of any masses or lesions. The test would be noninvasive, easy to perform, cause minimal risk or discomfort to the patient, and be inexpensive and quick. It would permit the patient to perform a full range of laryngeal functions during the exam, allow high definition video recording of the findings, and provide a mechanism for procedural intervention.

Since this ideal examination technique does not exist, the choice of any laryngeal examination technique depends on the goals of testing. For most patients, including those undergoing evaluation for routine thyroid and parathyroid surgery, laryngoscopy to assess for mucosal lesions and an evaluation of gross motor function of the RLNs is sufficient [6, 9]. Other patients, such as those with dysphagia or concerns for aspiration, may require testing of laryngeal sensation and airway protection mechanisms, while patients with dysphonia may require more detailed stroboscopic or electromyographic studies [30].

Laryngeal History and Physical Examination

Evaluation of the larynx and vocal function begins with a thorough history and assessment of the patient's voice. Although there are more objective methods to assess laryngeal function and voice production as discussed below, the patient's voice before and after thyroid surgery plays a significant role in the threshold physicians have for proceeding to further examination.

The patient's voice complaints are completely investigated, including a history of any concomitant swallowing and/or breathing problems. The time of onset of the voice complaints is important because problems that were present prior to thyroid surgery may indicate preoperative vocal disturbances that may or may not be related to RLN function. It is also important to note whether the patient's voice has ever returned back to its baseline, even temporarily, as this may indicate causes unrelated to neuro-laryngological function.

Patient rating scales are available for assessment of vocal quality. The most common rating scales for patients are the Voice Handicap Index (VHI) [31] and its shorter version, the VHI-10 [32], as well as the Voice-Related Quality of Life (V-RQoL) questionnaire [33]. These instruments serve to quantify a patient's perception of his or her voice, while the GRBAS serves as a measure of the examiner's impression of voice quality. The GRBAS scale of the Japan Society of Logopaedics and Phoniatrics became internationally known after publication of Hirano's *Clinical Examination of Voice* in 1981 [34]. It is an auditory-perceptual scale used by clinicians to categorize the voice using five descriptive perceptual parameters: overall grade (G), roughness (R) of the voice, breathiness (B), asthenia (A), and strain (S). Despite the wide variety of scales available, each is meant to provide unique information and they should be thought of as complementary clinical tools [35].

Once the patient history and rating scales have been reviewed, the next component of the laryngeal physical examination is neck palpation. When examining the neck, it is important to palpate the hyoid bone, thyrohyoid space, thyroid cartilage, cricothyroid space, and cricoid cartilage. Some pathology may cause tightness in the membranous spaces, such as thyrohyoid space tenderness or tightness as seen with muscle tension dysphonia. Lateral movement of the larynx over the anterior cervical bodies may produce some crepitus, which is normal. There should also be normal excursion of the larynx upward and forward with swallowing. Any tracheal deviation or thyroid gland findings on neck palpation should also be noted.

Mirror Indirect Laryngoscopy

Mirror indirect laryngoscopy is one of the oldest methods of laryngeal examination still practiced today. The procedure has persisted because it is fast, straightforward, and most importantly offers adequate views of the larynx with minimal equipment or expense.

The patient sits upright and leans slightly forward. The tongue is grasped with gauze and gently retracted anteriorly. The laryngeal mirror is treated to prevent fogging. This can be accomplished with warming beads, a commercial antifog solution, or by touching the mirror to the patient's tongue or inner cheek to coat it with saliva. Using a head mirror or headlight for illumination, the laryngeal mirror is advanced just below or barely touching the soft palate until it is adjacent to the uvula, then angled into the oropharynx to expose the larynx. The patient is asked to phonate ("eee"), and vocal fold movement is assessed.

The procedure can be performed in seconds by an experienced examiner with a compliant patient, and is generally adequate to assess gross vocal fold mobility before or after thyroid and parathyroid surgery. However, mirror indirect laryngoscopy may be limited by patient tolerance and gag response. Visualization of the anterior larynx may be difficult [36], and dynamic voice evaluation and swallowing is restricted. Additionally, there is no ability to magnify the view or record the examination for serial comparison, consultation, or patient education.

Rigid Laryngoscopy

Rigid laryngoscopy is primarily used to evaluate dysphonia. It produces excellent image quality and offers stroboscopic capabilities for detailed analysis of laryngeal motion. Examinations can

Fig. 2.1 Rigid laryngoscopy. The patient's tongue is gently retracted anteriorly, facilitating visualization of the glottis

be recorded for serial comparison, consultation, and patient education.

