ISSN: 2581 – 3633
PubMed - National Library of Medicine - ID: 101745081

International Journal of Medical Science and Advanced Clinical Research (IJMACR)

Available Online at:www.ijmacr.com

Volume – 7, Issue – 2, March - 2024, Page No. : 76 - 95

A comparison of transcutaneous laryngeal ultrasonography with flexible fiberoptic laryngoscopy for assessment of vocal cord movement in thyroidectomy and parathyroidectomy patients

[1]Dr.Sonu Abraham, Senior Resident, Pushpagiri Medical College, Tiruvalla, Kerala.

[2]Dr.Divya Zacharias Mannala, Senior Resident, Pushpagiri Medical College, Tiruvalla, Kerala.

[3]Dr.Falguni Shah, Consultant Anaesthesiologist, Lilavati Hospital and Research Centre, Bandra, Mumbai.

[4]Dr.Ritesh Agrawal, Consultant Surgeon, Lilavati Hospital and Research Centre, Bandra, Mumbai.

Corresponding Author: Dr. Sonu Abraham, Senior Resident, Pushpagiri Medical College, Tiruvalla, Kerala.

How to citation this article: Dr. Sonu Abraham, Dr. Divya Zacharias Mannala, Dr. Falguni Shah, Dr. Ritesh Agrawal, "A comparison of transcutaneous laryngeal ultrasonography with flexible fiberoptic laryngoscopy for assessment of vocal cord movement in thyroidectomy and parathyroidectomy patients", IJMACR- March - 2024, Volume – 7, Issue - 2, P. No. 76 – 95.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Introduction: Transcutaneous laryngeal ultrasonography (TLUSG) is an easy non-invasive reliable tool to assess perioperative vocal cord movement. This study is a comparison of TLUSG with flexible fiberoptic laryngoscopy (FFL) for assessment of vocal cord movement and identify vocal cord palsy/paresis in thyroidectomy and parathyroidectomy patients.

Methods: The study was conducted on 50 patients belonging to ASA I to III with or without preoperative vocal cord palsy (VCP) who underwent thyroid and parathyroid surgeries. TLUSG and FFL were done before and after the surgery and vocal cord movements were graded independently.

Results: Among the 3 patients who were detected with VCP on TLUSG, only 1 patient had true unilateral VCP which was confirmed with the gold standard technique of flexible fiberoptic laryngoscopy. The sensitivity, specificity, positive predictive value and negative predictive value of TLUSG were 100.0%, 98.0%, 33.3% and 100.0% respectively. The accuracy of TLUSG in finding vocal cord movement impairment is found to be 98.04%.

Conclusion: TLUSG can be used as a screening tool for selecting patients for invasive laryngoscopic technique.

Keywords: Flexible Fiberoptic Laryngoscopy, Parathyroidectomy, Thyroidectomy, Transcutaneous Laryngeal Ultrasonography, Vocal Cord Palsy.

Introduction

The use of ultrasonography (USG) is becoming increasingly important in daily practice of anaesthesia. The major advantages of this diagnostic and therapeutic tool are easy use at patient bed side, reproducible images, radiation free and above all real time renderings[1,2]. The upper airway ultrasonography helps in localization of cricothyroid membrane, tracheostomy, movement of vocal cords, prediction difficult airway, proper placement of airway device and evaluating airway lesions[1,2]. Ultrasonography also aid in peripheral blocks and regional anaesthesia, vascular access, assessment of emergency lung pathologies like pneumothorax, pleural effusion and pulmonary oedema, neuromonitoring of intracranial pressure and in assessment of gastric contents in patients with unknown prandial status[2].

The ultrasound machine has a pulse generator, oscilloscope and a transducer with lead zirconate crystal which has piezo-electric properties[2]. The Spanish singing teacher, Manuel Patricio Rodriguez García (1805-1906) is credited for the true laryngoscopy[3]. The examination of larynx was done with the reflections of mirror and a light source in the olden days, which was cumbersome and produced lot of patient discomfort. In early 1900, the principles of fiberoptic, which was based on refraction of light was developed. The potential for applying fiberoptic imaging to bronchoscopy and laryngoscopy took place after 1950. Flexible laryngoscopes were easy to use and less cumbersome but being an invasive procedure produces anxiety and discomfort in patients[4].

Postoperative vocal cord paresis or palsy (VCP) is an important procedure-related complication in thyroid and parathyroid surgeries due to the close anatomical location of recurrent laryngeal nerve[1,5,6,7,8,9,10,11,12,13]. The incidence of recurrent laryngeal nerve injury varies from 1-5% following surgeries of thyroid and parathyroid glands [1,5,6,7,10,12]. The vocal cords are supplied by the recurrent laryngeal nerve help in phonation and protection of airway [1,8]. The nerve supply to the larynx is by recurrent laryngeal nerve and superior laryngeal nerve, which are the branches of vagus[8, 10, 14, 15, 16]. Recurrent laryngeal nerve injury can affect the vocal cord movements and cause the impairment of its functions. Unilateral vocal cord palsy often leads to voice impairment but can also be asymptomatic[6, 8, 9, 10, 12]. Bilateral vocal cord palsy can cause acute respiratory distress, requiring a temporary or permanent tracheostomy[6,9,10,12]. Malignant disease, previous thyroid surgery, Graves' disease, anatomical variations, extensive lymphadenopathy and the inexperience of the surgeon increases the risk for postoperative vocal cord palsy[5,6].

Recurrent laryngeal nerve injury occurs more in thyroid surgeries than parathyroid surgeries[10]. The recurrent laryngeal nerve contains 500- 1000 motor axons and all are myelinated[16]. In a case of thyroid surgery, bilateral neck exploration is more often performed resulting in two recurrent laryngeal nerves to be at risk[10]. Both the recurrent laryngeal nerves enter the larynx through the inferior constrictor muscles at the level of the cricothyroid joint. The left recurrent laryngeal nerve is longer than the right (12cm vs 6 cm) and is more commonly injured during surgeries[8]. The parathyroid surgeries have different preparation and dissection techniques when comparing with thyroid surgery, which explains why injuries after parathyroidectomy are less frequent[10]. Identifying the recurrent laryngeal nerve during thyroid dissection is the gold standard to avoid

neural injury[10,12]. This is challenging in some cases like voluminous multinodular goiter, redo surgery, malignancy and due to anatomical variability in position and early division in branches[5, 10].

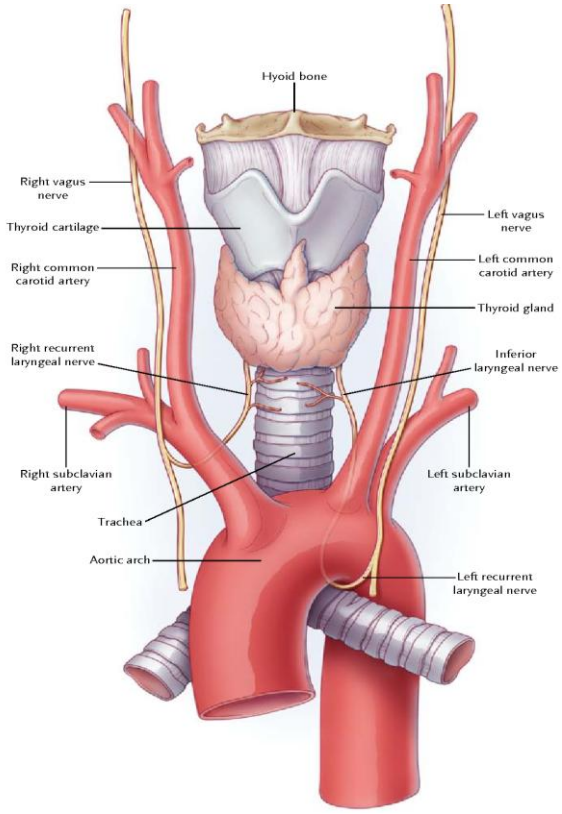


Figure 1: Anatomy and course of right and left recurrent laryngeal nerves

Recurrent laryngeal nerve can be injured by different intraoperative actions like cutting, clamping, stretching, compressing and heat [10]. Multiple methods have been described to help in detecting the nerve like intraoperative nerve stimulator [10]. As per the literature, most of the vocal cord palsies are transient [5, 6 ,7, 10]. Transient vocal cord palsy usually resolves by itself in 4-6 weeks following surgery[6,13]. If it persists more than 1 year it is considered as permanent vocal cord palsy [10]. Speech therapy or vocal exercises are usually the first measures in the management of vocal cord palsy[10]. In the case of definitive injury, vocal cord surgery can be offered like vocal cord medialization using Vox implants or autologous fat and arytenoids cartilage resection [10].

