



Comparison between Cuff Leak Test and Ultra Sound Assessment of Laryngeal Edema in Predicting Successful Extubation in Mechanically Ventilated Patients

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Objects: Endotracheal intubation commonly leads to local complications, including mechanical lesions, such as friction and compressions between the tube and the anatomic structures of the larynx leading to laryngeal edema manifested as “stridor” after extubation. There is no standard method to predict patients at risk of post-extubation stridor. This study was conducted to compare between cuff leak test and ultra sound in predicting successful extubation in mechanically ventilated patients.

Patients and Methods: We included a total of 83 mechanically ventilated patients with endotracheal intubation > 24 hours. They were divided according to the outcome after extubation into 72 patients who didn't develop laryngeal edema and 11 patients who developed laryngeal edema. The patients were extubated when they fulfilled the criteria of extubation and become negative to cuff leak test. All patients underwent both cuff leak test (CLT) and ultra-sound to assess air column width difference (ACWD) after intubation and before extubation.

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Results: All patients were matched as regard demographic data. There was a significant increase in the duration of mechanical ventilation in the LE group. No significant difference was detected between the two groups regarding CLT and ACWD after intubation. However, cases with laryngeal edema had significantly lower CLT and ACWD before extubation. Using a cut off value of 1.52 mm, ACWD had sensitivity and specificity of 90.9 and 91.7% respectively to predict laryngeal edema after extubation.

Conclusions: Laryngeal Ultrasonography could be a useful, reliable, non-invasive method in the evaluation of vocal cords, laryngeal morphology and airflow passing through the vocal cords or subglottic area in intubated patients in comparison with cuff leak test.

Keywords: Cuff leak test; ultrasound; laryngeal edema; mechanically ventilated patients.

1. INTRODUCTION

Prolonged endotracheal intubation mostly causes damage to the airway, leading to laryngeal edema (LE), ulceration, and injury to the vocal cords. These injuries are generally reversible, but they may cause a decrease in the airway lumen leading to respiratory difficulty directly after extubation, which results in an increase of air flow velocity, resulting in post-extubation stridor (PES), which is a clinical marker of post-extubation laryngeal edema (PLE) [1].

Laryngeal edema in intubated patients is common in intensive care unit (ICU) patients. This complication leads to reintubation that is associated with an increase in hospital mortality, nosocomial pneumonia, and the duration of ICU stay [2].

Diagnosis of PLE & PES is of significant clinical importance as the patients can benefit from close monitoring and specific therapies. Up till now, there is no consensus on a method to identify patients at risk of PLE & PES. Cuff leak test consists of deflating the balloon cuff of the endotracheal tube in order to assess the air leak around the tube, permitting an indirect evaluation of upper airway patency. A reduced cuff-leak volume suspects presence of LE [3].

Ultrasound is a promising non-invasive method that is widely used in ICU, and allows visualization of vocal cords and larynx. The study by Ding et al, using intensive care ultrasound, has shown the new assessment, namely, air column width (ACW) measurement of vocal cords. Their study has found that patients without post-extubation stridor have significant greater increase of vocal cord ACW and (air column width difference [ACWD]) after deflation of endotracheal tub cuff [4].

This study was conducted at Tanta University Hospitals aiming to compare between cuff leak

test and laryngeal ultrasound in predicting successful extubation in mechanically ventilated patients.

2. PATIENTS AND METHODS

This observational controlled study was carried out at Tanta University Hospitals on all mechanically ventilated patients admitted at the surgical ICU during the period of six months, from January to June 2018. Every patient had a secret code number to ensure privacy to participants and confidentiality of data.

We included patients aged from 18 to 50 years intubated via an orotracheal tube with proper tube size (tube with internal diameter 6.5-7 mm for females and 7- 7.5 mm for males) for a minimum duration of 24 hours. On the contrary, patients with cervical spine injury, active skin lesions at the site of ultrasound placement, upper airway obstruction, or vocal cord paralysis were excluded.

A total of 83 cases were finally included, and they received the standard respiratory care. All ventilators equipped with bacterial filter at position of gas inlet and outlet. The cuff pressure in all patients routinely monitored by cuff pressure manometer and maintained at 20 mm Hg.

