



Comparison of Laryngeal Ultrasound and Cuff Leak Test to Predict Post-Extubation Stridor in Total Thyroidectomy

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Cite this article as: Bhargava T, Kumar A, Bharti A, Khuba S. Comparison of Laryngeal Ultrasound and Cuff Leak Test to Predict Post-Extubation Stridor in Total Thyroidectomy. *Turk J Anaesthesiol Reanim.* 2021; 49(3): 238-243

Abstract

Objective: Prediction of post-extubation stridor (PES) after thyroid surgeries has been challenging, and many criteria such as preoperative clinical parameters and intraoperative cuff leak test (CLT) have been used with variable results. The application of laryngeal ultrasound in predicting PES is a relatively new and non-invasive technique. Measurement of the air column width difference (ACWD) by laryngeal ultrasonography can predict PES. This study aimed to evaluate the efficacy of laryngeal ultrasound in the prediction of PES in patients after thyroidectomy and compare it with that of the CLT.

Methods: A total of 200 patients who had undergone total thyroidectomy under general anaesthesia in a tertiary healthcare hospital were enrolled in the study. At the end of the surgery, air column widths (ACWs) were measured during endotracheal cuff inflation and deflation using laryngeal ultrasound in patients with spontaneous breathing. ACWD was measured and compared with that of the CLT at the time of extubation to predict PES.

Results: A total of 12 (6%) patients developed PES. ACWD using laryngeal ultrasound and CLT showed high sensitivity (91.7% and 92.6%, respectively), specificity (91.7% and 90.4%, respectively) and negative predictive value (99.43% and 99.42%, respectively) with low positive predictive value (44% and 37.93%, respectively) for both the diagnostic tests.

Conclusion: Application of laryngeal ultrasound in combination with CLT can help the anaesthesiologist in decision making with the extubation plan after thyroid surgeries.

Keywords: Air column width, cuff leak test, laryngeal ultrasound, post-extubation stridor, thyroidectomy, tracheomalacia

Introduction

Thyroid surgeries and their perioperative complications have decreased over the decades owing to improved surgical and anaesthesia techniques. Post-thyroidectomy stridor is a rare and dreaded postoperative complication of thyroid surgeries.^{1,2} It is a clinical marker for underlying airway narrowing. Longstanding compression can cause destruction or weakening of the cartilaginous rings of the trachea leading to poor support of the trachea resulting in tracheomalacia. Tracheomalacia is a complex clinical condition with no universally accepted definition. Although definite criteria are lacking, information from radiological imaging studies suggest a 50% reduction of the tracheal lumen as a prerequisite for its diagnosis.¹ Tracheomalacia can lead to post-extubation stridor (PES) and respiratory distress. Early diagnosis of post-thyroidectomy stridor is essential because these patients are at a higher risk of extubation failure.

Cuff leak test (CLT) is a non-invasive and easily performed clinical test that has been traditionally used to predict airway narrowing in intubated patients. Many studies have questioned the applicability of CLT as a routine test because of varied specificity and sensitivity.³

Laryngeal ultrasound is a relatively new and non-invasive method of examining the airway anatomy. The ultrasound can analyse the laryngeal anatomy in intubated patients, and the dynamic changes in the laryngeal air column during balloon inflation and deflation can be easily appreciated. Variations in the air column dimensions reflect the changes of air leak and airflow around the endotracheal tube. This study aimed to identify the risk of developing PES in patients planned for total thyroidectomy using laryngeal ultrasound and comparing it with the CLT.⁴

Methods

This prospective study was conducted in a tertiary care medical centre. After obtaining institutional Sanjay Gandhi Post Graduate Institute of Medical Sciences Ethics Committee approval (2016-56-MD-90), written informed consent was taken from all the patients. The study was registered with the Clinical Trial Registry of India (reference-CTRI/2019/10/021587) before the commencement of the study. There is a wide variability in the incidence of PES in different clinical scenarios. The sample size calculation was carried out on the basis of previous literature.⁵ The effect size of the study was estimated by the Hedges' method. The Hedges' method requires sample sizes of both groups (with and without laryngeal oedema) and mean and standard deviation of air column width difference (ACWD) of the previous study. The effect size was estimated to be 1.14, which depicts a large difference effect. Considering a power of 80% and type I error of 0.05, the sample size was estimated to be 195. The study population included 200 American Society of Anesthesiologists I and II patients in the age group of 18–60 years of both sexes with thyroid masses planned for elective total thyroidectomy. Refusal to give consent, documented vocal cord (VC) abnormalities and redo neck explorations were excluded from the study. All the patients who were enrolled for the study underwent primary preanaesthetic examination as per the institutional protocol. All the participants received 150 mg oral ranitidine on the night before surgery. In the operating room, an intravenous line was secured, and fentanyl was administered