The other nerve supply to larynx is by the superior laryngeal nerve which divides into internal and external branches. The internal branch, which pierces the thyrohyoid membrane, provides sensory innervation to the supraglottic larynx, whereas the external branch, carrying motor innervation, travels to and innervates the cricothyroid muscle and thyroarytenoid muscle[14]. Superior laryngeal nerve paresis and paralysis leading to voice pitch limitation is diagnosed with laryngeal electromyography because of a lack of consistent laryngeal findings and leads to only voice pitch limitation, [14,15].

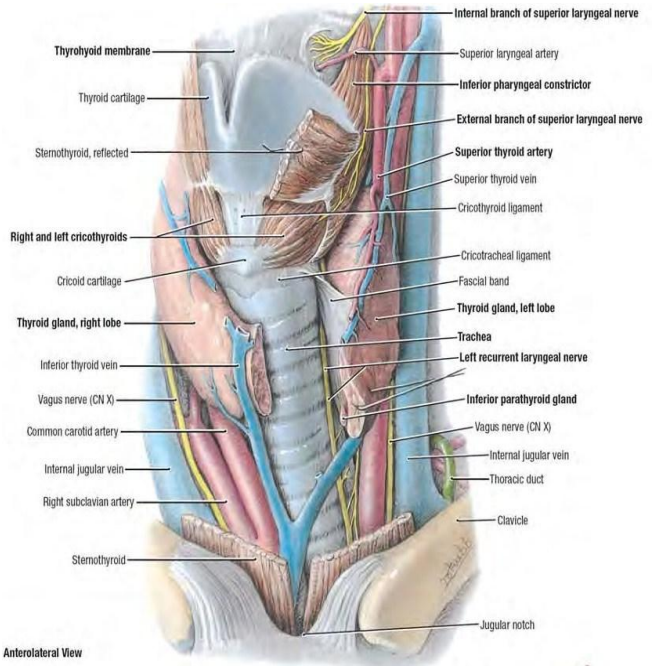


Figure 2: Anatomy and course of Superior laryngeal nerve

The various differential diagnosis for vocal cord palsy - [16]

1. Dislocation/subluxation of cricoarytenoid joint with ankylosis [18]
2. Ankylosis of cricoarytenoid joint

3. Laryngeal malignancy with involvement of cricoarytenoid joint or thyroarytenoid muscle

4. Posterior glottis stenosis or interarytenoid scarring

Various methods used in assessment of vocal cord paralysis and recurrent laryngeal nerve injuries include[5, 6] :

1. Direct visualization of vocal cord movement under flexible fiber optic laryngoscope (FFL),

2. Ultrasonography (USG),

3. Indirect mirror laryngoscopy[3,5,6,9,11,16,20,21],

4. Stroboscopy and videostroboscopy[6,9,11],

5. High speed laryngeal imaging[16],

6. Videokymography[16],

7. Electroglottography[16],

8. Laryngeal electromyography[5,11,16],

9. Computed tomography[5,8,11,16,20,22],

10. Magnetic resonance imaging[5,8,11],

11. Palpation of larynx during stimulation of recurrent laryngeal nerve[5,6],

12. Electromyography with orotracheal tube inserted electrodes[5,6].

Flexible fiberoptic laryngoscopy with direct visualization of vocal cords is considered as one of the gold standard technique for assessment of vocal cord movement [6,13,15,17,18,25,31,33]. Laryngoscopy being an invasive procedure is associated with patient discomfort and that could potentially lead to poor patient cooperation and compliance, especially in pediatric cases[4,26,28,31,39].

The most consistent glottis findings in unilateral vocal cord palsy are shortened and bowed vocal cords [16]. The examiner should take care not to be misled by small amounts of vocal cord motion that may be caused by the interarytenoid muscle still partially innervated from the contra lateral nerve or by an intact cricothyroid muscle. In such cases, there may appear to be slight adduction on phonatory effort, but the vocal cords will not abduct from its position of rest[16]. The vertical level of the paralyzed vocal cords may be either lower or higher than or may show the same horizontal level as does the normal vocal cords during phonation which must be considered when planning phonosurgery.

In unilateral vocal cord palsy, the glottal gap may be of two principal configurations: spindle-shaped (involving principally the membranous portion of the vocal cords) or V-shaped (marked by greater distance between the vocal processes of the arytenoids cartilage). The presence of a prolapsed arytenoid suggests profound denervation with loss of muscular support for the cartilage[16]. This overhanging, anteriorly displaced arytenoids cartilage is sometimes mistaken for an arytenoid cartilage dislocation which occurs in traumatic cases and must be evaluated with electromyography [16,18]. In longstanding unilateral vocal cord palsy, supraglottic hyper function may obscure visualization of the vocal cords [16]. Maneuvers such as humming can serve to relax the ventricular folds to permit a more thorough evaluation of the glottis closure [16].

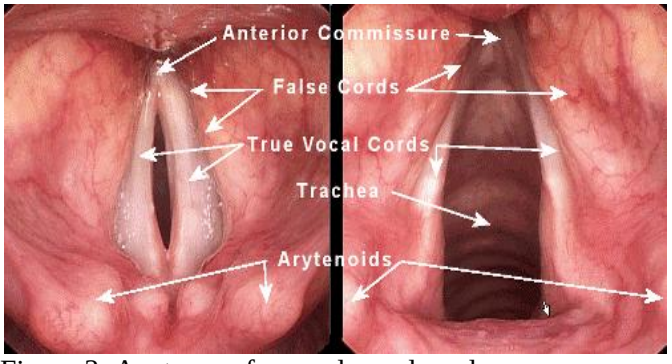


Figure 3: Anatomy of normal vocal cords

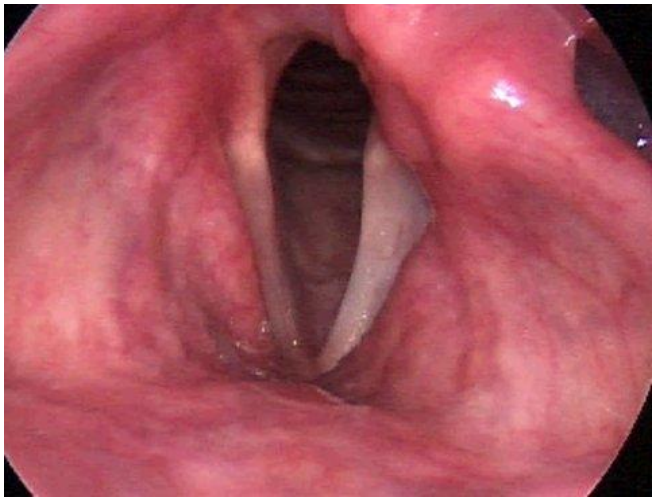


Figure 4: FFL showing vocal cord palsy

The routine assessment of vocal cords using laryngoscopy causes patient discomfort with gagging sensations, local trauma, aspiration risk and fear of invasive procedure, leading to poor patient compliance to the procedure[1,4,6,7,33]. Routinely after the surgeries of thyroid and parathyroid, the anaesthesiologists perform laryngoscopy to detect the laryngeal oedema and vocal cord palsy. Laryngoscopy can evoke a transient but significant sympathetic response with release of catecholamines leading to increase in heart rate and blood pressure[4,31]. It is also associated with an increase in intracranial pressure[4]. The pressor response to laryngoscopy is provoked by stimulation of pharynx and larynx and is mediated by the vagus and glossopharyngeal nerves.