The patient sits upright in the examination chair. Though topical anesthesia is not required, it may be beneficial in patients with a strong gag response. The examiner grasps the tongue with gauze and gently retracts it anteriorly. Alternatively, patients may retract their own tongue, allowing the examiner to stabilize the endoscope with one hand while advancing the scope with another (Fig. 2.1). A 70° or 90° rigid endoscope is attached to a light source and video monitor, then treated with a commercial anti-fog solution. The endoscope is advanced past the soft palate adjacent to the uvula and into the oropharynx without touching the tongue, then rotated to view the larynx as the patient phonates.

Rigid endoscopy offers many advantages over mirror laryngoscopy, but may also be subject to patient tolerance. Additionally, only limited dynamic evaluation of the larynx can be performed, and swallowing function cannot be assessed. This technology may also not be available outside of specialized office practices.

Flexible Laryngoscopy

Flexible fiberoptic laryngoscopy, also referred to as nasopharyngoscopy, is the most widely used procedure to evaluate laryngeal function. It is fast, well tolerated by patients, easy to learn [36], and provides excellent visualization of the nasal cavity and all pharyngeal structures. Patients are able to swallow and perform a full range of vocalization during the procedure, and laryngeal sensation can be tested. The image quality is excellent, especially when using distal chip endoscopes, and many systems allow stroboscopic examination of the larynx. The exam findings can be recorded for consultation and serial comparison, and the examination can be displayed in real time on a video monitor, allowing patients to see their disease and enhancing biofeedback techniques. Additional diagnostic and therapeutic procedures such as biopsy of suspicious lesions and laser treatments can be performed in the office through flexible endoscopes with a working channel.

The procedure begins by decongesting the nasal cavity and anesthetizing the nose and pharynx with an aerosolized 50/50 mixture of 4 % lidocaine and oxymetazoline. After an appropriate period of time to allow the medications to work, the patient leans forward slightly with the neck and chin mildly extended anteriorly, and the endoscope is introduced into the nasal cavity. A commercial anti-fog solution may be used or the tip of the scope may be touched to the patient's tongue, but generally these are unnecessary, as the patient's body heat generally clears the scope and prevents further fogging by the time the inferior turbinate is encountered. The examiner's dominant hand operates the scope, while the nondominant hand is placed gently on the patient's nose or cheek to stabilize the scope.

The endoscope is advanced along the floor of the nose between the nasal septum and inferior turbinate. If severe septal deviation or nasal spurs are present, the scope can be advanced through a more superior pathway above the inferior turbinate or placed in the contralateral side. The patient is instructed to breathe through the nose, which drops the soft palate and exposes the oropharynx. The endoscope is then advanced inferiorly to visualize the larynx and hypopharynx. The patient is asked to swallow or perform a variety of vocalizations, depending on the indications for the procedure. A normal larynx demonstrates brisk and complete volitional abduction and adduction of the true vocal folds, no pooling of secretions or signs of laryngeal penetration or aspiration, and a strong cough or gag response to laryngeal palpation with the tip of the endoscope (when indicated) (Fig. 2.2a).

When assessing laryngeal function before or after thyroid or parathyroid surgery, the examiner looks for signs of recurrent and superior laryngeal nerve dysfunction, such as bilateral true vocal fold paresis or paralysis, vocal fold atrophy (late finding), pooling of secretions, and evidence of reduced laryngeal sensation (Fig. 2.2b). Patients are asked to cough or perform repetitive phonotory exercises (e.g. "eee"-sniff) to demonstrate vocal fold mobility. It should be noted that flexible laryngoscopy does not distinguish between vocal fold immobility due to nerve injury and immobility of the cricoarytenoid joint. If there is a history of traumatic intubation or other conditions that may affect cricoarytenoid joint function, then operative laryngoscopy with palpation of the joint may be necessary.

Flexible fiberoptic laryngoscopy is easily performed in the majority of patients and is generally well tolerated. Epistaxis and mild discomfort during the insertion of the endoscope may occur, but these can be minimized by appropriate decongestion and anesthesia and careful technique. Nasal abnormalities such as severe septal deviation may challenge the exposure, but rarely do they preclude the procedure.