at 2 µg kg⁻¹. Induction of general anaesthesia was carried out with 1.5–2 mg kg⁻¹ propofol, and muscle relaxation was achieved by 0.12 mg kg⁻¹ vecuronium bromide after confirming bag and mask ventilation. Endotracheal intubation was performed by inhalational induction with the preservation of spontaneous respirations in case of the anticipated difficult airway. Anaesthesia was maintained with 50% air in oxygen and sevoflurane. Intermittent doses of 0.01 mg kg⁻¹ vecuronium bromide were administered according to subjective train-of-four (TOF) monitoring to maintain a moderate neuromuscular blockade. Analgesia was achieved with an intermittent intravenous dose of 1–2 µg kg⁻¹ fentanyl. Normocarbica (end-tidal CO₂ 35–40 mmHg) was maintained by adjusting the minute ventilation. The duration of surgery was recorded that was defined as the time between skin incision and wound closure. Neuromuscular blockade monitoring was achieved using TOF monitoring. At the end of the surgery, the reversal of neuromuscular blockade was performed with neostigmine and glycopyrrolate. After the return of spontaneous respiration with full recovery from the neuromuscular block (TOF count of 4 and subjective TOF ratio >0.9), a minimum alveolar concentration of 0.7 was maintained with sevoflurane.

The CLT was performed as previously described in the literature.⁶ The patient was switched to the assist-control mode of ventilation with 5 cm of H₂O of positive end-expiratory pressure, and the tidal volume was adjusted until the peak airway pressure was up to 16–20 cm of H₂O. After gentle suctioning of the oral secretion, the endotracheal tube cuff was deflated. The lowest 3 exhaled volumes were noted and averaged.

Gentle oral and endotracheal suctioning was performed before the measurement to prevent the alterations of cuff leak volume and flow owing to the pooling of secretions around the endotracheal tube. When deflating the cuff of the endotracheal tube, the patient may cough, increasing the leak volume and air column width (ACW). To reduce this error in measurements, the patients were kept sedated while the tests were being performed, and the data were collected during the period without cough. The cuff leak volume is defined as the difference between the preset inspiratory tidal volume (6 mL kg⁻¹ ideal body weight) and the mean of the lowest 3 exhaled volumes.

Laryngeal ultrasound was performed with SonoSite M-turbo portable USG machine (Fujifilm SonoSite Inc., Bothell, WA, USA) equipped with a 5–13 MHz probe. The patients were placed in the sniffing position by placing a pillow under the occiput. Laryngeal ultrasound was performed by a single experienced anaesthesiologist who was blinded to the findings of CLT. The probe was placed on the cricothyroid membrane with a transverse view of the larynx. The standard scanning

Main Points:

- Post-extubation stridor is a rare and dreadful complication of total thyroidectomy.
- The laryngeal ultrasound is a simple and non-invasive technique for preventing airway complications.
- The air column width difference measured by laryngeal ultrasound helps predict airway narrowing after resection of long standing thyroid mass.
- The laryngeal ultrasound has high sensitivity and specificity in predicting post extubation stridor and can be used to plan post thyroidectomy extubation.

