Original Investigation

Assessment of Vocal Fold Function Using Transcutaneous Laryngeal Ultrasonography and Flexible Laryngoscopy

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IMPORTANCE Evaluation of preoperative and postoperative vocal fold function is important in patients undergoing thyroid or parathyroid surgical procedures. Transcutaneous laryngeal ultrasonography (TLUSG) has been proposed as a promising noninvasive technique and alternative to flexible fiberoptic laryngoscopy.

OBJECTIVE To determine whether TLUSG can be an alternative to flexible laryngoscopy in evaluating vocal fold function.

DESIGN, SETTING, AND PARTICIPANTS A prospective study was performed from March 1, 2013, to July 31, 2014. Patients who were scheduled to undergo thyroid or parathyroid surgery by a single surgeon at a North American, university-based tertiary care center and who agreed to undergo preoperative and postoperative TLUSG and flexible fiberoptic laryngoscopy were enrolled. Patients were divided into 2 groups: nonoverweight (body mass index [calculated as weight in kilograms divided by height in meters squared] <25) and overweight or obese (body mass index ≥25). Follow-up was completed on February 28, 2015, and data were analyzed from March 1, 2013, to February 28, 2015.

INTERVENTIONS Preoperative and postoperative TLUSG and flexible fiber optic laryngoscopic assessments of vocal fold function.

MAIN OUTCOMES AND MEASURES The findings of TLUSG and flexible fiber optic laryngoscopy were compared for all patients and each body mass index group to assess the accuracy of TLUSG in assessing vocal fold function.

RESULTS A total of 250 patients (500 vocal folds) underwent evaluation, of whom 208 (83.2%) were women and with a mean (SD) age of 52.7 (14.3) years. On flexible fiberoptic laryngoscopy findings, 13 patients had preoperative vocal fold paralysis (VFP), and 14 postoperative new incidents of VFP were identified. Only 7 (53.9%) of the preoperative cases of VFP and 15 (55.6%) of the postoperative cases of VFP were identified by TLUSG. The sensitivity, specificity, and accuracy of preoperative TLUSG were 53.8%, 50.5%, and 50.6%, respectively; for postoperative TLUSG, 55.6%, 38.7%, and 39.6%, respectively. In the nonoverweight group, the preoperative TLUSG sensitivity, specificity, and accuracy were 100%, 70.0%, and 70.5%, respectively; in the overweight-obese group, 45.4%, 43.4%, and 43.5%, respectively (odds ratio, 3.16; 95% CI, 2.06-4.84; $P < .001$). Postoperative visualization of the vocal folds was more challenging, with a sensitivity, specificity, and accuracy of 83.3%, 55.6%, and 56.8%, respectively, in the nonoverweight group, and 47.6%, 32.6%, and 33.4%, respectively, in the overweight-obese group (odds ratio, 2.62; 95% CI, 1.75-3.94; $P < .001$).

CONCLUSIONS AND RELEVANCE When evaluation of vocal fold function is indicated in patients undergoing thyroid and parathyroid surgery, TLUSG should not be considered as an alternative to the current practice of flexible fiberoptic laryngoscopy. Adequate ultrasonographic visualization of the vocal folds and arytenoids is challenging, especially in overweight and obese patients and in the postoperative setting.

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Thyroid and parathyroid surgical procedures are common operations. Owing to the close anatomic relationship between the thyroid and parathyroid glands and the laryngeal nerves, iatrogenic injury to the recurrent laryngeal nerve (RLN) with subsequent vocal fold paralysis (VFP) or paresis is one of the most commonly encountered complications. Mechanisms of iatrogenic RLN injury may include mechanical (ie, compression, crush, stretch, or laceration), thermal, or vascular (ie, ischemic injury) factors. Nonetheless, the presence or absence of RLN dysfunction alone does not predict functional voice outcome after thyroidectomy. Other mechanisms can affect vocal fold function, including injury to the external branch of the superior laryngeal nerve; postoperative inflammation; laryngeal edema; surgical trauma to the cricothyroid muscle, the extralaryngeal or strap muscles, or the cricoarytenoid joint; endotracheal intubation-related trauma; and laryngotracheal fixation.[1-3] Vocal manifestations from these various injuries can range from a seemingly normal voice or transient voice fatigue to profound and permanent dysphonia with a substantially adverse effect on the patient's quality of life.[4-6] Such complications are of concern not only for the patients but for the surgeons because these complications are common causes of medicolegal litigation.[7]