Ultrasonography of larynx is a alternative which is simple, non-invasive, radiation free, easily available and cost effective with minimal patient discomfort[1, 11]. The development of gray-scale, real time, high resolution, B-mode USG helps in visualization of normal anatomy of the larynx, and the movements of vocal cords[5,23,25]. The best window to visualize vocal cords is transversely through the thyroid cartilage, moving the linear transducer slightly into a cephalic angle in the cephalocaudal direction[9,12,19]. The false vocal cords appear as a paired hyperechoic triangular structures with apex directed anteriorly and the true vocal cords appear as paired hypoechoic structures [9,12,19]. The increased echogenicity of false vocal cords are due to the presence of fibrofatty tissue while the true vocal cords are hypoechoic as the bulk is made up of muscles [1, 19].

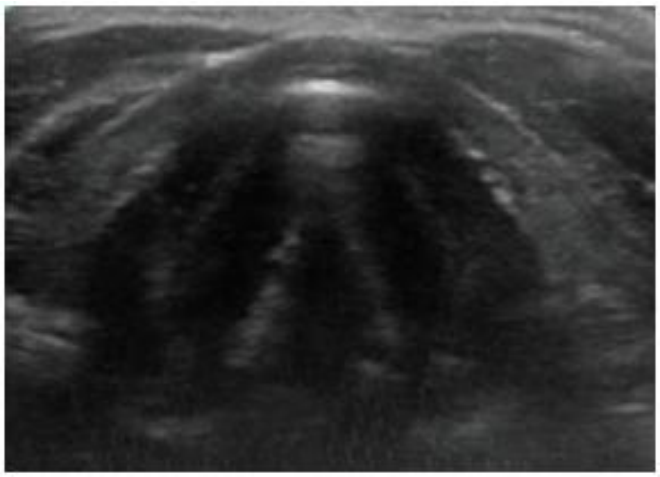


Figure 5: TLUSG of normal vocal cords

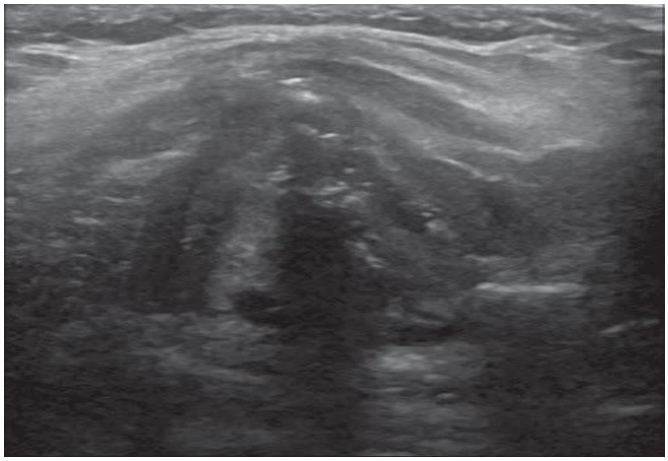


Figure 6: TLUSG of vocal cord palsy

The vocal ligament is the free margin of true cord which is seen as an echogenic band running anteroposteriorly in oblique fashion[19,29]. It is approximately 2 cms and the space in between the two vocal ligaments is called rima glottidis, which is narrower anteriorly and wider posteriorly[19]. The paired arytenoids are seen as rounded echogenic structures posteriorly. Epiglottis looks like an

inverted 'C' shaped hypoechoic structure in transverse view[12]. Trachea appears as alternating hyper and hypoechoic bands representing the cartilaginous rings and annular ligaments[12, 19]. Thyroid and cricoid cartilages undergo progressive calcifications. The abduction and adduction movements of vocal cords are rapid, and at times jerky, but always symmetrical. On phonation and breath holding at end of inspiration, the vocal cords assume a fully adducted position. Abduction becomes prominent during deep inspiratory effort[30]. The motion of vocal cords is easily observed during normal breathing[30]. The false vocal cords also exhibit adduction and abduction movements during respiration, but parallels to the true vocal cords.

The known risk factors of difficult visualization of vocal cords are age, male gender, height, thyroid cartilage calcification, and a collar incision closer to thyroid cartilage[1,6,10,29]. The postoperative hematoma and laryngeal oedema in major extensive surgeries is also associated with poor visualization of vocal cords[6,13,10]. Some studies claim that best postoperative vocal cord visualization is on postoperative days 7-10[6]. Neck adiposity may interfere the findings and visualization of vocal cords[13]. The poor assessability of vocal cords are associated with progressive calcification of thyroid cartilage in elderly leading to poor propagation of USG waves and thereby poor USG images [1, 5, 6, 29, 35]. In males with steep angulation of thyroid cartilage the placement of USG probe was difficult and can hinder the visualization rates[1, 5, 6, 35]. The usage of saline filled balloon helped to overcome the angle of thyroid cartilage and maximized the contact area between the thyroid cartilage and linear probe[1].

Figure 7: USG using saline filled bag

Transcutaneous laryngeal USG is a non-invasive, easy, bedside technique in comparison to flexible fiberoptic laryngoscopy which is an invasive direct visualization technique for vocal cord assessment [1,33].

Ultrasonography has a shorter learning curve and costs less for the patient [7]. It is safe, fast, reproducible, portable, and renders real time images. It is radiation free and is safe in pregnant patients [32]. Studies have found that of the vocal cords are assessable by USG and concluded that it could be used as a tool for selecting patients to undergo a preoperative direct laryngoscopy.

Vocal cord paralysis/paresis (VCP) can be caused by any lesion along the course of the vagal nerves above the branching of the recurrent laryngeal nerves or of the recurrent laryngeal nerves itself[7,8]. Due to long anatomical course of the vagal and recurrent laryngeal nerves, there are many disease processes that can cause vocal cord palsy like surgery, malignancy, trauma, infection and inflammation [8]. A preoperative vocal cord assessment will be ideal and can serve as a medicolegal proof[1,10,33]. It allows adequate comparison of vocal cords before and after the surgery to tailor the surgical correction later[7,10].

In cases of preoperative vocal cord palsy, the patient must be counselled appropriately before the surgery and the surgeon could take extra care on contralateral recurrent laryngeal nerve to avoid an emergency tracheostomy[1].

Methodology

After obtaining institutional ethics committee approval, diagnostic interventional study was conducted in 50 patients undergoing thyroid and parathyroid surgeries. Referring to article "A prospective, assessor-blind evaluation of surgeon-performed transcutaneous laryngeal ultrasonography in vocal cord examination before and after thyroidectomy" by Kai-Pun Wong [1], the sample size required for the study will be 45 patients considering the sensitivity of 94% of direct laryngoscopy and prevalence rates of thyroidectomy is around 40%. The power of the study is 90%, 95% confidence interval and level of significance is 5%.

N (sample size) = (FP+TN)/ (1-P);

Where $(FP+TN) = Z^2[(SP (1-SP))]/W^2$

Z=1.96

FP=False Positive

TN=True Negative

P= Prevalence rate =40%

SP=Sensitivity =94%

W=Accuracy=89%

Direct visualization of vocal cord movement by laryngoscopy is considered as gold standard to which the findings of USG are compared[6, 13, 17, 18]. Sensitivity and specificity of TLUSG was calculated comparing with flexible fiberoptic laryngoscopy. Data collected in continuous form was presented in terms of mean and SD while data collected in of categorical form was presented as count and percentage. Chi-square test was applied to find the level of significance. P value <0.05 was considered to indicate a statistically significant difference. SPSS 15.1 was used to perform the analysis.