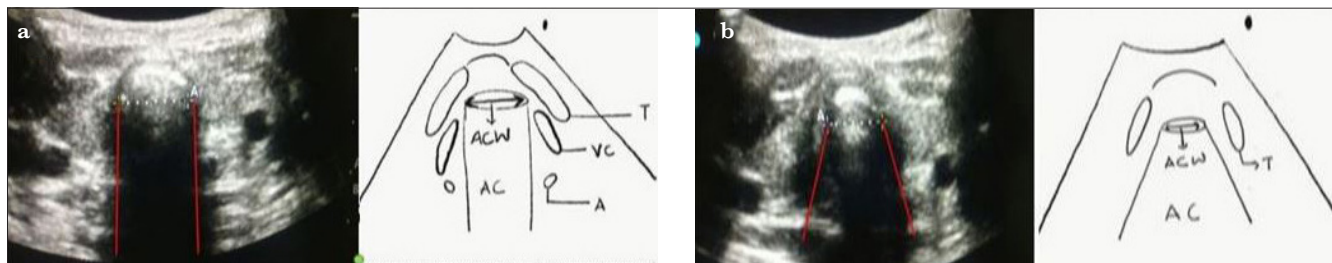


Figure 1. a, b. The ultrasound image and schematic diagram of air column width difference at endotracheal cuff deflation and inflation. (a) The ultrasound image shows a square-shaped air column with hyperechoic air column bands and acoustic shadows on balloon inflation. Paired hypoechoic true cords are over both sides of the air column. The schematic diagram on the right shows typical structures visualised in laryngeal ultrasound. Hyperechoic arytenoid cartilages are behind the true vocal cords and beside the air column. (b) Ultrasound image of the laryngeal air column during balloon-cuff deflation in the same patient who did not develop post-extubation stridor. The air column became trapezoid in shape and the air column width decreased. The arytenoids and part of the vocal cords are not visible owing to the acoustic shadows

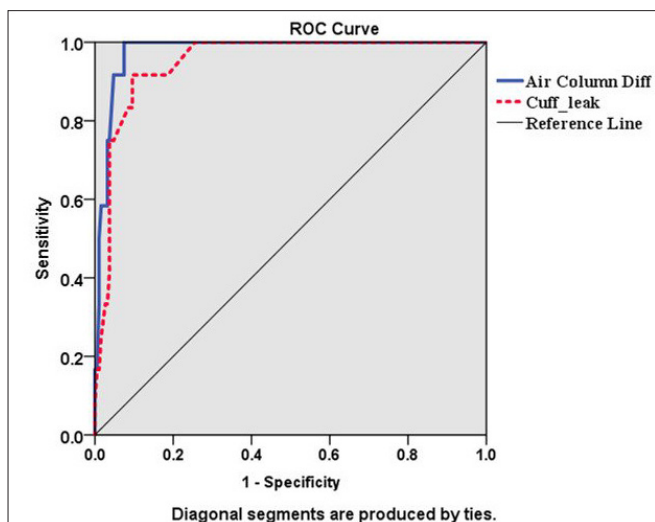


Figure 2. Receiver operating characteristic curve of air column width difference (blue) and one for the cuff leak test (red) obtained by measuring the air leak around the endotracheal tube

plane was predetermined, which contained several landmarks, including the VCs, false cords, thyroid cartilage and arytenoids cartilage, to avoid examination bias (Figure 1a).

Using ultrasonography, the ACW, which is defined as the width of the acoustic shadow present at the level of the VCs, was measured. The ACW was measured before and after endotracheal cuff deflation, and the ACWD was calculated. The measurements were taken after the oral and laryngeal secretions were suctioned, and all the settings were the same as the CLT.

Measurements were first taken with the endotracheal cuff inflated. The ultrasound probe was placed at the level of the cricothyroid membrane, and the standard scanning plane

was then visualised. The VCs were delineated sonographically in the transverse plane, and the acoustic shadow was demonstrated and measured. The air column was square-shaped, and the ACW was measured (Figure 1a). The arytenoid cartilage was visible when the cuff balloon was inflated. In contrast, the air column became trapezoidal and masked the arytenoid cartilage when the balloon cuff was deflated. The width of the top of the trapezoidal air column was measured (Figure 1b). The difference in ACW was measured, and ACWD was calculated.⁴ The ACWD was the width difference between balloon-cuff inflation and balloon-cuff deflation. The ACWD was recorded and averaged over 3 respiratory cycles. The patients were extubated after fulfilling the extubation criteria with a complete reversal of neuromuscular blockade (TOF>0.9) and observed for the development of PES. The patients with stridor were considered as the stridor group, whereas the patients who did not develop PES were the non-stridor group. PES was defined as respiratory distress occurring immediately after extubation characterised by inspiratory sounds of whistling, wheezing or grunting.