Therefore, assessment of vocal fold function is important in the preoperative and postoperative evaluation of patients.[5] This assessment will detect an existing preoperative RLN palsy or an early iatrogenic RLN injury.[5,6,8] Although most postoperative voice changes resolve spontaneously within 3 to 6 months of thyroid surgery, patients can develop maladaptive compensatory mechanisms during the postoperative recovery.[9-11] Such vocal behaviors can persist after resolution of the underlying vocal fold injury and are most appropriately evaluated and treated by experienced speech-language pathologists or otolaryngologists. Early identification of voice dysfunction and referral to a speech-language pathologist or an otolaryngologist for vocal rehabilitation could be beneficial to these patients so that vocal function can be optimized. However, owing to the low reported incidence of VFP after thyroid and parathyroid surgery, especially in experienced hands, some investigators[12] have argued against routine laryngeal evaluation. Unfortunately, guidelines from professional bodies in the United States are lacking on this topic, and no consensus is available. Only the recent guidelines from the American Thyroid Association[13] and the American Academy of Otolaryngology–Head and Neck Surgery[14] recommend that preoperative laryngeal assessment be performed in patients with an impaired voice, thyroid cancer with extrathyroidal extension, or previous surgery jeopardizing the RLN or the vagus nerve and postoperative assessment in patients with voice changes.

Since 2010, transcutaneous laryngeal ultrasonography (TLUSG) has been proposed as a promising noninvasive technique to examine perioperative vocal fold function.[15-19] Ultrasonography is noninvasive, inexpensive, and well tolerated by patients. However, the diagnostic accuracy and reliability of TLUSG rely on clear visualization of the real-time movement of vocal folds and arytenoids during the examination. Some factors responsible for the low sensitivity of TLUSG are postoperative changes and obesity, the latter of which has been reported to affect as much as 34.9% of the US population.[20] The aim of this study is to explore the feasibility of using TLUSG as an alternative to flexible laryngoscopy in evaluating vocal fold function, when indicated, in a US population undergoing thyroid and parathyroid surgery.

Methods

We enrolled patients diagnosed with thyroid or parathyroid disease and scheduled to undergo thyroidectomy or parathyroidectomy during the 16-month period from March 1, 2013, to July 31, 2014, at Tulane University Medical Center. All operations were performed at the medical center by one of us (E.K.). All demographic characteristics of the recruited patients were collected. Patients were divided into the following 2 groups based on their body mass index (BMI; calculated as weight in kilograms divided by height in meters squared): a nonoverweight group (BMI <25) and an overweight or obese group (BMI ≥25). This study was approved by the institutional review board of Tulane University. All patients provided oral informed consent.

All patients initially underwent TLUSG followed by flexible fiberoptic laryngoscopy preoperatively and postoperatively. Cervical TLUSG was performed using a 12-MHz linear transducer by the same surgeon (E.K.) on the same device to avoid any variability in vocal fold assessment. The patients were positioned flat in a supine position with the neck extended. After applying an ample amount of gel, the ultrasonographic transducer was placed transversely over the thyroid cartilage and scanned caudocranially to visualize the vocal folds during quiet spontaneous breathing. The false vocal folds, true vocal folds, and arytenoids were sought carefully and identified when possible. Active movements of the vocal folds were then assessed by asking the patient to pronounce the letter E. These findings were recorded prospectively. Second TLUSG and flexible fiberoptic laryngoscopy were performed at 1 postoperative week. Final follow-up was completed on February 28, 2015.

Flexible fiberoptic laryngoscopy findings were classified as normal or impaired vocal fold function. Impairment included vocal fold weakness, asymmetry, and complete paralysis. Flexible laryngoscopy was used as the standard to which the TLUSG findings were correlated. The TLUSG findings were recorded as correctly or incorrectly correlating with the flexible laryngoscopy finding.

A true-negative finding was defined as detection of movement of a normally mobile vocal fold by TLUSG, whereas a false-positive finding was defined as an inability to detect this normal movement. A true-positive finding was defined as the ability of TLUSG to detect a dysfunctional vocal fold, whereas a false-negative finding was defined as the inability to view the dysfunctional fold.