All the patients were explained about the procedure and purpose of the study, and an informed written consent was obtained. The patients belonging to ASA grade I, II and III[5], aged above 18 years[5, 6], with or without preoperative vocal cord palsy were included in the study. All type of thyroid and parathyroid surgeries were considered in the study. Patients with hoarseness of voice due to reasons other than vocal cord palsy (sulcus vocalis, atrophic corditis, vocal nodule, vocal polyp, chronic laryngitis[5, 6] and ASA IV were excluded from the study. The patients were asked specifically if they had any voice and laryngeal symptoms. Patients were instructed to keep silence during the study, while the anaesthesiologists performing the USG/FFL were also instructed to not talk to the patient so that he/she will be unaware of the patient's voice quality throughout the assessment[1].

Figure 8: Ultrasound machine with 13-6MHz probe (Sonosite S-Nerve)

The patient was taken in operation theatre, monitors were attached and patient was positioned flat with the neck slightly extended and arms on the side[(1)]. All USG examinations were performed by the same anaesthesiologist using the same portable ultrasound machine (Sonosite S-Nerve) and the same 13-6 MHz linear transducer, to decrease the assessment variability [(1,7,34)]. After applying ample gel over anterior neck and under all aseptic precautions, the ultrasound transducer was placed transversely over the middle portion of the thyroid cartilage and scanned craniocaudally until both true and false cords were visualized[(34)]. The grey scale was adjusted to optimize the images until false cords became hyperechoic while the true cords became hypoechoic[(1)]. The movement of the vocal cords was assessed during quiet spontaneous breathing (passive) and during phonation with a sustained vowel 'aa' (active). The movement of vocal cords was graded from I to III. Patients with grade II and III were defined as having vocal cord palsy [(1)]

Table 1: Grades of vocal cord movement [(1, 6, 13, 17)]

Grade I	Full or normal symmetrical movement of vocal cords
Grade II	Impaired or decreased movement in one or both vocal cords
Grade III	No movement in one or both vocal cords

Immediately after the USG, the patients underwent flexible fiberoptic laryngoscopy (Karl Storz bronchoscope) which was performed by another anaesthesiologist who was also unaware of the patient's voice quality and the USG findings. Patient was given mild sedation with midazolam 0.05 mg/kg and one puff of lignocaine spray locally prior to laryngoscopy. Using the similar grading system, the extent of vocal cord movement on flexible fiberoptic laryngoscopy was graded from I to III. The postoperative status of vocal cords after thyroidectomy and parathyroidectomy was assessed in operation theatre after the end of surgery using both the techniques and was graded accordingly. All the patients were enquired regarding postoperative changes in voice at the time of discharge from the hospital (on 4th postoperative day). Patients with grade II or III postoperatively was defined as having vocal cord palsy, were referred to otolaryngologists and speech therapists for further management.

Figure 9: Flexible fiberoptic bronchoscope (Karl Stroz)

Results and Discussion

In this study, we evaluated the sensitivity, specificity, positive predictive value, negative predictive value and accuracy of transcutaneous laryngeal ultrasonography (TLUSG) in comparison to flexible fiberoptic laryngoscopy (FFL) in assessment of vocal cord

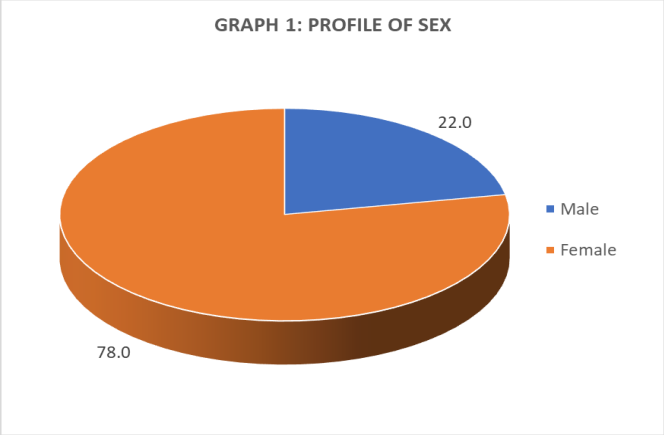
movement and diagnosing perioperative vocal cord palsy in patients undergoing thyroid and parathyroid surgeries, by blinding the assessors to the patient's voice symptoms in a prospective manner. The study also aimed to determine whether transcutaneous laryngeal ultrasonography can be used as a screening tool for selecting patients for flexible fiberoptic laryngoscopy in vocal cord assessment.

Demography

Table 2: Demographic Data

Parameters	
Number of cases	50
Age	Years
Mean	50.32
SD	14.36
Range	16-72
Sex	No. of patients (Percentage)
Male	11 (22.0%)
Female	39 (78.0%)

The study included 50 patients in which 39 cases (78%) were females and remaining 11 (22%) cases were males with a mean age of 50.32 ±14.36 years. Majority of the patients undergoing thyroid and parathyroid surgeries were females. Similar findings were observed in the studies conducted by Wong KP (78.9%) and Kumar A (72%). The mean age group in these studies was 52 years and 44 years respectively.



ASA Grade

Out of the total 50 cases, 13(26%) were ASA I, 36 (72%) were ASA II and 1(2%) case was ASA III.

Thyroid and Parathyroid Diseases

Majority of patients (n=23) were having multinodular goiter which constitutes to 46% of the study. The other pathologies of thyroid for which patients underwent surgery were for solitary thyroid nodule (24%), Graves' disease (2%), colloid goiter (4%) and Hashimoto's thyroiditis (2%). 9 patients (18%) had primary hyperparathyroidism and 4% (2 cases) were having both thyroid and parathyroid lesion. The patients having thyroid and parathyroid malignancy, Graves' disease, previous surgery and extensive lymphadenopathy are more prone for perioperative recurrent laryngeal nerve injury [5,6,10].

Table 3: Profile of Diagnosis among Study Cases

Diagnosis	No. of cases (N = 50)	Percentage (%)
Solitary thyroid nodule	12	24.0
Multinodular goiter	23	46.0
Graves' disease	01	2.0
Primary hyperparathyroidism	09	18.0
Colloid goiter	02	4.0
Hashimotos thyroiditis	01	2.0

Solitary thyroid nodule with primary hyperparathyroidism	01	2.0
Multinodular goiter with primary hyperparathyroidism	01	2.0

Type of surgeries under study

In our study, 37 (78%) patients underwent thyroid surgery, 9 (18%) cases underwent parathyroid surgery and remaining 2 patients (4%) underwent resection of both. Total thyroidectomy with lymph node dissection (34%) was more commonly done for thyroid pathologies followed by total thyroidectomy (22%) in our institution. The patients associated with higher risks for vocal cord palsy are those with extensive resection for thyroid carcinoma with lymphadenopathy, re-intervention and anatomical variations [(5)]. In our study, a total of 21 patients have undergone lymph node dissection and 2 patients underwent revision thyroidectomy which had increased risk for postoperative vocal cord palsy. Recurrent laryngeal nerve injury occurs more in thyroid surgeries than parathyroid surgeries due to the different preparation and dissection techniques[(10)]. In a case of thyroid surgery, bilateral neck exploration is more often performed resulting in two recurrent laryngeal nerves to be at risk[(10)]. Left recurrent laryngeal nerve due to the longer anatomical course is more prone for injury when compared to the right side[(8)]. But in our study, the patient who underwent right sided parathyroidectomy with lymph node dissection had developed the unilateral vocal cord palsy in the right side due to the extensive lesion in that side.