Statistical analysis

The IBM Statistical Package for Social Sciences version 20.0 (IBM SPSS Corp.; Armonk, NY, USA) was used for statistical analysis. Quantitative data were presented in terms of mean±standard deviation, and frequency and percentage measures of diagnostic accuracy were analysed using the receiver operating characteristic (ROC) curve and cross-table analysis. A comparison of ACWD and cuff leak volume was done using the Wilcoxon signed-rank test. The value *P* < 0.05 was considered significant.

Results

A total of 200 patients with longstanding thyroid mass were included in the study. No eligible patients required exclusion

Table 1. Area Under the Receiver Operating Characteristics Curve

SN	Test result variable(s)	Area	P	95% CI	
				Lower bound	Upper bound
1	Air column width difference	0.977	0.000	0.957	0.997
2	Cuff leak volume	0.950	0.000	0.910	0.989

CI: confidence interval. The test result variable(s): Air column width difference and cuff leak volume have at least 1 tie between the positive actual state group and the negative actual state group.

Table 2. Sensitivity, Specificity, FNR, FPR and Likelihood Ratio of CLT and Laryngeal Ultrasound in Predicting PES at the Cut-Off Value

Test result variable(s)	Sensitivity	Specificity	FNR	FPR	LR+	LR-	Overall accuracy
Air column width difference (in cm)							
1.00	0.917	0.926	0.083	0.074	12.392	0.089	0.925
Cuff leak (in mm)							
162.0	0.917	0.904	0.083	0.096	9.552	0.000	0.905

FNR: false-negative ratio; FPR: false-positive ratio; LR: likelihood ratio; CLT: cuff leak test; PES: post-extubation stridor

Table 3. Patient Characteristics and Variables

Variables	Distribution of study variables (n=200)	
	Stridor (n=12)	Non-stridor (n=188)
Age (years)	46±17.78	45±14
Sex		
Male	3	60
Female	9	128
Duration of mass (years)	11±7.9	8±6.7
Body mass index (kg m ⁻²)	23.65±3.4	22.7±3.8
Duration of surgery (minutes)	140±58	130±43

Data presented as median (interquartile range)

from this study. The sample included predominantly female (69%) (n=137), and 31% (n=63) were male. The average duration of the surgery was 140±58 minutes in the stridor group and 130±43 minutes in the non-stridor group. Means were compared for ACWD between stridor (n=12) 0.29±0.026 and non-stridor (n=188) 0.13±0.03 groups by applying the independent t-test, and the result indicated that the means were statistically significantly different between the stridor and non-stridor groups (P < 0.05).

Of the 200 patients, 12 (6%) developed PES. The ROC curve revealed that ACWD measured by laryngeal ultrasound (Figure 2) (area under the curve [AUC]: 0.977; 95% confidence interval [CI]=0.957–0.997, P < 0.001) is a better diagnostic test than CLT (AUC: 0.950; 95% CI=0.910–0.989, P < 0.001) (Table 1).

The appropriate cut-off values of the diagnostic tests were identified by balancing sensitivity and specificity. The cut-off values for ACWD and CLT were determined to be 1 mm and 162 mL, respectively. ACWD of 1 mm has a sensitivity of 91.7%, a specificity of 92.6% and a positive likelihood ratio of 12.3. The cuff leak volume of 162 mL has a sensitivity of 91.7%, a specificity of 90.4% and a positive likelihood ratio of 9. A 2 by 2 table analysis was done to determine the positive predictive value and negative predictive value at the cut-off values (Table 2). There was no significant association of age, sex, body mass index, duration of thyroid mass and duration of surgery with the development of stridor in the patients (Table 3).

Discussion

PES is a troublesome complication of thyroid surgeries that can lead to serious postoperative complications, including difficult post-extubation ventilation, difficulty in maintaining oxygen saturation and difficult re-intubation.

Prolonged compression because of a longstanding mass can lead to weakening of the cartilaginous rings of the trachea, and removal of the compressive source (that is, thyroidectomy) may induce life-threatening airway collapse (particularly during expiration) causing PES and may require emergency tracheostomy. The incidence of tracheomalacia is variable ranging from 0% to 10%.² Tracheomalacia is a rare but potentially fatal complication seen in patients with a large thyroid mass with increased duration of mass and retrosternal extension of goitre. Other risk factors that can lead to PES include laryngeal oedema because of airway manipulation and VC paralysis during thyroid resection.