Data were analyzed from March 1, 2013, to February 28, 2015. Testing for the association with the BMI categories was performed using the Fisher exact test for categorical variables and 2-tailed *t* test for continuous variables. The calculation of sensitivity, specificity, accuracy, and negative and positive predictive values was applied to test the validity of TLUSG compared with flexible fiberoptic laryngoscopy. We used logistic regression to calculate the odds ratios (ORs) and 95% CIs

Table 1. Patient Characteristics and Association of Selected Variables With the Outcome of Interest[a]

Characteristic	All Patients	Group With BMI <25	Group With BMI ≥25	*P* Value[b]
Age, mean (SD), y	52.7 (14.3)	51.4 (16.0)	53.1 (13.7)	.40
Age categories, y				
≤45	69/250 (27.6)	19/66 (28.8)	50/184 (27.2)	.87
>45	181/250 (72.4)	47/66 (71.2)	134/184 (72.8)	
Sex				
Male	42/250 (16.8)	11/66 (16.7)	31/184 (16.9)	>.99
Female	208/250 (83.2)	55/66 (83.3)	153/184 (83.2)	
BMI, mean (SD)	30.5 (7.3)	NA	NA	NA
Preoperative TLUSG				
Correct correlation with FL	253/500 (50.6)	93/132 (70.4)	160/368 (43.5)	<.001
Incorrect correlation with FL	247/500 (49.4)	39/132 (29.5)	208/368 (56.5)	
Preoperative flexible fiberoptic laryngoscopy				
Normal	487/500 (97.4)	130/132 (98.5)	357/368 (97.0)	.54
Vocal fold motion impairment	13/500 (2.6)	2/132 (1.5)	11/368 (3.0)	
Postoperative TLUSG				
Correct correlation with FL	198/500 (39.6)	75/132 (56.8)	123/368 (33.4)	<.001
Incorrect correlation with FL	302/500 (60.4)	57/132 (43.2)	245/368 (66.6)	
Postoperative flexible fiberoptic laryngoscopy				
Normal	473/500 (94.6)	126/132 (95.4)	347/368 (94.3)	.82
Vocal fold motion impairment	27/500 (5.4)	6/132 (4.5)	21/368 (5.7)	

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); FL, flexible laryngoscopy; NA, not applicable; TLUSG, transcutaneous laryngeal ultrasonography.

[a] Unless otherwise indicated, data are expressed as number/total number (percentage) of patients (n = 250) or vocal folds (n = 500).

[b] Calculated using the Fisher exact test for categorical variables and 2-tailed *t* test for continuous variables for comparison of the BMI groups.

Table 2. Validity Analysis for TLUSG Compared With Flexible Fiberoptic Laryngoscopy as Associated With BMI

	Finding								
BMI	TP	TN	FP	FN	Sensitivity, %	Specificity, %	PPV, %	NPV, %	Accuracy, %
Preoperative assessment									
All	7	246	241	6	53.8	50.5	2.8	97.6	50.6
<25	2	91	39	0	100	70.0	4.9	100	70.5
≥25	5	155	202	6	45.4	43.4	2.4	96.3	43.5
Postoperative assessment									
All	15	183	290	12	55.6	38.7	4.9	93.8	39.6
<25	5	70	56	1	83.3	55.6	8.2	98.6	56.8
≥25	10	113	234	11	47.6	32.6	4.1	91.1	33.4

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); FN, false-negative; FP, false-positive; NPV, negative predictive value; PPV, positive predictive value; TLUSG, transcutaneous laryngeal ultrasonography; TN, true-negative; TP, true-positive.

to control for selected variables. Statistical significance was set as $P < .05$. All analyses were performed using SAS software (version 9.2; SAS Institute Inc).

Results

The study included 250 patients who underwent a total of 500 vocal fold assessments. The mean (SD) age of the study group was 52.7 (14.3) years, and 208 patients (83.2%) were women. Descriptive statistics of our patient population are shown in **Table 1**, where we also compare the variables between the overweight-obese and nonoverweight groups. Fifty-eight patients (23.2%) underwent total thyroidectomy; 134 patients (53.6%), thyroid lobectomy or completion thyroidectomy; and 58 patients (23.2%), parathyroidectomy.