All patients underwent both cuff leak test (CLT) and ultra-sound assessment to airway patency. The cuff leak was measured after intubation and when the patient presumed ready for extubation. The procedure was performed at the start of expiration according to the protocol proposed by Miller and Cole [5].

The laryngeal US was performed with a linear Sonoscape-probe (5 MHz) for visualization of the vocal cords according to the protocol described by Ding and colleagues [4] (Fig. 1). The test was

performed with the same ventilator settings as the CLT with the balloon cuff inflated and deflated. The laryngeal air column width was defined as the width of air passed through the vocal cords as determined by US. It was recorded for three consecutive times, and the mean value was recorded. The air-column width difference (ACWD) is the width difference between balloon-cuff inflation and deflation.

Patients were extubated when they full fill criteria of weaning and were negative for cuff leak test (leak volume >110ml) [6]. Patients were evaluated for post extubation laryngeal edema and post extubation stridor (PES) and need for reintubation after extubation. PES was defined as the presence of a high-pitched inspiratory sound requiring medical-intervention, associated with respiratory distress within 24 hours of extubation, and accompanied with a respiratory rate >30/minute or increase by >10 cycles/minute from baseline.

Patients were divided according to the outcome after extubation into two groups; the first group included 72 patients who didn't develop laryngeal edema (No LE group), and the other group included the remaining 11 patients who developed laryngeal edema (LE group).

2.1 Statistical Analysis

Data entered and analyzed using Microsoft Excel software. Data were then imported into Statistical Package for the Social Sciences (SPSS 22.0, IBM/SPSS Inc., Chicago, IL) software for

analysis. Baseline characteristics of the study population were presented as frequencies and percentages (%) or mean values and standard deviations (SD) or median and range. According to the type of data, the following tests were used to test differences for significance; Fisher's Exact Test, Chi square test, Independent samples t-test and Mann-Whitney U test. Receiver operating characteristic (ROC) analysis followed by determination of the optimal cutoff value. P values <0.05 are considered significant.

3. RESULTS

3.1 Demographic Data

No significant difference was detected between the two groups regarding demographic variables or tubal size. However, there was a significant increase in the duration of mechanical ventilation in the LE group compared to the other group ($p < 0.001$). There was no significant difference between the two groups regarding cuff leak test or ACWD ($p = 0.087$ and 0.531 respectively). Table 1 illustrates these data.

There was a significant increase in the cuff leak test in the no LE group compared to the LE group (153.6 vs. 130.5 ml – $p < 0.021$). These data are illustrated at Table 2.

Before extubation, there was a significant decrease in ACWD in the LE group compared to the No LE group (0.9 vs. 2.6 mm – $p < 0.001$). Table 3 illustrates these data.