These complications often place the anaesthesiologists and surgeons in a dilemma regarding the postoperative management of these patients. Therefore, predicting the likelihood of developing PES is critically important. Assessment of preoperative and intraoperative risk factors has not resulted in formulating definite and conclusive criteria for predicting postoperative respiratory complications and the need for tracheotomy.^{7,8} There is no conclusive test to predict the postoperative respiratory complications after thyroidectomy. In this study, we evaluated 200 patients who underwent total thyroidectomy, and the incidence of stridor was 6%, which is similar to that of previous studies performed on patients in the intensive care unit.^{9,10} Among the various methods used for predicting PES, one is CLT. However, its sensitivity and specificity are variable as demonstrated in previous studies.^{8,11,12} These studies were conducted in patients admitted to critical care units who required a prolonged duration of mechanical ventilation. Another method to predict PES is laryngeal ultrasonography. Laryngeal ultrasound has been presumed to have a wide applicability in airway management, including prediction of PES.¹³ In this study, the ACWD on the laryngeal ultrasound and the cuff leak volume correlated with PES in patients undergoing thyroidectomy. Ultrasound can analyse the laryngeal anatomy in intubated patients and identify the laryngeal air column, and the changes in ACW during cuff inflation and deflation can be measured. The difference in the width of the column reflects the airflow or the change in air leak around the endotracheal tube. The air column thus measured by ultrasound represents the air passing through the VCs. When the cuff is deflated, there is an air leak around the peritubular space.

If the patient develops tracheomalacia or laryngeal oedema, the air leak around the deflated endotracheal tube is reduced; this can lead to postoperative stridor. These patients have lower ACWD resulting from the decreased airflow around the endotracheal tube, thus proving that the ACWD measured by the laryngeal ultrasound can potentially predict PES in patients after thyroidectomy. Most of the previous studies have described the ACWD and cuff leak cut-off values for predicting PES in critical care settings. El-Baradei et al.¹⁴ have conducted a similar study in 432 critically ill patients. A cuff leak volume of less than 200 mL and ACWD of less than 0.9 mm was the threshold value for predicting PES; for CLT and ACWD, the sensitivity was 94% and 91%, respectively, the specificity was 64% and 72%, respectively, the positive predictive value was 97% and the negative predictive value was 66% and 50%, respectively. Similarly, other studies^{5,15} have shown high sensitivity and specificity but varied positive and negative predictive values.

In our study, an ACWD by laryngeal ultrasound of less than 1 mm and cuff leak volume of 162 mL was the threshold for

predicting PES. They showed high sensitivity (91.7% and 92.6%, respectively), specificity (91.7% and 90.4%, respectively) and negative predictive value (99.43% and 99.42%, respectively), with low positive predictive value (44% and 37.93%, respectively) for both the diagnostic tests. Thus, an ACWD of 1 mm or above suggests that extubation is likely to be successful. However, neither a positive CLT nor a positive ACWD result can be used to delay extubation.

Application of laryngeal ultrasound in combination with a CLT can help the anaesthesiologist in decision making with the extubation plan after thyroid surgeries and prevent unnecessary delay in extubation and morbidities related to thyroid surgery.

This study was limited by subjective observations of sonography needing expertise, small sample size owing to the low incidence of the complication and heterogeneous thyroid diseases posted for surgery. Because of the low incidence of PES in thyroid surgeries, there is a need for further large sample-sized multicentre trials to explore the application of laryngeal ultrasound in predicting post-extubation airway complications in the thyroid surgeries.

Conclusion

Application of laryngeal ultrasound in conjunction with CLT can help the anaesthesiologists in decision making of the extubation plan after thyroid surgeries and guide the airway management during extubation. The applications of laryngeal ultrasound in thyroid surgeries should be explored further by large randomised controlled studies.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Sanjay Gandhi Post Graduate Institute of Medical Sciences (2016-56-MD-90, Date: 17.03.2016).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – A.B., S.K.; Design – T.B., A.K., A.B.; Supervision – A.B., S.K.; Resources – A.B., S.K.; Materials – T.B., A.K.; Data Collection and/or Processing – T.B., A.K.; Analysis and/or Interpretation – T.B., A.K.; Literature Search – T.B., A.K.; Writing Manuscript – A.K., T.B.; Critical Review – S.K., A.B.; Other (approval of final version of manuscript) – T.B., A.K., A.B., S.K.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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