Comparative Study Between Laryngeal Ultrasound and Cuff Leak Test in Predicting Post Extubation Airway Edema in Head and Neck Surgeries

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Abstract

Background: Complications arising from intubation or extubation, such as post-extubation edema, are among the leading causes of reintubation, extended mechanical ventilation, and increased morbidity. This study aimed to reduce the risk of post-extubation complications by comparing the predictive value of laryngeal ultrasound and the cuff leak test in detecting post-extubation airway edema in head and neck surgeries.

Methods: This prospective cross-sectional study was carried out on 40 patients aged more than 18 years old, both genders, undergoing head and neck surgeries, American Society of Anesthesiologists I and II, and intubated and mechanically ventilated for a minimum of 3 h. All patients were evaluated for risk of airway edema by both techniques (ultrasonography and cuff leak test before extubation).

Results: The ultrasound measurements of air column width difference air column width difference had better accuracy 95% with higher specificity 94.7% and positive predictive value (PPV) 50% while cuff leak volume difference accuracy was 85%, specificity 84.2% and PPV 25% in predicting post-extubation air way edema.

Conclusions: Ultrasonography serves as a valuable and non-invasive method for assessing the vocal cords and laryngeal structure in intubated patients. Measuring the air-column width via ultrasound can potentially pinpoint patients at risk for post-extubation stridor, indicating the need for careful monitoring after extubation.

Keywords: Laryngeal Ultrasound; Cuff Leak Test; Post Extubation Airway Edema; Head and Neck Surgeries

Introduction

Endotracheal intubation is a vital procedure which is indicated in several clinical situations [1]. Complications arising from intubation or extubation, such as post-extubation edema, are among the most common reasons for reintubation, extended mechanical ventilation, and heightened morbidity [2]

Factors that increase the risk of developing post-extubation edema include advanced age, female gender, the size of the endotracheal tube, use of a cuffed tube, prolonged intubation duration, existing airway diseases, traumatic intubation, tracheal aspiration, tube movement, and the patient resisting the endotracheal tube or attempting to speak [3]

Laryngeal ultrasound is a new and non-invasive way of examining the airway anatomy. The ultrasound can evaluate the laryngeal anatomy in intubated patients, and the dynamic changes in the laryngeal air column during balloon inflation and deflation. Variations in the air column dimensions reflect the changes of air leak and airflow around the endotracheal tube [4, 5].

Cuff leak test (CLT) is a non-invasive and easily performed clinical test that has been traditionally used to predict airway edema in intubated patients. Many studies have questioned the applicability of CLT as a routine test because of varied specificity and sensitivity [6].

The cuff leak test is performed when a patient is considered ready for extubation. It involves deflating the balloon cuff of the endotracheal tube to assess the air leak around the tube, providing an indirect evaluation of upper airway patency. A reduced cuff leak volume indicates a higher risk of developing post-extubation laryngeal edema. [7].

In our study, we tested the predictive value of laryngeal ultrasound versus CLT in post extubation airway edema in order to prevent such complications as much as possible.

The aim of this work was to decrease the risk of post extubation complications by evaluating the predictive value of Laryngeal ultrasound versus CLT in post extubation airway edema in head and neck surgeries.

Patients and Methods

This prospective cross-sectional study was carried out on 40 patients aged 18 years old or more, both sexes, undergoing head and neck surgeries, American Society of Anesthesiologists I and II, and intubated and mechanically ventilated for a minimum of 3 h.

An informed written consent was obtained from the patient or relatives of the patients. The study was done after approval from the Ethical Committee Suez Canal University Hospital approval code.: 5356

Exclusion criteria were patients who refused to participate in the study, who had vocal cord abnormalities and dysfunction, with laryngeal carcinoma, and having neck radiotherapy.

All patients were subjected to complete history taking [history of chronic diseases, allergies to any medications, history of hospitalization, history of previous operations and associated anesthetic complications, and fasting hours], and clinical examinations [Blood pressure, pulse, oxygen saturation, respiratory rate, temperature measurement, and chest, cardiac and abdominal examination].

All of the patients were intubated with a soft, high-volume, low- pressure cuffed endotracheal tube (ETT) with an internal diameter size of 6.5– 8 mm (7 mm for females and 7, 5 mm for males).