Table 4: Profile of surgery among study cases

Surgery	No. of cases (N = 50)	Percentage (%)
Hemithyroidectomy	09	18.0
Total thyroidectomy	11	22.0
Total thyroidectomy with lymphnode dissection	17	34.0
Parathyroidectomy	06	12.0
Parathyroidectomy with thymectomy and lymphnode dissection	03	6.0
Revision thyroidectomy	02	4.0
Hemithyroidectomy with parathyroidectomy	01	2.0
Hemithyroidectomy, parathyroidectomy with thymectomy and lymphnode dissection	01	2.0

Histopathology of thyroid and parathyroid lesions

Table 5: Profile of histopathology report among study cases

Histopathology	No. of cases (N = 50)	Percentage (%)
Benign lesion of thyroid	22	44.0
Malignant lesion of thyroid	13	26.0
Thyroiditis	03	6.0
Parathyroid adenoma/ hyperplasia	10	20.0
Benign lesion of thyroid with parathyroid adenoma/ hyperplasia	02	4.0

44% of the cases had benign thyroid lesions and thyroid malignancy was found in 26 % of the cases under study. 20% of the cases had parathyroid adenoma/hyperplasia in the histopathology. The risk of vocal cord palsy is more with malignant lesions than benign lesions[5, 8]. In our study, the patient who underwent parathyroidectomy with lymph node dissection had developed vocal cord palsy more likely due to the extensive resection and histopathology was suggestive of benign parathyroid hyperplasia.

Preoperative Status

We could assess the vocal cords of all the 50 patients preoperatively and were showing grade I normal mobility of vocal cords in laryngeal ultrasonography and none of the patients had any voice complaints. The flexible laryngoscopy done prior to the surgery also suggested grade I vocal cord mobility in all the 50 patients and hence confirmed that none of the 50 patients under the study were having any preoperative vocal cord palsy/paresis. All the patients were not having any laryngeal or voice complaints preoperatively.

The preoperative vocal cord assessment will be ideal as many clinical conditions like infection, inflammation, trauma, malignancy and surgery can cause vocal cord palsy in patients[48,53]. About 30-40% of the patients with unilateral VCP are asymptomatic[6, 8]. It can serve as a medico-legal proof, allows to compare and tailor the surgical correction later and help the surgeon to take extra care in cases of preoperative vocal cord palsy[10, 57]. In 2016, American Head and Neck Society (AHNS) consensus stated that a preoperative and postoperative laryngeal examination should be performed in all patients who are at risk for nerve injury[11]. They suggested that flexible laryngoscopy is the optimal method but have suggested ultrasound for documenting gross vocal cord movement abnormalities especially in pediatric population[11,26,28,31].

Cheng SP et al conducted the study for preoperative detection of vocal cord palsy, in which the patients having abnormal vocal cord movement and unclear images in USG and normal USG finding with laryngeal symptoms were selectively chosen for flexible fiberoptic laryngoscopy in the second phase of the study and they found that the results were promising. They suggested an incidence of preoperative vocal cord palsy of 0.6 – 7.7% and the assessability of vocal cords using USG was more than 80% [7]. They also mentioned that vocal cord movement can be observed in quiet breathing and during the “ee” pronunciation maneuver it was difficult to stabilize the transducer probe to make reliable quantitative measures due to the concurrent movement of thyroid cartilage which was observed in our study also[7]. There are many studies claiming that TLUSG visualization and assessment of vocal cords can be made better by valsalva maneuver and phonation[1, 5, 15, 23, 24, 35]. But in our study we did only the qualitative assessment of vocal cord movements which could be done even on quiet respiration. Hence in all the 50 patients we were able to visualize the vocal cords movements [7].

Postoperative Status

Postoperatively, laryngeal ultrasound was done in operation theatre showed grade II vocal cord mobility in 3 patients while majority (94%) showed normal grade I mobility. Flexible fiberoptic laryngoscopy done following the ultrasound showed only 1 case with a unilateral grade II mobility among the 3 ultrasound detected postoperative vocal cord palsy cases.

Table 6: Comparison of transcutaneous laryngeal ultrasonography with flexible fiberoptic laryngoscopy in detecting vocal cord palsy

Parameters	FFL detected VCP	FFL normal	Total
USG detected VCP	1(a)	2(c)	3(a+c)
USG normal	0(b)	97(d)	97(b+d)
Total	1(a+b)	99(c+d)	100

a-true positive, b-false negative, c-false positive, d- true negative

The postoperative flexible fiberoptic laryngoscopy showed that 49 cases had normal grade I vocal cord mobility suggesting the incidence of vocal cord palsy was 1 in 50 cases of thyroid and parathyroid surgeries. After comparing the laryngeal ultrasonography and flexible laryngoscopic findings obtained from 50 patients who underwent thyroid and parathyroid surgeries, the sensitivity, specificity and the accuracy were calculated. The transcutaneous laryngeal ultrasonography findings were compared with flexible fiberoptic which is considered as the gold standard technique and the sensitivity, specificity, positive predictive value and negative predictive value were found to be 100.0%, 98.0%, 33.3% and 100.0% respectively. The accuracy of transcutaneous laryngeal ultrasonography in finding vocal cord movement impairment is found to be 98.04% when compared to flexible fiberoptic laryngoscopy.

Table 7: Profile of sensitivity & specificity in transcutaneous laryngeal ultrasonography with respect to flexible fiberoptic laryngoscopy

Parameters	By TLUSG Value (%)	95 % Cl (%)
Sensitivity	100.00	2.5 to 100.00
Specificity	98.0	93.0 to 99.8
Positive Predictive Value	33.3	11.22 to 66.35
Negative Predictive Value	100.00	-
Accuracy	98.04	83.10 to 99.76

A 64 years old ASA II male patient who had primary hyperparathyroidism underwent parathyroidectomy with lymph node dissection. The postoperative TLUSG and FFL showed similar findings of right sided grade II vocal cord movement and patient was diagnosed to have vocal cord palsy. This patient had complained of hoarseness of voice after the surgery. This patient had normal vocal cord movements and no hoarseness prior to the surgery. The histopathology was suggestive of benign parathyroid hyperplasia. A 68 years old ASA II female patient who have underwent total thyroidectomy with lymph node dissection for multinodular goiter was diagnosed to have left side grade II vocal cord movement in postoperative period and the same patient had complains of hoarseness of voice which was present after the surgery. But the patient had normal vocal cord movements on direct visualization with FFL. The histopathology of this patient was suggestive of benign lesion. Similarly, another 60 years old ASA II female patient who have underwent revision thyroidectomy with histopathology suggestive of malignancy also showed vocal cord palsy in TLUSG (Grade II) and had hoarseness of voice postoperatively. But the FFL showed normal vocal cord movements and hence vocal cord palsy was ruled out. In our study, a total of 6 patients had complained of hoarseness of voice in the postoperative period. These patients were found to have

underwent total thyroidectomy with lymph node dissection (n=4), revision thyroidectomy (n=1) and parathyroidectomy with lymph node dissection (n=1).

Table 8: Changes In Voice Quality (Hoarseness)

Parameter	Preoperative (N = 50)		Postoperative (N = 50)	
	N	%	N	%
Yes	-	-	*6	12.0
No	50	100.0	44	88.0

Among the 6 patients who had complains of hoarseness of voice only 1 had true vocal cord palsy which was confirmed in FFL. The 5 patients who complained of postoperative hoarseness of voice was given symptomatic treatment like steam inhalation and their voice quality gradually improved within a week. The patient who developed true vocal cord palsy was advised on speech therapy. There are studies which have mentioned that upto 30% of patients with no underlying recurrent laryngeal nerve injury also have complained of voice symptoms after thyroid surgery[6]. Hoarseness of voice alone is not a reliable indicator of vocal cord palsy[5, 35]. There are many pathologies which can present with hoarseness like atrophic corditis or sulcus vocalis[5]. Wong have published an article on the lessons learned after 1000 transcutaneous laryngeal ultrasound with laryngoscopic validation, suggested that hoarseness of voice is neither sensitive nor specific to diagnose. In the study it was showed that hoarseness has a sensitivity of 33.3% in detecting vocal cord palsy and only 3 out of 64 patients with hoarseness had actual vocal cord palsy. The Voice Handicap Index-30 questionnaire, hoarseness and USG findings were evaluated for the diagnosis of vocal cord palsy in the study.[35] The TLUSG was found to have a sensitivity 87% and assessability was 92.4%. They concluded that more than 87% of patients could be saved from laryngoscopic evaluation if TLUSG was performed as a first line evaluation [35].