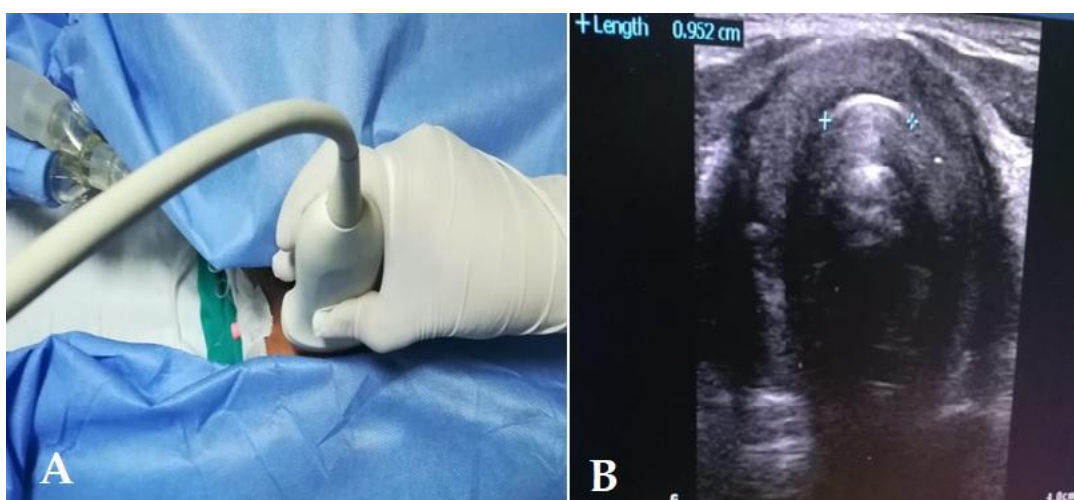


Fig. 1. (A) Laryngeal ultrasonic examination. (B) Ultrasound view of larynx with deflated cuff

Table 1. The demographic data, patient characteristics, endotracheal tube size, duration of mechanical ventilation, cuff leak and ACWD after intubation in both groups

		Group (No LE) N=72	Group LE N =11	P value
Age (y)	Mean ± SD	37 ± 9	33 ± 9	0.256
	Range	19-50	20-45	
Sex	Male	43 (59.7%)	6 (54.5%)	0.753
	Female	29 (40.3%)	5 (45.5%)	
Weight (kg)	Mean ± SD	81 ± 12	76 ± 7	0.178
	Range	62-110	62-87	
Tube size (mm)	6.5	5 (6.9%)	1 (9.1%)	0.066
	7	27 (37.5%)	4 (36.4%)	
	7.5	40 (55.6%)	6 (54.5%)	
Duration of MV (hours)	Mean	171	261.6	<0.001*
	SD	61.8	54.6	
Cuff leak (ml) after intubation	Mean	184.5 + 34.8	165.55 + 21.8	0.087
	Range	127 -199	120 - 295	
ACWD after intubation (mm)	Mean	2.8 + 0.8	2.7 + 0.5	0.531
	Range	1.29-4.3	2.03-3.51	

ACWD: Air column width difference; MV: Mechanical ventilation

Table 2. Cuff leak (mL) before extubation in both groups

	No LE n=72	LE n=1
Mean	153.6	130.5
SD	31.6	13.4
Range	110-276	112-164
P value	<0.021*	

P value significant if < 0.05

Table 3. ACWD (mm) before extubation in both groups

	No LE n=72	LE n=11
Mean	2.6	0.9
SD	0.7	0.5
Range	1.11-3.81	0.23-1.86
P value	<0.001*	

ACWD: Air column width difference. P value significant if < 0.05

Table 4. Diagnostic accuracy of ACWD

Cut-off	Sensitivity	Specificity	PPV	NPV	AUC	P value
1.52	90.9%	91.7%	86.8%	85.7%	0.965	<0.001*

PPV: Positive predictive value; NPV: Negative predictive value; AUC: Area under curve

Table 5. AUC and 95% CI b for cuff leak test and ACWD

Variable	AUC	95% CI b
Cuffleak	0.75	0.643 to 0.839
ACWD	0.965	0.899 to 0.993

ACWD: Air column width difference; AUC: Area under curve; CI: Confidence interval.

Using a cut off value of 1.52 mm, ACWD had sensitivity and specificity of 90.9 and 91.7% respectively to predict laryngeal edema after extubation. Table 4 and Fig. 2 illustrate these data.

Compared with the cuff leak test, the area under the ROC curve of ACWD by laryngeal ultrasound there was statistically significant increase in the areas under the ROC curves of ACWD than cuff leak test (ACWD was better) with P value (<0.001) and 95% confidence interval (0.899 to 0.993) as shown in Fig. 3, Table 5.