Cuff pressures were measured using an aneroid manometer, with a TT cuff pressure of 20–30 cm of water considered the standard for intubation. Since the number of intubation attempts increases the risk of airway edema, the procedure was performed by professional anesthesiologist. Patients requiring more than two attempts were excluded from the study. Normocarbia (end-tidal CO2 35–40 mmHg) was maintained by adjusting the minute ventilation,

At the conclusion of the surgery, neuromuscular blockade was reversed. Once spontaneous respiration resumed, procedures were monitored while the patient remained sedated by prolonging anesthesia to prevent coughing on the tube. During extubation, a minimum alveolar concentration of 0.7 was maintained using sevoflurane.

Cuff leak test:

The procedure was performed according to the protocol proposed by Miller & Cole [8]. Prior to the test measurement, oral and endotracheal secretions were suctioned. The ventilators were set to assist-control mode with 5 cmH2O of positive end-expiratory pressure, and the tidal volume (VT) was adjusted to achieve a peak airway pressure of 16-20 cmH2O. Tidal volumes were recorded with the cuff both inflated and deflated. Six consecutive breath cycles were measured, and the average value was calculated. The leak volume, defined as the difference between the pre-set inspiratory tidal volume (6 mL/kg ideal body weight) and the calculated average value, was used to predict post-extubation stridor, with a cut-off value of less than 200 mL.

Laryngeal ultrasound:

The laryngeal US was performed with a Philips InnoSight ultrasound machine, a low frequency liner probe was used for the visualization of the vocal cords according to the protocol described by Ding et al. [9]. Patients were positioned in the sniffing position by placing a pillow under the occiput. The ultrasound probe was placed on the cricothyroid membrane to obtain a transverse view of the larynx. The predetermined standard scanning plane included landmarks such as the vocal cords, false cords, thyroid cartilage, and arytenoid cartilage.

Using ultrasonography, the air column width (ACW), defined as the width of the acoustic shadow at the level of the vocal cords, was measured before and after deflating the endotracheal cuff. The air column width difference (ACWD) was then calculated. Measurements were taken after suctioning oral and laryngeal secretions, with all settings identical to those used for the cuff leak test (CLT).

Initial measurements were taken with the endotracheal cuff inflated. The vocal cords (VCs) were visualized sonographically in the transverse plane, and the acoustic shadow was measured. The air column appeared square-shaped, and the air column width (ACW) was recorded, with the arytenoid cartilage visible when the cuff balloon was inflated. When the balloon cuff was deflated, the air column became trapezoidal, obscuring the arytenoid cartilage. The width of the top of the trapezoidal air column was measured. The difference in ACW, known as the air column width difference (ACWD), was calculated as the width difference between balloon-cuff inflation and deflation. The ACWD was recorded and averaged over three respiratory cycles, with a cut-off value of less than 0.9 mm used to predict post-extubation stridor.

Measurements:

If the patient had Post extubation edema, he was recorded as positive. While if not occurred, he was recorded as negative. Variables suspected to be correlated to post-extubation stridor (PES) was assessed, as: Age, gender, BMI, comorbidities, intubation duration, cuff-leak volume, and air-column difference. Comparisons between non-stridor and stridor groups was assessed.

Sample Size:

n= sample size

Zα/2 = 1.96 (The critical value that divides the central 95% of the Z distribution from the 5% in the tail).

E = 0.1 (margin of error at 90% confidence interval).

P = 0.06= prevalence of PES [10].

SP = 0.904= Specificity of Cuff leak (in mm) [10].

By equation, n= 36 and after adding 10% for drop out, the total sample size was 40 patients.

Statistical analysis

Statistical analysis was done by SPSS v27 (IBM©, Armonk, NY, USA). Shapiro-Wilks test and histograms were used to evaluate the normality of the distribution of data. Quantitative parametric data were presented as mean and standard deviation (SD) and were analysed by unpaired student t-test. Quantitative non-parametric data were presented as the median and interquartile range (IQR) and were analysed by Mann Whitney-test. Qualitative variables were presented as frequency and percentage (%) and analysed using the Chi-square test or Fisher's exact test when appropriate. Diagnostic specificity measures the incidence of true negative results in a non-diseased

group. Positive Predictive value (PPV) is the percentage of true positive results among total positive results. Negative Predictive value (NPV) is the percentage of true negative results among total negative results. A two-tailed P value < 0.05 was considered statistically significant.