The initial studies conducted by Sindhu et al found that the sensitivity and specificity of TLUSG were only 62% and 94% and it was concluded that TLUSG was not a reliable alternative to direct laryngoscopy [1, 36]. With improvement in the USG quality and technique over time, more recent studies have reported better sensitivity and specificity than older reports. The study conducted by Wong KP et al in 2013 involving 204 patients who underwent thyroid and parathyroid surgeries also showed similar results with a sensitivity, specificity, positive predictive value and negative predictive values of 93.3%, 97.8%, 77.8% and 99.4% respectively[1]. The assessability rates in preoperative and postoperative settings were 96% and 95% respectively in the study conducted by Wong[1]. But in our study there was no difficulty in visualization of the vocal cords both in the preoperative and postoperative settings. The poor assessability of vocal cords are associated with progressive calcification of thyroid cartilage in elderly leading to poor propagation of USG waves and thereby poor USG images[1, 5, 6, 35]. In males with steep angulation of thyroid cartilage the placement of USG probe was difficult and can hinder the visualization rates[1, 5, 6, 35]. The usage of saline filled balloon helped to overcome the angle of thyroid cartilage and maximized the contact area between the thyroid cartilage and linear probe[1, 40]. The study done by Wong claimed the usage of low frequency probe (5-10 MHz) allows better tissue penetration and increases the rate of vocal cord visualization[1].

The mean age of our study population was 50 years with 78% of cases being female patients which was comparable to the study conducted by Wong (mean age-

52years and 78% female cases)[1]. In our study, usage of 6-13 MHz frequency probe, with better quality USG machine and usage of saline balloon in difficult cases have favored the better visualization of vocal cords when compared to the other studies. In another article published by Wong, they have suggested that identifying all 3 sonographic landmarks of false vocal cords, true vocal cords and arytenoids are not mandatory and each one of them had similar reliability and diagnostic accuracy in finding VCP. The visualization rates of false vocal cords, true vocal cords and arytenoids were 92.7%, 36.7% and 89.8%[37].

The study done by Bozzato A on the influence of thyroid ossification in elderly and USG imaging claims that even with presence of varying degrees of ossification, majority of the laryngeal structures can be visualized with high end resolution ultrasound and methodological experience of the operator[38]. In 2018, Kumar A et al conducted an observational study in 65 patients undergoing similar surgeries and the calculated sensitivity and specificity on comparison with videorhinolaryngoscope were 100% and 93% respectively. There was a higher visualization rate of 96% with USG. The study included 72 % female population with the study population having a mean age of 44 years. The studies used Color Doppler imaging to quantify the tissue displacement velocity of vocal cords[5,23]. The sensitivity and specificity obtained is comparable to our study[5]. The TLUSG transducer type used in majority of the studies was linear but the band with varied, ranging from 5 to 10MHz[4,5,6,34,43]. The most common position of the probe in majority studies was transverse than vertical[34]. Some argue that lateral approach as transverse approach uses true vocal cords which is difficult to visualize due to poor ultrasonic permeability of air and arytenoids as reference[34]. Mohseni M et al studied the vocal cord movement impairment using ultrasonography in 144 participants and compared the transthyroid and suprathyroid windows in a transverse plane with and without water bath. The study concluded that transthyroid window is better than suprathyroid in visualization of vocal cord movement[40].

Wang et al published many articles on USG evaluation of vocal cord movement and the studies concluded it is reliable method for diagnosing vocal cord palsy both in adult and even in pediatric population[26,28,31,39,49]. Ghassan AS et al did the prospective study on ultrasonography assessment of vocal cords mobility in 400 children after cardiac surgery in intensive care unit and suggested a sensitivity of 100% and specificity of 80%[28]. In young infants FFL assessment of vocal cords is difficult due to the altered anatomy of epiglottis, floppy tongue and adenoids and the movement of larynx during expiration, leading to increased risk of trauma and injury[28]. The usage of FFL is limited in pediatric age groups due to the lack of cooperation[26,31,49]. In our study we have excluded pediatric population but there are many other studies of vocal cord assessment in children using TLUSG which had promising results.

The patients were more comfortable and cooperative during the ultrasonography when compared to laryngoscopy[4]. The patients were anxious and some had gag reflex during laryngoscopy inspite of the suitable measures taken. But TLUSG on the other hand was more easier, comfortable and patient friendly in the younger population. TLUSG is radiation free and hence is safe in pregnant patients[41]. The low incidence of preoperative and postoperative vocal cord palsy and smaller sample size has been a limitation in our study. The incidence of

vocal cord palsy is less in our institute due to better facilities like nerve monitoring with usage of special endotracheal tubes and surgical expertise. The assessor bias was minimized by blinding the assessors to patient voice quality and symptoms before examination. TLUSG do not produce good enough images to diagnose coexisting laryngeal conditions and finer details of vocal cords that could affect the voice of patients[13, 58, 59].

The skill of USG can be learned easily and fast with appropriate training and there is a short learning curve when compared to FFL[6, 7]. The results can be improved by applying other quantitative measurements like arytenoid angle and tissue displacement velocity with Doppler mode[26, 31, 51, 55]. Ooi et al reported that the color Doppler imaging for vocal cord examination is more sensitive than B mode real time USG and is accurate as laryngoscopy[5, 7, 23]. In the study conducted by Dedecjus et al, patents were asked to sustain the vowel "aa" to determine vocal cord displacement velocity using pulsed Doppler gate and real time high resolution USG. It quantifies the vocal cord movement but the method was limited by poor reproducibility and angle dependence[5, 7, 25]. Lazard DS et al involved two quantitative criteria taking into account motion symmetry (symmetry index) and amplitude (mobility index) of for the TLUSG evaluation of VCP[15] . These are generally too complex and difficult to apply for those other than an experienced radiologist. The chance of missing vocal cord palsy by ultrasonography was very minimal in our study and there was a high success rate in visualizing and assessing the vocal cord mobility. Inspite of the encouraging results, it should not be believed that TLUSG is an alternative to direct laryngoscopy [13, 45, 46, 52, 56, 60] . Hence, we conclude the transcutaneous laryngeal ultrasonography can be used as a screening tool to select patients for flexible fiberoptic laryngoscopy and laryngoscopy must be considered only in patients with grade II or III vocal cord movement in TLUSG, symptomatic patients and those with inaccessible vocal cords in TLUSG[6]. Thereby we can reduce the overall number of invasive laryngoscopy done in patients in this era of minimally invasive procedure.