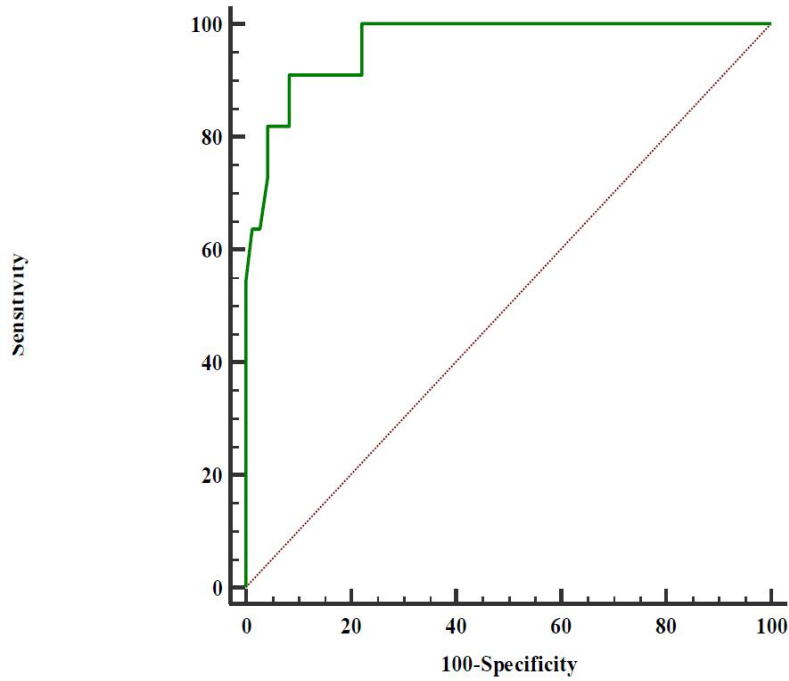


Fig. 2. ROC curve of ACWD

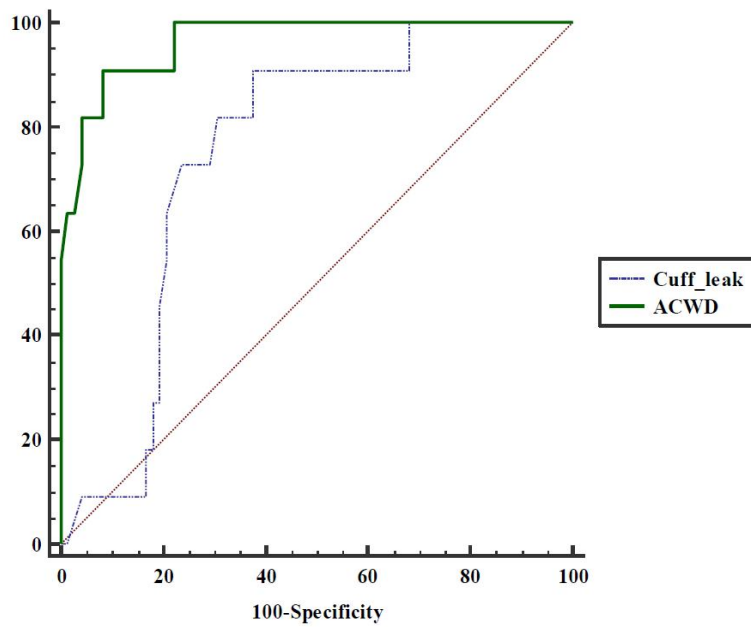


Fig. 3. ROC curve of ACWD and cuff leak test

4. DISCUSSION

This study was conducted at Tanta University hospitals aiming to compare between cuff leak test and laryngeal ultrasound in predicting successful extubation in mechanically ventilated patients. We found that the duration of intubation was increased significantly in the *LE group* compared to *No LE group*.

This was confirmed by many studies. Jaber et al. conducted their observational study on 112 patients, and they noted an increased risk of stridor in patients with increased duration of MV [7]. Also, Kriner et al. studied PES in 462 ICU ventilated patients, and they reported that patients who developed PES were more likely to have longer duration of intubation [8]. Furthermore, Tadie et al. concluded that longer duration of intubation is a risk factor for laryngeal edema [9].

Moreover, Venkate gowda et al. found that there was a significant decrease in the duration of ventilation in non-stridor group compared with stridor group, and there was a correlation between stridor and number of intubation days [10]. Fuji et al. confirmed this finding in their retrospective study investigating the cause of reintubation in 262 adult patients who were extubated after MV for more than 24 hours. They reported longer duration of intubation in the re-intubation group compared with successful extubation group. Subgroup analysis revealed long intubation duration in the non-respiratory insufficiency group which included LE, mucosal ulcers, granulation and vocal cord paralysis or lowered level of consciousness compared with successful extubation group [11].