Results

A total of 40 patients were recruited as one group, 15 were males (37.5%) and 25 females (62.5%), age < 40 was 14(35.0%) and >40 was 26(65.0%). Age was with mean value 48.43 ± 13.09, and mean BMI was 28.65 ± 3.91. 32 (80%) had cuff leak volume ≥200 while 8 (20%) had CLT <200 with mean 231.0 ± 60.50, 36(90%) had ACWD ≥0.9 while 4 (10%) only had ACWD <0, 9 with mean 1.30 ± 0.44. PES was 2 (5%) and no PES was 38 (95%). Intubation duration was with mean value 5.33±1.16, and o2 saturation post extubation was with mean 96.07 ± 2.30. **Table 1**

Table 1: Distribution of the studied cases according to demographic data, air column difference, cuff leak volume, PES, intubation duration, and o2 saturation post extubation (n=40)

		Patients (n = 40)
Age (years)	**<40**	14 (35.0%)
	>40	26 (65.0%)
	Mean ± SD.	48.43 ± 13.09
	Median (IQR)	51.0 (36.50 – 60.50)
Gender	**Male**	15 (37.5%)
	Female	25 (62.5%)
BMI (kg/m^2)	**Mean ± SD.**	28.65 ± 3.91
	Median (IQR)	29.0 (25.0 – 32.0)
Cuff leak volume (ml)	**≥200**	32 (80.0%)
	<200	8 (20.0%)
	Mean ± SD.	231.0 ± 60.50
	Median (IQR)	230.0 (200.0 – 280.0)
ACWD (mm)	**≥0.9**	36 (90.0%)
	<0.9	4 (10.0%)
	Mean ± SD.	1.30 ± 0.44
	Median (IQR)	1.20 (1.0 – 1.60)
PES		2 (5.0%)
Intubation duration (hours)	**Mean ± SD.**	5.33 ± 1.16
	Median (IQR)	5.0 (4.0 – 6.0)
o2 saturation post extubation	**Mean ± SD.**	96.07 ± 2.30
	Median (IQR)	96.0 (96.0 – 97.0)

Data are presented as mean ± SD, frequency (%) or median (IQR). IQR: interquartile range, BMI: Body mass index, ACWD: air column width difference, PES: post-extubation stridor.

Table 2 shows comparison between the accuracy of ACWD and CLT where ACWD show Sensitivity and Specificity of (100% and 94.74%) respectively and PPV and NPV of (50% and 100%) respectively with cut of point of 0.9 mm, while the CLT show Sensitivity and Specificity of (100% and 84.21`%) respectively and PPV and NPV of (25% and 100%) respectively with cut of point of 200 ml, difference between the two procedures was in favor of air column difference regarding specificity, and positive predictive value. Only 2 patients of 40 developed post extubation airway edema, both had ACWD below 0.9 mm (cut point), while the 38 patients who had no post extubation airway edema had ACWD above 0.9 mm.

Table 2: Agreement (sensitivity, specificity and accuracy) according to Cuff leak volume (ml) and air column difference (n=40)

		PES		Sensitivity	Specificity	PPV	NPV	Accuracy
		No (n= 38)	Yes (n= 2)					
Air column difference (mm)	**≥0, 9**	36 (94.7%)	0 (0.0%)	100.0	94.74	50.0	100.0	95.0
	<0, 9	2 (5.3%)	2 (100.0%)					
Cuff leak volume (ml)	**(≥200)**	32 (84.2%)	0 (0.0%)	100.0	84.21	25.0	100.0	85.0
	<200	6 (15.8%)	2 (100.0%)					

Data is presented as frequency (%). PPV: positive predictive value, NPV: negative predictive value.

ACWD is more accurate (95%) than cuff leak volume difference (85%) in predicting post extubation air way edema, which shows no statistically significant difference between the two methods in accuracy. **Table 3**

Table 3: Comparison between the 2 methods according to Their accuracy to detect PES

	ACWD	Cuff leak volume (ml)	p
Stridor	38 (95.0%)	34 (85.0%)	0.263

Data is presented as frequency (%). ACWD: air column width difference.