Conclusion

A prospective, interventional diagnostic and comparative study on 50 patients scheduled for elective thyroid and parathyroid surgeries underwent transcutaneous laryngeal ultrasonography followed immediately by a confirmatory flexible fiberoptic laryngoscopy in the operation theatre before and after surgery by 2 blinded examiners. Among the 3 USG detected vocal cord palsy patients in the postoperative period, 1 patient had true unilateral vocal cord palsy which was confirmed with the gold standard technique of flexible fiberoptic laryngoscope. All the patients who were having normal vocal cords in USG showed similar normal movements in flexible fiberoptic laryngoscopy. The hoarseness in the voice even if newly present in the postoperative period is not a reliable indicator of vocal cord palsy. There are many pathologies or even the process of intubation can contribute to hoarseness of voice. The vocal cord movement findings of transcutaneous laryngeal ultrasound and flexible fiberoptic laryngoscopy were comparable and the sensitivity and specificity of transcutaneous laryngeal ultrasonography was 100.0% and 98.0% when compared with flexible fiberoptic laryngoscopy as the gold standard. The positive predictive value, negative predictive value and the accuracy of transcutaneous laryngeal ultrasonography in finding vocal cord movement impairment is found to be 33.3%, 100% and 98.04%

respectively. Transcutaneous laryngeal ultrasound is not an alternative to flexible fiberoptic laryngoscope nor can it replace the gold standard technique. Transcutaneous laryngeal ultrasonography can be used as a screening tool for selecting patients for invasive laryngoscopic assessement for vocal cord movement assessment due to its high sensitivity and negative predictive value. Thus, it can significantly reduce the number of patients who subjected to the invasive, uncomfortable and hemodynamically stress inducing flexible fiberoptic laryngoscopy.

Abbreviations

USG - Ultrasonography

TLUSG - Transcutaneous laryngeal ultrasonography

FFL - Flexible fiberoptic laryngoscopy

VCP - Vocal cord palsy/paresis

ASA - American Society of Anaesthesiologist

CT - Computed tomography

MRI - Magnetic resonance imaging

ICU - Intensive Care Unit

ENT - Ear Nose Throat

References

1. Wong KP, Lang BH, Ng SH, Cheung CY, Chan CT, Lo CY. A prospective, assessor blind evaluation of surgeon performed transcutaneous laryngeal ultrasonography in vocal cord examination before and after thyroidectomy. J Surg. 2013 Aug 19;154(6):1158-64.
2. Terkawi AS, Karakitsos D, Elbarbary M, Blaivas M, Durieux ME. Ultrasound for the anaesthesiologists: present and future. Scientific World J. 2013 Nov 20: 683-685.
3. Lapena JF. Mirrors and Reflections: The evolution of indirect laryngoscopy. Ann Saudi Med 2013 Mar-Apr; 33(2): 177-181.
4. Paul BC, Rafii B, Achlatis S, Amin MR, Branski RC. Morbidity and patient perception of flexible laryngoscopy. Ann Otol Rhinol Laryngol. 2012 Nov;121(11):708-713.
5. Kumar A, Sinha C, Kumar A, Singh AK, Vardhan H, Bhavana K, et al. Assessment of functionality of vocal cords using ultrasound before and after thyroid surgery: An observational study. Indian J Anesth. 2018 Aug;62(8):599-602.
6. Borel F, Delemazure AS, Espitalier F, Spiers A, Mirallie E, Blanchard C. Transcutaneous ultrasonography in early postoperative diagnosis of vocal cord palsy after total thyroidectomy. World J Surg. 2016 Jan 7;40:665-671.
7. Cheng SP, Lee JJ, Liu TP, Lee KS, Liu CL. Preoperative ultrasonography assessment of vocal cord movement during thyroid and parathyroid surgery. World J Surg. 2012 June; 36(10):2509-2515.
8. Dankbaar JW, Pameijer FA. Vocal cord paralysis: anatomy, imaging and pathology. Insights Imaging.2014 Oct 15; 5:743-751.
9. De Miguel M, Pelaez EM, Caubet E, Gonalez O, Velasco M, Rigual L. Accuracy of transcutaneous laryngeal ultrasound for detecting vocal cord paralysis in immediate postoperative period after total thyroidectomy. Minerva Anaestesiologica. 2017 Dec; 83(12):1239-1247.
10. Joliat GR, Guarnero V, Demartines N, Schweizer V, Matter M. Recurrent laryngeal nerve injury after thyroid and parathyroid surgery- incidence and postoperative evolution assessment. Medicine, 2017 April;96:17(e6674).
11. Sinclair CF, Bumpous JM, Haugen BR, Chala A, Meltzer D, Miller BS, et al. Laryngeal examination

in thyroid and parathyroid surgery: An American head and neck society consensus statement. Head Neck 2016 Jun;38(6):811-819.

12. Linares JPA. Use of ultrasound in evaluation of vocal folds following thyroid surgery. Rev Colomb Anestesiol. 2014 May 23;42(3):238-242.
13. Kandil E, Deniwar A, Noureldine SI, Hammad AR, Mohamed H, Qurashi ZA, et al. Assessment of vocal fold function using transcutaneous laryngeal ultrasonography and flexible laryngoscopy. JAMA Otolaryngol Head Neck Surg. 2016 Jan;142(1):74-78. Neck Surg. 2014 Dec;22(6): 439–443.
14. Orestes MI, Chhetri DK. Superior laryngeal nerve injury: effects, clinical findings, prognosis, and management options. Curr Opin Otolaryngol Head
15. Lazard DS, Cassagne HS, Lefort M, Leenhardt L, Russ G, Fourin F, et al. Transcutaneous laryngeal ultrasonography for laryngeal immobility diagnosis in patients with voice disorders after thyroid/parathyroid surgery. World J Surg. 2018 Jan;17:4428-2.
16. Afsah OE. Approach to diagnosis of vocal cord immobility: literature review. Eygpt J Otolaryngol. 2015 Nov;31:78-91.
17. Fukuhara T, Donishi R, Matsuda E, Koyama S, Fujiwara K, Takeuchi H. A novel lateral approach to the assessment of vocal cord movement by ultrasonography. World J Surg. 2018; 42(1):130-136.
18. Ruan Z, Ren R, Dong W, Ma J, Xu Z, Mao Y et al. Assessment of vocal cord movement by ultrasound in ICU. Intensive care med. 2018 Dec;44(12):2145-2152.
19. Raghavendra BN, Horii SC, Reede DL, Rumancik WM, Persky M, Bergeron RT. Sonographic anatomy of larynx, with particular reference to the vocal cords. J Ultrasound Med. 1987 May;6(5):225-230.
20. Nasr WF, Amer HS, Askar SM, Enaba MM. Laryngeal ultrasound as effective as CT scans for the diagnosis of various laryngeal lesions. Eygpt J Otolaryngol. 2013;29(2):93-98.
21. Tamura E, Kitahara S, Kohno N. Clinical assessment of intralaryngeal ultrasonography. Laryngoscope. 2001 Oct;111(10):1767–70.
22. Noyek AM, Zizmor J. The evolution of diagnostic radiology of the larynx. J Otolaryngol Suppl. 1977;3:12–6.
23. Ooi LL, Chan HS, Soo KC. Color doppler imaging for vocal cord palsy. Head Neck. 1995 Jan-Feb;17(1):20-3.
24. Vats A, Worley GA, Bruyn R, Porter H. Laryngeal ultrasound to assess vocal fold paralysis in children. J Laryngol Otol. 2004 June;118(6):429-31.
25. Dedecjus M, Adamczewski Z, Brzezinski J, Lewinski A. Real-time, high-resolution ultrasonography of the vocal folds—a prospective pilot study in patients before and after thyroidectomy. Lanenbecks Arch Surg. 2010 Sep;395(7):859-64.
26. Wang LM, Zhu Q, Ma T, Li JP, Hu R, Rong XY, et al. Value of ultrasonography in diagnosis of pediatric vocal fold paralysis. Int J Pediatr otorhinolaryngol. 2011 Sep; 75(9):1186-90.
27. Wang CP, Chen TC, Yang TL, Chen CN, Lin CF, Lou PJ, et al. Transcutaneous ultrasound for evaluation of vocal fold movement in patients with thyroid disease. Eur J Radiol. 2012;81:e288-91.
28. Shaath GA, Jijeh A, Alkurdi A, Ismail S, Ismail S, Elbarbary M, Kabbani MS. Ultrasonography assessment of vocal cords mobility in children after

cardiac surgery. J Saudi Heart Assoc. 2012 Jul; 24(3):187-190.