Conversely, De Bast and his associates used the cuff leak test to predict failure of tracheal extubation due to laryngeal edema in 76 patients. They found that there was statistically insignificant differences in the duration of MV between low leak and high leak groups [12]. Also, in the study carried out by Ding et al. using laryngeal ultrasound in predicting post extubation stridor, results showed that there was statistically insignificant difference in the days of intubation between non-stridor and stridor groups [4].

Sutherasan et al. used ultrasound for predicting laryngeal edema in 101 intubated patients. Their results showed that there was statistically insignificant differences between the two groups as regard days of intubation [13]. In addition,

Zytoun and his co-workers studied the role of the laryngeal US in predicting post extubation laryngeal edema on 80 patients, and they found that there was a statistically insignificant difference as regard the duration of mechanical ventilation between stridor and non-stridor groups [14].

The difference between the results of the present study and those of De Bast et al., Ding et al., Sutherasan et al., and Zytoun et al. may be due to relatively short duration of mechanical ventilation compared with the present study, which may not be long enough to cause significant LE manifested as PES [4,12-14].

In the current study, we found that there was no significant difference between the two groups regarding mean cuff leak volume after intubation. While, before extubation there was a significant decrease in the mean cuff leak volume in *LE group* compared to *No LE group*.

In agreement with our results, De Bast et al. observed a significant decrease in the cuff leak volume in patients developing laryngeal edema compared to patients who did not require re-intubation for laryngeal edema [12]. Moreover, Ding et al. reported that the cuff leak volume was markedly increased in non-stridor group than stridor group [4]. Also, the results of Sutherasan et al. showed that the mean cuff leak test in patients with vocal cord edema was significantly lower than that in patients without vocal cord edema [13].

Venkategowda et al. reported a significant increase in cuff leak volume before extubation in non-stridor group compared to the stridor group [10]. Additionally, Sahbal and his colleagues studied laryngeal ultrasound versus cuff leak test for predicting post-extubation stridor in 50 patients. Their results showed that there was statistically significant increase in cuff leak volume in non-stridor group compared to the stridor group [3].

In the current study, there was a significant decrease in ACWD in the *LE group* compared to the *No LE group* (0.9 vs. 2.6 mm – $p < 0.001$).

Similarly, Venkate gowda et al. reported that there was a significant increase in ACWD in non-stridor group than stridor group [10].

In consistent with our result, Ding et al. have reported the ability of ultrasound to visualize the

vocal cords and larynx. It also showed some benefits for predicting LE. Their study reported significantly higher mean ACWD in the non-stridor group than the other group [4]. Also, Sutherasan et al. showed that there was a significant increase in ACWD in No LE group than LE group [13].

In contrary with our findings, Sahbal et al. found that there was no statistically significant difference regarding ACWD between both stridor and non-stridor group [3].

Despite there are many studies investigating cuff leak test and ACWD for identifying patients at risk for laryngeal edema due to mechanical ventilation, there are few studies evaluating the sensitivity and specificity of both tests.

In the present study there was a significant increase in the area under the ROC curve in ACWD compared to cuff leak test with values of 0.75 and 0.965 for cuff leak test and ACWD respectively. The cutoff value for ACWD was identified at 1.52 mm with sensitivity and specificity of 90.9 % and 91.7% respectively. That offers safety in extubating patients with ACWD above 1.52 mm.

In agreement with our findings, Zytoun et al. revealed an ACWD cutoff point of 0.9 mm with sensitivity of 80% and specificity of 90% PPV of 72.7 and NPV of 93.1% in predicting the success of extubation based on that investigation [14].

The decreased sensitivity and specificity of the cuff leak test is supported by the study of De Bast et al. at which the ROC curve yielded a cut-off value of 15.5%. The sensitivity of the cuff leak test was 75% and the specificity was 72.1%. In addition, the PPV was 25% while the NPV was 96.1%. However, this very high NPV was calculated to all their patients, half of them was ventilated for less than 48 hour (38 patients) and therefore, this value may not be an appropriate value, and it doesn't have a practical importance [12].