Preoperative TLUSG was able to assess 253 of the 500 vocal folds examined (50.6%). Thirteen patients (5.2%) were found to have unilateral VFP before the operation. Of 487 normal-functioning vocal folds, TLUSG assessed 246 correctly for a specificity of 50.5%. Of the 13 patients with preoperative VFP, 7 patients were identified correctly by TLUSG for a sensitivity of 53.8% (**Table 2**).

Of 473 mobile vocal folds assessed postoperatively, 198 were assessed correctly, revealing a specificity of 38.7%. Fourteen patients developed postoperative unilateral VFP in addition to the 13 patients who presented with VFP preoperatively. Of these 27 patients, TLUSG assessed 15 vocal folds correctly, giving a sensitivity of 55.6%. The accuracy of detection of vocal fold movement decreased from 50.6% preoperatively to 39.6% postoperatively. In no case was preoperative or postoperative bilateral VFP reported.

Table 3. Ultrasonographic Findings Comparing the Earliest Vocal Cords Assessed to the Latest Vocal Cords Assessed

TLUSG Finding	No. (%) of Vocal Folds[a]		*P* Value[b]
	First 250	Last 250	
Preoperative assessment			
Correct	138 (55.2)	115 (46.0)	.049
Incorrect	112 (44.8)	135 (54.0)	
Postoperative assessment			
Correct	114 (45.6)	84 (33.6)	.008
Incorrect	136 (54.4)	166 (46.4)	

Abbreviation: TLUSG, transcutaneous laryngeal ultrasonography.

[a] From the first and last 125 patients in the study.

[b] Calculated using the Fisher exact test for categorical variables.

Preoperative TLUSG assessed 93 of 132 vocal folds (70.5%) correctly in the nonoverweight group in contrast to 160 of 368 (43.5%) in the overweight-obese group (OR, 3.16; 95% CI, 2.06-4.84; $P < .001$). Postoperative TLUSG identified 75 of 132 vocal folds (56.8%) correctly in the nonoverweight group and 123 of 368 vocal folds (33.4%) in the overweight-obese group (OR, 2.62; 95% CI, 1.75-3.94; $P < .001$). The accuracy of TLUSG in the assessment of vocal folds was lower postoperatively (39.6%) when compared with the preoperative assessment (50.6%) (OR, 1.53; 95% CI, 1.22-2.01; $P < .001$). We found no correlation between the patients' age or sex and the efficacy of preoperative or postoperative assessment of vocal folds using TLUSG. In addition, we found no significant difference in vocal fold visualization between women and men preoperatively (OR, 1.80; 95% CI, 0.95-3.43; $P = .07$) or postoperatively (OR, 1.50; 95% CI, 0.79-2.85; $P = .21$).

Discussion

Use of ultrasonography in vocal fold assessment has been studied by many researchers since 1964.[21-28] Ultrasonography was proposed as an alternative to flexible fiberoptic laryngoscopy because it is less expensive and causes less discomfort to the patient. Some studies[15-17] supported its use as an accurate method for preoperative assessment of the vocal folds in the Asian population. However, a study performed in Australia[29] concluded that TLUSG is not reliable as an alternative to laryngoscopy in assessing vocal folds and reported a TLUSG sensitivity of 62%. A recent multi-institutional study[19] suggested the use of TLUSG as a screening option instead of laryngoscopy despite showing a low rate of visualization (17%) in men compared with women (83%). The authors concluded that the main obstacles in vocal fold visualization by TLUSG are thyroid cartilage calcification and male sex, whereas no correlation was found between BMI and vocal fold visualization.

Previous studies have reported that vocal folds are assessed more easily by TLUSG in female and young patients,[15] which we were not able to demonstrate in our study group of a US population. However, we were able to demonstrate that patient BMI significantly affected the sensitivity and specificity of TLUSG in assessment of vocal fold function. This effect might explain the higher sensitivity of TLUSG in an Asian population with lower BMI compared with a US population.