29. El Hennawi DE, Ahmed M, Farid A, Hal H. Utilisation of laryngeal ultrasound and laryngoscopy for the diagnosis and management of bilateral vocal cord paralysis. Egypt J Otolaryngol. 2015 Jan;31(4):231-236.
30. Wong KP, Woo JW, Li JYY, Lee KE, Youn YK, Lang BHH. Using transcutaneous laryngeal ultrasonography to assess postthyroidectomy patients' vocal cords: Which maneuver best optimizes visualization and assessment accuracy? World J Surg. 2016 Nov 9;40(3):652-658.
31. Ongkasuwan J, Ocampo E, Tran B. Laryngeal ultrasound and vocal fold movement in pediatric cardiovascular intensive care unit. Laryngoscope.2017 Jan;127(1):167-172.
32. Kumar A, Sinha C, Singh AK, Bhadani UK. Vocal cord dysfunction: ultrasonography aided diagnosis during routine airway examination. Saudi J Anaesth.2017 Jul- Sep;11(3):370-371.
33. Sadacharan D, Ferdinant J, Rakeshchandru K,Thalavai S. The utility of surgeon performed transcutaneous laryngeal ultrasound for assessment of vocal cords in post thyroidectomy patients. Int Surg J. 2018 Nov;5(11):3505-3509.
34. Da Costa BOI, Rodrigues D de SB, Santos AS, Pernambuco L. Transcutaneous laryngeal ultrasonography for the assessment of laryngeal function after thyroidectomy: a review. Ear Nose Throat J. 2019 Oct;2:145561319870487.
35. Wong KP, Au KP, Lam S, Lang BH. Lessons learned after 1000 cases of transcutaneous laryngeal ultrasound with laryngoscopic validation: is there a role of TLUSG in patients indicated for laryngoscopic examination before thyroidectomy? Thyroid. 2017 Jan 1;27(1):88-94.
36. Sidhu S, Stanton R, Shahidi S, Chu J, Chew S, Campbell P.Initial experience of vocal cord evaluation using grey-scale, real-time, B-mode ultrasound. ANZ J Surg. 2001 Dec;71(12):737-9.
37. Wong KP, Woo WJ, Youn YK, Chow FC, Lee KE, Lang BH. The importance of sonographic landmarks by transcutaneous laryngeal ultrasonography in post-thyroidectomy vocal cord assessment. Surgery 2014 Dec;156(6):1590-1596.
38. Bozzato A, Zenk J, Gottwald F, Koch M, Iro H. Influence of thyroid cartilage ossification in laryngeal ultrasound. Laryngorhinootologie.2007 Apr;86(4):276-281.
39. Wang LM, Zhu Q, Ma T, Li JP, Hu R, Rong XY, et al. Value of ultrasonography in diagnosis of pediatric vocal cord paralysis. Int J Pediatr Otorhinolaryngol. 2011 Sep;75(9):1186-90.
40. Mohseni M, Alimian M, Zaman B, Faiz SHR, AhmadiS, Koleini ZS. The diagnosis of vocal cord movement impaiement using ultrasonography: a comparison of transthyroid and suprathyroid views. Ann Anesth Crit Care. 2017 Jul; 6;2(2): e58051.
41. Matta IR, Halan KB, Agrawal RH, Kalwari MS. Laryngeal ultrasound in diagnosis of vocal cord palsy: An underutilized tool? J Laryngol Voice. 2014 Sep;4(1):2-5.
42. Misron K, Balasubramanian A, Mohamad I, Hassan FH. Bilateral vocal cord palsy post thyroidectomy: lessons learnt. BMJ Case Rep. 2014 Mar 24;2014:bcr2013201033.
43. Hu Q, Zhu SY, Luo F, Gao Y, Yang XY. High frequency sonographic measurements of true and

false vocal cords. J Ultrasound Med. 2010 Jul;29(70):1023-1030.

44. Abadin SS, Kaplan EL, Angelos P. Malpractice litigation after thyroid surgery: the role of recurrent laryngeal nerve injuries,1989–2009. Surgery. 2010 Oct;148(4):718-22.
45. Schlosser K, Zeuner M, Wagner M, Slater EP, Dominguez FE, Rothmund M, et al. Laryngoscopy in thyroid surgery-essential standard or unnecessary routine? Surgery. 2007 Dec;142(6):858-64.
46. Shaha AR. Routine laryngoscopy in thyroid surgery: a valuable adjunct. Surgery. 2007 Dec;142(6):865-6.
47. Dionigi G, Boni L, Rovera F, Rausei S, Castelnuovo P, Dionigi R. Postoperative laryngoscopy in thyroid surgery: proper timing to detect recurrent laryngeal nerve injury. Langenbecks Arch Surg. 2010 Apr;395(4):327-31.
48. Randolph GW, Kamani D. The importance of preoperative laryngoscopy in patients undergoing thyroidectomy: voice, vocal cord function, and the preoperative detection of invasive thyroid malignancy. Surgery. 2006 Mar;139(3):357-62.
49. Friedman EM. Role of ultrasound in the assessment of vocal cord function in infants and children. Ann Otol Rhinol Laryngol. 1997 Mar;106(3):199-209.
50. Tsai CG, Chen JH, Shau YW, Hsiao TY. Dynamic B-mode ultrasound imaging of vocal cord vibration during phonation. Ultrasound Med Biol.2009 Nov;35(11);1812-1818.
51. Tsui PH, Wan YL, Chen CK. Ultrasound Imaging of the Larynx and Vocal Folds: Recent Applications and Developments. Curr Opin Otolaryngol Head Neck Surg. 2012 Dec;20(6):437-442.
52. Murthy N, Bhatia D. Role of ultrasound in analysis of vocal cord movements in comparison with laryngoscopy. Asian J Med Radiol Res. 2019 Jul-Dec;7(2):32-35.
53. Rivest EK, Mitmaker E, Payne RJ, Hier MP, Mlynarek AM, Young J, et al. Preoperative vocal cord paralysis and its association with malignant thyroid disease and other pathological features. J Otolaryngol Head Neck Surg. 2015 Sep 11;44(1):35.
54. Ruan Z, Ren R, Dong W, Ma J, Xu Z, Mao Y, et al. Assessment of vocal cord movement by ultrasound in ICU. Intensive Care Med. 2018 Dec;44(12):2145-2152.
55. Amis RJ, Gupta D, Dowdall JR, Srirajakalindini A, Folbe A. Ultrasound assessment of vocal cord paresis: a correlation case series with flexible fiberoptic laryngoscopy and adding the third dimension (3-D) to vocal fold mobility assessment. Middle East J Anaesthesiol. 2012 Feb;21(4):493-498.
56. Carnerio-Pla D, Miller BS, Wilhelm SM, Milas M, Gauger PG, Cohen MS, et al. Feasibility of surgeon-performed transcutaneous vocal cord ultrasonography in identifying vocal cord mobility: a multi-institutional experience. Surgery.2014 Dec;156(6):1597-602.
57. Sabaretnam M, Ramakant P, Abraham DT, Paul MJ. Preoperative ultrasonography assessment of vocal cord movement during thyroid and parathyroid surgery. World J Surg. 2013 Dec;37:1740.
58. Maghraby H, El-haseeb HA. Value of laryngeal ultrasound in comparison to vocal cord video stroposcopy in diagnosis of various laryngeal lesions. Al-Azhar Med J. 2015 Oct;44(4):317-326.
59. Xia CX, Zhu Q, Zhao HX, Yan F, Li SL, Zhang SM. Usefulness of ultrasonography in assessment of

laryngeal carcinoma. Br J Radiol. 2013 Oct;86(1030):20130343.

60. Kundra P, Kumar K, Allampalli V, Anathkrishnan R, Gopalakrishnan S, Elangovan S. Use of ultrasound to assess superior and recurrent laryngeal nerve function immediately after thyroid surgery. Anaesthesia. 2012 Mar;67(3):301-302.G.