Laryngeal Electromyography

Though flexible laryngoscopy is currently the most commonly used method to clinically evaluate vocal fold mobility, it cannot distinguish between neurologic and mechanical causes of immobility (i.e., RLN injury vs. cricoarytenoid joint pathology), and it cannot offer prognostic information about the potential for neurologic recovery. Electromyography (EMG) measures the electrical activity of a muscle in response to neural stimulation and displays the resulting

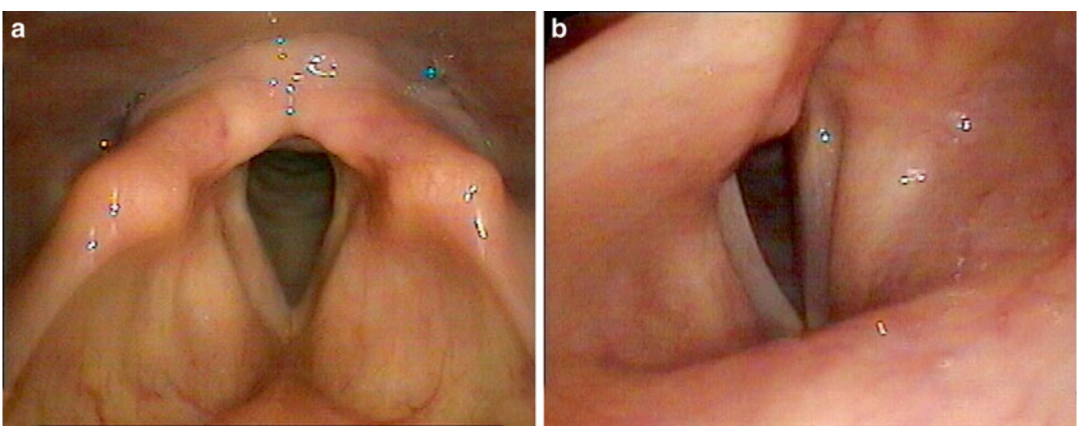

Fig. 2.2 Flexible laryngoscopy. (**a**) Symmetric normal vocal fold abduction. (**b**) Unilateral paralysis of the right true vocal fold. Note that the right vocal fold is bowed and foreshortened, with medial prolapse of the arytenoid

motor unit action potential. Laryngeal electromyography (LEMG) may be used to assess the neurologic integrity of both the recurrent and superior laryngeal nerves, evaluate spontaneous and voluntary laryngeal muscle function, differentiate vocal fold immobility caused by nerve injury from that caused by cricoarytenoid joint disorders, evaluate neurologic disorders affecting the larynx, predict recovery after a nerve injury, help determine the timing of treatment after nerve injury, and guide interventions such as laryngeal injection of botulinum toxin [37–41].

A number of different electrode options are available for LEMG, and they can be placed either transorally or transcutaneously [39–41]. Transoral LEMG requires endoscopic visualization of the larynx, which may also be beneficial in some cases of transcutaneous LEMG [41]. Depending on the technique and type of electrodes used, LEMG is able to test the integrity of individual laryngeal muscles.

Transcutaneous LEMG, which is more common in the outpatient setting, is generally performed by an otolaryngologist or neurologist. The patient sits upright in an examination chair or is placed supine, depending on their comfort and the preferences of the examiner. Topical laryngeal or cutaneous local anesthesia is used at the discretion of the physician, but it is not always necessary [39, 41]. The sequence of the examination depends on the examiner's preference and the specific muscles that require testing, but evaluation of the thyroarytenoid, posterior cricoarytenoid, and cricothyroid muscles provides information on the crucial functions of both the recurrent and superior laryngeal nerves.

Evaluation of the thyroarytenoid muscle begins by inserting the needle in the midline of the cricothyroid membrane, just beneath the inferior border of the thyroid cartilage, then directing it 30° laterally and 15° superiorly. The needle should be advanced approximately 15 mm, into the thyroarytenoid muscle. Care should be taken to avoid entering the airway, which may produce coughing. Appropriate placement is confirmed by increased, sustained EMG activity with phonation or a short burst of activity with swallowing or breath holding [41].

The posterior cricoarytenoid muscle is accessed by rotating the larynx and introducing the needle posterior to the thyroid cartilage or anteriorly, passing through the airway and cricoid cartilage. This latter approach may be difficult if the cartilage is ossified. Placement is confirmed by increased EMG activity with sniffing, and weaker activity with phonation [39, 41].

The CTM is identified by inserting the needle 5 mm lateral from the midline into the region of the CTM. The needle is then advanced laterally at 30–50° for 15–20 mm until the muscle is entered. The patient phonates at a low pitch, then raises the voice to a high pitch. A sharp increase in EMG activity confirms appropriate placement [39, 41].