Preoperative TLUSG missed 6 of 13 patients with VFP; postoperative TLUSG missed 12 of 27 patients. Mistaking VFP has a more profound impact than missing a mobile vocal fold because VFP affects the patient's prognosis and may delay referral for evaluation by experienced speech-language pathologists. We found that TLUSG was not accurate in assessing impairment of vocal fold motion, which may be an important factor in surgical planning for some surgeons.[19,29] Other vocal fold abnormalities that cause hoarseness and may be misdiagnosed as a VFP, such as bowing, polyps, hematoma from intubation, and, although rare, vocal fold cancer, cannot be detected by TLUSG. The air in the larynx and subglottic spaces may be a barrier owing to the air-tissue interface that can affect the accuracy of ultrasonographic images. Calcification of the thyroid cartilage seen in old age was reported as an obstacle to its use in older patients.

Studies that proposed the use of ultrasonography as an alternative to laryngoscopy in assessing vocal folds in most patients have concluded that ultrasonography could not replace laryngoscopy completely.[15-17,19] Some studies[15,16,30] report that TLUSG can be used to select patients who will need further testing with laryngoscopy. Another study[17] documented that TLUSG can be used when the laryngoscope is unavailable or when radiologists or surgeons are relatively inexperienced with laryngoscopy.

In our study, a single endocrine surgeon with 8 years of experience in ultrasonography and laryngoscopy performed all of the TLUSG and flexible fiberoptic laryngoscopy procedures. We compared the percentage of vocal folds correctly detected between the first and last 125 patients. We found that more vocal folds were correctly detected in the earlier group of patients compared with the later group preoperatively and postoperatively (**Table 3**). This finding suggests that increased experience with the TLUSG examination does not improve the test outcomes. All of our patients undergo routine preoperative ultrasonography and laryngoscopy as part of their preoperative surgical evaluations. We used a 12-MHz linear transducer to perform the TLUSG; other studies used 5- to 10-MHz,[15] 5- to 12-MHz,[16] and 7- to 18-MHz[17] linear array transducers. The 5- to 10-MHz linear transducer seemed to provide the best imaging results. Also, using a lateral approach for unilateral TLUSG that was described by Dedecjus et al[18] seems to provide better visualization of the vocal folds, especially in male patients or patients with ossification of the thyroid cartilage.

One of the shortcomings of this study is the low number of patients with preoperative and postoperative VFP, which may affect the data on TLUSG sensitivity in the assessment of VFP. This smaller number also makes the positive predictive values small. Other shortcomings may include the surgeon's prior knowledge of the patient's vocal symptoms, whereas blinding might avoid any possibility of observer bias; lack of

assessment of the performance of the ultrasonography, which is operator dependent; and the lack of comparison between different ultrasonographic devices and probe modalities.

Conclusions

We found no significant difference in the ability of TLUSG to visualize vocal fold function in both sexes and all age groups. The sensitivity and specificity of TLUSG in assessing vocal fold function are significantly decreased in patients with a BMI of 25 or greater. In addition, postoperative changes may have contributed to the decreased accuracy of TLUSG because assessment of vocal fold function was much more difficult after surgery. Surgeon-performed TLUSG should not be considered a replacement for the current practice of flexible fiber optic laryngoscopy to evaluate vocal folds in patients undergoing thyroid and parathyroid surgery.

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REFERENCES

1. McIvor NP, Flint DJ, Gillibrand J, Morton RP. Thyroid surgery and voice-related outcomes. *Aust N Z J Surg*. 2000;70(3):179-183.

2. Roubeau B, Chevrie-Muller C, Lacau Saint Guily J. Electromyographic activity of strap and cricothyroid muscles in pitch change. *Acta Otolaryngol*. 1997;117(3):459-464.

3. Jones MW, Catling S, Evans E, Green DH, Green JR. Hoarseness after tracheal intubation. *Anaesthesia*. 1992;47(3):213-216.

4. Jeannon JP, Orabi AA, Bruch GA, Abdalsalam HA, Simo R. Diagnosis of recurrent laryngeal nerve palsy after thyroidectomy: a systematic review. *Int J Clin Pract*. 2009;63(4):624-629.

5. 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;139(3):357-362.

6. Farrag TY, Samlan RA, Lin FR, Tufano RP. The utility of evaluating true vocal fold motion before thyroid surgery. *Laryngoscope*. 2006;116(2):235-238.