Distribution of the studied cases according to difficult intubation, 34 (85%) were easy intubation while 6(15%) were difficult intubation, both patients who developed PES were easy intubation. Distribution of the studied cases according to type of surgery, both patients who developed PES underwent total thyroidectomy. **Table 4**

Table 4: Distribution of the studied cases according to difficult intubation, and type of surgery (n=40)

		N (%)	PES
Difficult intubation		6 (15.0%)	0
Type of surgery	**Mandibular fracture**	9 (22.5%)	0
	Total thyroidectomy	6 (15.0%)	2
	Brain tumor excision	6 (15.0%)	0
	Hemithyroidectomy	5 (12.5%)	0
	Subtotal thyroidectomy	3 (7.5%)	0
	Face squamous cell carcinoma excision	2 (5.0%)	0
	Functional endoscopic sinus surgery	2 (5.0%)	0
	Suprasellar mass excision	2 (5.0%)	0
	Tympanoplasty	2 (5.0%)	0
	Brain meningioma excision	1 (2.5%)	0
	Fracture mandible	1 (2.5%)	0
	Transsphenoidal hypophysectomy	1 (2.5%)	0

Data is presented as frequency (%). PES: post-extubation stridor.

Discussion

Endotracheal intubation is used in a variety of clinical conditions, including acute respiratory failure, airway protection in upper airway obstruction, and patients at risk of aspiration, most commonly due to disturbed mental status. Furthermore, several surgical procedures require elective intubation [11].

Some issues that can lead to reintubation include post-extubation laryngeal edema. Intubation takes longer when there is laryngeal edema [12]. PES is an indication of laryngeal edema. The reported prevalence of post-extubation airway edema ranges from 4% to 37% [2].

According to type of surgery in our study, both patients who developed PES underwent total thyroidectomy. A study conducted by Tsai et al. [13] showed that patients with PES had a longer length of intubation compared to those without PES. The findings corroborated the previously established association between prolonged intubation and the likelihood of post-extubation stridor (PES). A particular study revealed that patients who underwent total thyroidectomy in the operating room exhibited a PES incidence of up to 6%. This suggests that even a relatively brief period of tracheal intubation can lead to PES. (e.g., 130-140 minutes) can lead to PES in the operating room. Therefore, it is advisable to consider utilizing sonography-measured ACWD for individuals who have head and neck procedures before removing the breathing tube, regardless of how long they have been intubated. This can help improve patient safety.

In our study, the PES occurred in only 2 cases (5%) similarly in Tsai et al. [13] meta-analysis aiming to assess the diagnostic accuracy of ultrasound-measured laryngeal ACWD in predicting PES in intubated adult patients, found the incidence of PES among the studies was 4–25%.

Higher rate was reported in Bhargava et al. [10] study among 200 patients who had undergone total thyroidectomy under general anaesthesia in a tertiary healthcare hospital were registered in the study, A total of 12 (6%) patients developed PES.

In a recent study by Hassanen et al. [14] in Egypt, the number of patients examined was 75 intubated patients, 18.7% of the cases had PES representing 14 cases. The other 81.3% of the cases had no signs of PES.

In our study, 36 (90%) had ACWD ≥0.9 while 4 (10%) only had ACWD <0, 9 ranged from 0, 30-2, 20 with mean 1.30 ± 0.44, ACWD show high Sensitivity and Specificity of (100% and 94, 74%) respectively and PPV and NPV of (50% and 100%) respectively with cut of point of 0.9 mm.

Similarly, Zytoun et al. [15] mentioned a cutoff point of 0.9 mm change in ACWD (ACWD at vocal cords) was identified (P<0.001), below which a high probability of developing PES was noticed. The sensitivity and specificity of ACWD below or equal to 0.9 mm were 80% and 90% in predicting PES, respectively, with a negative predictive value of 0.931 and a positive predictive value of 0.727.

With lower values, In Mohammad et al. [16] study who aimed to estimate the efficiency of the CLT vs. laryngeal U/S in identifying PES, ACWD was a significant predictor of PES incidence at Cut off value ≤0.8 mm, P=0.02 with 71.43% sensitivity, 78.33 % specificity, 43.5 % PPV, and 92.2 % NPV.

In contrast, Tsai et al. [13] meta-analysis, the cut-off values of ACWD for prediction of PES varied from 0.45 to 1.6 mm. The pooled sensitivity and specificity of ACWD for PES were 0.8 and 0.81, respectively. Patients with PES had a smaller ACWD compared to those without PES.