In contrary to the result of the present study, Sahbal et al. found that the CLT had a sensitivity of 75%, specificity of 93.5%, NPV of 97.7 %, and PPV of 50% using a cutoff point of 132.5 ml. In the same study, ACWD cut off value of 0.905 mm showed 50% sensitivity, 73.9% specificity, and 94.4% NPV. However, clinical application of their results must be taken with caution as the cutoff value of the cuff leak test was high 132.5

mL allowing high PPV of 50% with an increase in the risk of unnecessary prolonged intubation. Also, the cut-off value of the ACWD is low 0.9 mm, and this might explain the decreased sensitivity and specificity of ACWD in their study [3].

Sutherasan et al. found no significant difference between CLT and ACWD in predicting LE in intubated patients. They reported that the area under the ROC curve of ACWD with cutoff value of 1.6 mm was 0.823 with sensitivity of 0.706, specificity of 0.702, PPV of 0.324, and NPV of 0.922. The sensitivity and specificity of the CLT \geq 110 mL were 0.8 and 0.82 respectively. The PPV and NPV were 0.46 and 0.96. However, they demonstrated no correlation between ACWD and CLT [13].

Ultrasonography has many advantages as it is simple, safe, quick, widely available, non-invasive, repeatable, painless, convenient, gives real-time dynamic imaging, and doesn't depend on the tubal size [15].

The cut-off value for CLT varies widely among the published studies, it ranged from 88ml in the study conducted by Wang et al. [16] to 310 ml in the study of Engoren et al. [17].

Miller and Cole [5] and Kriner et al. [8] used a cut off value of 110 ml, Chung et al. used a cut off value of 140 ml [18], while Mikeili et al. [19] used a higher value (249 ml). Others used cut off values as percentage of the tidal volume as De Bast et al. who used 15% value [12].

Decreasing the cutoff value leads to decreasing in the false positive results and consequently decreasing the risk of prolonged unnecessary intubation, whereas increasing the cutoff value leads to reduction of the false negative results and decreasing the risk of extubation failure.

So, in the present study we aimed to decrease both the false positive and false negative results and used the cutoff value of 110 ml.

The reduced accuracy of the CLT is supported by the study of Ochoe et al. in their systematic review. Their results showed that the CLT had a moderate accuracy in predicting upper air way obstruction and low accuracy in predicting re-intubation secondary to upper airway obstruction [20].

This limited accuracy may be due to the outcome of the CLT which is significantly affected by the inspiratory leak volume as the expiratory leak volume is only 30% of the total leak volume. The inspiratory leak volume is significantly affected by the respiratory system compliance and inspiratory flow which are additional determinants of CLV.

Therefore, the timing of cuff deflation is important and it should be deflated immediately prior to expiration to eliminate the inspiratory leak volume. Plujms et al. [1] reported that inspiratory parameters as compliance or inspiratory flow can affect the amount of leak.

The expiratory flow through the upper air way is influenced by the size of the ETT in relation to the size of the larynx. If the ETT size is large the expiratory flow into the upper air way may be hindered even in the absence of LE. So, CLT may identify decreased expiratory flow through the upper air way, but this may be due to mechanical factors other than LE, and this may explain the high false positive rate of CLT [8].

Our study has some limitations, first of all, it is a single center study. Also, the included number of cases was relatively small. Also, other risk factors of laryngeal edema after intubation should have been assessed. Hence, multiple studies should be conducted in the near future to cover these drawbacks.

5. CONCLUSION

Based on our findings, the air column width difference measured by ultrasound is a good predictor for laryngeal edema in intubated patients. Laryngeal Ultrasonography could be a useful, reliable, noninvasive method in the evaluation of vocal cords, laryngeal morphology, and airflow passing through the vocal cords or subglottic area in intubated patients in comparison with the cuff leak test.

CONSENT AND ETHICAL APPROVAL

The study was approved by the local ethical committee of Tanta University (approval code 32031/12/17). A written informed consent was obtained from all participants' guardian before participating in the study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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