7. Abadin SS, Kaplan EL, Angelos P. Malpractice litigation after thyroid surgery: the role of recurrent laryngeal nerve injuries, 1989-2009. *Surgery*. 2010;148(4):718-722.

8. 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;395(4):327-331.

9. Hong KH, Kim YK. Phonatory characteristics of patients undergoing thyroidectomy without laryngeal nerve injury. *Otolaryngol Head Neck Surg*. 1997;117(4):399-404.

10. Debruyne F, Ostyn F, Delaere P, Wellens W. Acoustic analysis of the speaking voice after thyroidectomy. *J Voice*. 1997;11(4):479-482.

11. Debruyne F, Ostyn F, Delaere P, Wellens W, Decoster W. Temporary voice changes after uncomplicated thyroidectomy. *Acta Otorhinolaryngol Belg*. 1997;51(3):137-140.

12. Schlosser K, Zeuner M, Wagner M, et al. Laryngoscopy in thyroid surgery: essential standard or unnecessary routine? *Surgery*. 2007;142(6):858-864.

13. Haugen BR, Alexander EK, Bible KC, et al. American Thyroid Association management guidelines for adult patients with thyroid nodules and differentiated thyroid cancer [published online October 14, 2015]. *Thyroid*. 2015. doi:10.1089/thy.2015.0020.

14. Chandrasekhar SS, Randolph GW, Seidman MD, et al; American Academy of Otolaryngology–Head and Neck Surgery. Clinical practice guideline: improving voice outcomes after thyroid surgery. *Otolaryngol Head Neck Surg*. 2013;148(6)(suppl):S1-S37.

15. 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. *Surgery*. 2013;154(6):1158-1164.

16. 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;36(10):2509-2515.

17. Wang CP, Chen TC, Yang TL, et al. Transcutaneous ultrasound for evaluation of vocal fold movement in patients with thyroid disease. *Eur J Radiol*. 2012;81(3):e288-e291.

18. Dedecjus M, Adamczewski Z, Brzeziński J, Lewiński A. Real-time, high-resolution ultrasonography of the vocal folds: a prospective pilot study in patients before and after thyroidectomy. *Langenbecks Arch Surg*. 2010;395(7):859-864.

19. Carneiro-Pla D, Miller BS, Wilhelm SM, et al. Feasibility of surgeon-performed transcutaneous vocal cord ultrasonography in identifying vocal cord mobility: a multi-institutional experience. *Surgery*. 2014;156(6):1597-1602.

20. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA*. 2014;311(8):806-814.

21. Menschi B. Analysis by ultrasonic exploration of the movement of isolated vocal cords [in French]. *C R Seances Soc Biol Fil*. 1964;158:2295-2296.

22. Kaneko T, Kobayashi N, Asano H, et al. Ultrasonoglottography [in French]. *Ann Otolaryngol Chir Cervicofac*. 1974;91(7-8):403-410.

23. Hertz CH, Lindström K, Sonesson B. Ultrasonic recording of the vibrating vocal folds: a preliminary report. *Acta Otolaryngol*. 1970;69(3):223-230.

24. Holmer NG, Kitzing P, Lindström K. Echo glottography: ultrasonic recording of vocal fold vibrations in preparations of human larynges. *Acta Otolaryngol*. 1973;75(5):454-463.

25. Raghavendra BN, Horii SC, Reede DL, Rumancik WM, Persky M, Bergeron T. Sonographic anatomy of the larynx, with particular reference to the vocal cords. *J Ultrasound Med*. 1987;6(5):225-230.

26. Wolfson VP, Laitman JT. Ultrasound investigation of fetal human upper respiratory anatomy. *Anat Rec*. 1990;227(3):363-372.

27. Garel C, Contencin P, Polonovski JM, Hassan M, Narcy P. Laryngeal ultrasonography in infants and children: a new way of investigating: normal and pathological findings. *Int J Pediatr Otorhinolaryngol*. 1992;23(2):107-115.

28. Ooi LL. B-mode real-time ultrasound assessment of vocal cord function in recurrent laryngeal nerve palsy. *Ann Acad Med Singapore*. 1992;21(2):214-216.

29. 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;71(12):737-739.

30. Amis RJ, Gupta D, Dowdall JR, Srirajakalindini A, Folbe A. Ultrasound assessment of vocal fold 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;21(4):493-498.