CLT is employed as an indirect method to examine the openness of the upper airway. It involves deflating the balloon cuff of the endotracheal tube to evaluate the leakage of

air around the tube. A decreased cuff-leak volume points to a population that is more expected to develop PES. Nevertheless, there is a significant disparity in the threshold value of the cuff-leak volume observed in prior research, and these conflicting findings can pose challenges for physicians when making judgments about extubation if the CLT yields positive results [14].

In our study, the CLT show Sensitivity and Specificity of (100% and 84, 21`%) respectively and PPV and NPV of (25% and 100%) respectively with cut of point of 200 ml.

The PES prediction cut-off factors for CLT are still the subject of debate. According to Hassanen et al. [14] data, the cut-off point of 110 ml had a sensitivity of 68%, specificity of 89.0, PPV of 69% and NPV of 87%. p value was (0.0016).

However, Mikaeili et al. [17] shown that CLT 249 mL, which is significantly higher than the recommended values in previous studies, exhibited good sensitivity and NPV but low PPV.

Similarly, Mohammad et al. [16] observed that CLT was sensitive in predicting PES (73.33%). In addition, the low PPV values for CLT methodologies may indicate that they are unable to reliably evaluate PES.

In contrast, regarding Schnell et al. [18] the CLT had poor diagnostic accuracy: sensitivity ranged from 27% to 46%, specificity from 70% to 88%, positive predictive values from 14% to 19%, and negative predictive values from 92% to 93%, this may be due to other factors such as respiratory mechanics and inspiratory flow which have been shown to influence the leak, thus rendering the interpretation of the test difficult.

The variability in cut-off values reported among studies is most likely due to the use of varied endotracheal tube sizes, which result in differing degrees of resistance within the tube. This resistance is related with higher cuff leak volumes when smaller tube sizes

are employed. Airway secretions that have solidified on the inside or outside of the tube beneath the voice cords may enhance resistance. There is considerable dispute about the cut-off positions for CLT in predicting PES. Most investigations on cuff leak volume reported excellent specificity and negative predictive values, meaning that individuals with a cuff leak volume greater than a given threshold had a low risk of developing PES. Nonetheless, the low sensitivity and PPV of these approaches may indicate their limited usefulness in forecasting PES [19]

By comparing both techniques ACWD is more accurate (95%) with higher specificity 94.7% and PPV 50% than cuff leak volume difference (85%), specificity 84.2% and PPV 25% in predicting post extubation air way edema, (P value >0.05) which shows no statistically significant difference between the two methods in accuracy, that showing.

Similarly, Bhargava et al. [10] study found that 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.

Moreover, Mohammad et al. [16] concluded that the positive predictive value and sensitivity of CLT for predicting PES are minimal. The US measurements of ACWD are an excellent predictor of PES.

In addition, prior research has documented several advantages of the ACWD approach, such as its safety and the convenience of capturing images due to prominent anatomical landmarks (namely, the cricoid and thyroid cartilage), which remain visible even in obese persons. Furthermore, the distance between the skin and vocal cords is quite short.

A further benefit is that a bigger airway cross-sectional diameter ACWD indicates a reduced likelihood of laryngeal edema, and this can be easily understood [5].

We recommended that additional research is required to validate the findings of the current study. The next research should involve a larger sample size of patients in many centres and focus on developing methods to accurately predict PES, the use of a portable bedside ultrasound should be considered prior to extubation in order to rule out the presence of substantial laryngeal edema, and to start organized training programs on bedside ultrasonography for ICU and anesthesia staff in order to enhance their knowledge with the use of ultrasonography for predicting PES and other airway management applications.

Limitations: The study was conducted in one center, so the findings of our study cannot be generalized, this study had a relatively small sample size, and roc curve couldn't be done in this study, due to small sample size and low prevalence of Post Extubation airway edema.

Conclusions

Ultrasonography is a useful and non-invasive tool for the evaluation of vocal cords and laryngeal morphology in intubated patients. The air-column width measured by US may potentially identify patients at risk of PES, in whom caution should be taken after extubation. Our study showed that the US measurements of air column width difference ACWD had better accuracy 95% with higher specificity 94.7% and PPV 50% while cuff leak volume difference accuracy was 85%, specificity 84.2% and PPV 25% in predicting post-extubation air way edema.

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