Normal neuromuscular activity generates biphasic motor unit potentials. An incomplete nerve injury may produce irregular, unstable or decreased signals, and provocative maneuvers may reveal evidence of synkinesis or polyphasic reinnervation potentials of various amplitudes. Acute nerve transection may show no voluntary muscle activity, followed in 2–3 weeks by fibrillation potentials, which indicate denervation [38, 41].

LEMG helps predict which patients will benefit from early intervention after nerve injury, and may change the diagnosis in up to 30 % of cases compared to endoscopy findings. The results should be interpreted with caution in patients who have had prior laryngeal surgery, as scarring and medialization materials may alter the results [40]. The procedure is qualitative, with no normative quantitative data for comparison [42]. It is invasive and requires significant compliance and participation by the patient. Access to the technology is limited outside of specialty practices, and the techniques and equipment are not standardized.

Ultrasound

Though flexible fiberoptic laryngoscopy is currently the most utilized and, arguably, the most clinically useful method for determining vocal fold mobility, the procedures may be perceived as invasive and uncomfortable by some patients.

Additionally, the equipment required to perform laryngeal visualization may not be present outside of otolaryngology-trained surgeons' offices, meaning that some patients may need to be referred to an otolaryngologist for formal evaluation of laryngeal function before undergoing thyroid or parathyroid surgery. For these reasons, alternate imaging modalities such as ultrasound have been investigated as potential methods to evaluate laryngeal function.

Ultrasound is a noninvasive, inexpensive way to visualize vocal fold mobility. It does not subject patients to radiation exposure, and can be performed by the surgeon during their office ultrasound examination of the thyroid or parathyroid glands. The technique does require in-office ultrasound capabilities and specific ultrasound training. Visualization of true vocal fold movement may be limited, and the reported sensitivity, specificity, and positive predictive value (PPV) of this technique varies considerably [43–47].

The evaluation is performed by placing the patient in a supine position with the neck slightly extended. A high frequency linear ultrasound transducer is placed over the thyroid cartilage and used to visualize the laryngeal structures. The image quality may be improved by decreasing the frequency and increasing the gain compared to the settings typically used for cervical ultrasound [47]. The bodies of the true vocal folds are hypoechoic, with a hyperechoic stripe medially, representing the vocal ligament [43] (Fig. 2.3). The false vocal folds are hyperechoic [43], and the arytenoids appear as paired oval structures posterior to the vocal folds [48, 49]. The patient is observed during both passive respiration and volitional phonation, permitting real-time assessment of vocal fold or arytenoid motion. Performing a sustained Valsalva maneuver adducts the vocal folds and may improve visualization of the vocal ligament in the midline [47].

Unequivocal identification of normal bilateral vocal fold movement on laryngeal ultrasound is considered sufficient proof of normal recurrent laryngeal nerve function. The limitation of ultrasound, however, is that the laryngeal anatomy is often inadequately and incompletely viewed with this modality. In Asian populations, the vocal folds could not be adequately visualized in

Fig. 2.3 Laryngeal ultrasound. The true vocal folds appear as hypoechoic structures with a hyperechoic medial border, representing the vocal ligament (*arrows*). The arytenoid cartilages are seen posteriorly (*asterisks*)

5–18 % of patients [43–45]. In a multi-institutional trial of Western patients, adequate visualization varied from 41 to 89 % [47]. The false vocal folds and arytenoids are identified most commonly (93 % and 90 %, respectively), while visualization of the true vocal folds is reported as low as 37 % [43]. Though there is no clear consensus as to what constitutes adequate vocal fold visualization [47], some authors propose that identifying normal movement in any one of these structures is sufficient to exclude vocal fold palsy [43].

Laryngeal ultrasound may be limited by several factors. Though most experienced head and neck ultrasonographers should be able to visualize the larynx, keeping the ultrasound beam perfectly aligned to provide constant clear visualization of the relatively narrow true vocal folds can be challenging, especially during phonation. In patients with thin necks, it may be difficult to maintain contact between the full length of the ultrasound probe and the neck. In these cases, the probe may need to be angled slightly, limiting visualization to only one side of the larynx at a time. Alternatively, a saline-filled glove may be placed between the probe and the patient's skin to increase the contact surface area [44].

Laryngeal visualization is significantly better in females and in patients without significant thyroid cartilage calcification. While ultrasound may be useful in distinguishing normal vocal fold movement from paralysis, the technique is less accurate for patients with paresis [47]. If the larynx is incompletely visualized with this technique, or if there is any question about the mobility of a vocal fold on ultrasound, then flexible laryngoscopy should be performed.

Computed Tomography and Magnetic Resonance Imaging

In addition to ultrasound, both computed tomography (CT) and magnetic resonance imaging (MRI) have been used to assess laryngeal function. While neither modality can directly visualize the extracranial portion of the vagus nerve or the laryngeal nerves, characteristic findings may suggest vocal fold paralysis and nerve injury [50, 51]. Additionally, unlike other methods of laryngeal examination, these imaging techniques allow for the entire course of the nerves to be evaluated from brain stem to mediastinum, and can detect potential causes of vocal fold immobility due to inflammatory or neoplastic pathology adjacent to the nerves or lesions affecting the larynx directly. While dynamic MRI has been described in research settings for investigating laryngeal motion during speech and swallowing, it is clinically used primarily to evaluate for lesions that may be causing vocal fold paralysis, rather than diagnosing it [52–54]. CT has been more extensively evaluated for its role in diagnosing vocal fold paralysis, based on a constellation of suggestive findings.

When performing CT to assess for vocal fold paralysis, the axial images should be obtained in a plane parallel to the true vocal folds to avoid distortion caused by oblique sectioning, with a slice thickness between 2 and 3 mm. Patients can be examined during a number of glottic activities, but images obtained during quiet respiration are generally preferred [50]. Axial, coronal, and sagittal views are evaluated to give a more comprehensive assessment of potential signs of nerve injury.

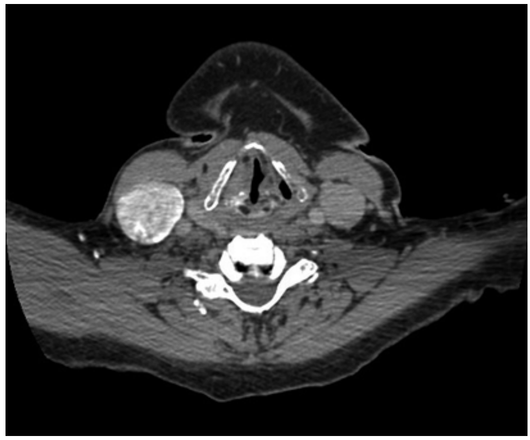

Fig. 2.4 Computed tomography of left vocal fold paralysis. There is atrophy of the vocal fold with asymmetric prominence of the left pyriform sinus and laryngeal ventricle, suggesting chronic denervation

It can be difficult to distinguish between paralyzed and mobile vocal folds on CT [51]. Since vocal fold movement is typically not captured by CT, the images are examined for a number of associated findings that, taken together, suggest a denervation injury of the larynx (Fig. 2.4). The most specific of these findings include enlargement of the laryngeal ventricle (due to thyroarytenoid atrophy), ipsilateral pyriform sinus dilation, posterior cricoarytenoid muscle atrophy and medialization, and thickening of the aryepiglottic fold [50, 51]. Additional supporting findings on axial imaging include ipsilateral atrophy of the constrictor muscles, dilation of the ipsilateral oropharynx, deviation of the uvula away from the affected side, and tilting of the thyroid cartilage due to CTM atrophy (in cases of high vagal or superior laryngeal nerve injury) [50, 51]. In addition to several of the above findings, coronal imaging may also reveal loss or flattening of the subglottic arch [50].

Due to cost and radiation concerns, CT is not used as a primary tool in evaluating laryngeal function. Additionally, CT results can be complicated by a number of factors. Oblique image acquisition or patient rotation or movement can prevent adequate imaging. Cricoarytenoid joint pathology or imaging artifacts from prior laryngeal procedures, especially medialization implant substances, can complicate image interpretation [50].

Finally, neoplastic or inflammatory disorders of the larynx or hypopharynx may produce some of the radiographic changes typically associated with neurologic injury. Findings suggestive of laryngeal nerve injury on CT should be further evaluated with laryngoscopy.

Conclusion

Perioperative voice complaints are common in patients undergoing thyroid surgery. Although neurologic injuries contribute to many cases of postoperative dysphonia, subjective voice findings are a poor predictor of vocal fold paralysis and many patients with vocal fold paralysis may be asymptomatic. Conversely, patients without any evidence of neural injury can have significant postoperative dysphonia. Formal voice assessment is therefore recommended before thyroid or parathyroid surgery, and objective documentation of vocal fold mobility should be strongly considered during the preoperative evaluation and in any patient with postoperative voice changes. Though several methods exist for evaluating laryngeal function, flexible endoscopic laryngoscopy remains the most widely available technique to provide unequivocal examination of vocal fold mobility.

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