

Use of Bedside Laryngeal Ultrasound to Predict Post-extubation Stridor in Critically Ill Mechanically Ventilated Children

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ABSTRACT

Background: the frequency of post extubation stridor (PES) may range between 2–15% in critical children and is a significant cause of reintubation with a higher degree of mortality. The laryngeal US to measure the air column width was described to be a possible method to PES and laryngeal edema.

Objectives: We aimed to investigate the reliability of laryngeal ultrasound for the prediction of PES.

Patients and Methods: A prospective observational study that was conducted at the PICU of Cairo University Hospital on 50 ventilated children between January 2020 and January 2021. The children underwent laryngeal ultrasound during the first 24 hours of admission and after passing the spontaneous breathing trial and preparing for extubation.

Results: the incidence of stridor was 18% and the main risk factors were the longer duration of ventilation and the repeated intubation attempts, the stridor group had a median of 12 days while the non-stridor group had a median of 6 intubation days (p-value = 0.023). The PES had a statistically significant variation in air column width ratio in stridor children compared to the non-stridor group (p- < 0.001). A cut-off point < 0.86 could predict PES with sensitivity of 100% and specificity of 97%. **Conclusion:** laryngeal air column width ratio is a safe, easy, and reliable method for the prediction of PES in critically ill mechanically ventilated children.

Keywords: Critical patients, Mechanical ventilation, Laryngeal ultrasound, Stridor.

INTRODUCTION

The frequency of post-extubation stridor (PES) may range between 2–15% in critical children and is a significant cause of reintubation with a higher degree of mortality. Methods for vocal cords examination were proposed as direct or indirect laryngoscopy, but this may be difficult and sometimes risky in intubated patients ⁽¹⁾.

It is believed that there are numerous contributing factors in the emergence of PES. There are a few predicted clinical characteristics that have been established, such as the length of the intubation, the number of times it was attempted, and infection ⁽²⁻⁴⁾. Age, gender, small tube size, gastro-esophageal reflux, narrow larynx, low birth weight, and low gestational age are additional risk factors. However, literature is variable with differing results ^(5, 6).

The air column width (LACWD) measured by the US was described to have a considerable ability to pre-post-extubation stridor in intubated mechanically ventilated patients ⁽⁷⁾. The laryngeal US to measure the air column width was described as a non-invasive method to better predict PES and laryngeal trauma from intubation and inflammation ^(8, 9). Previous studies evaluated the use of LACWD in the prediction of PES in adults ^(1, 9, and 10). Laryngeal air column width ratio may be a very effective for prediction of PES in children without any negative effects, according to a pediatric study of El Amrousy *et al.* ⁽¹¹⁾. We aimed to evaluate the ability of laryngeal ultrasound to predict PES in a group of mechanically ventilated children.

PATIENTS AND METHODOLOGY

Study design

This is a cohort study conducted on mechanically ventilated critically ill children from January 2020 to

January 2021 after receiving approval from the Ethical Committee and informed consents from the child's carers.

Data collection

Fifty children aged from 1 month to 13 years were included, and all children were ventilated more than 48 hours.

Exclusion criteria: Patients known to have congenital anomalies of the larynx, neonates; patients with an expected duration of ventilation fewer than 48 hours or stridor as a cause of ventilation.

Laryngeal ultrasonography was done to all patients within 24 hours after ventilation and again before extubation and upper endoscopy was performed for those who developed stridor. Patients were followed for their course of ventilation, extubation success or failure, intensive care unit (ICU) complications, and survival. Laryngeal ultrasound examination was carried out within 24 hrs after intubation and again before extubation after testing for the visibility of weaning after successful SBT and measurement of ACWR were performed after passing the trial successfully. Measurements were performed with a 13 MHz linear probe Vivid 5 GE machine made while patients were lying supine with their necks extended. The instrument was positioned on the cricothyroid membrane, and the air column diameter was measured (defined as the air passed through the VC). Three readings were taken, and the average was calculated. Before the measurements, oral and pharyngeal secretions were suctioned. Then air column width ratio measured (before extubation/after intubation) according to Venkategowda *et al.* ⁽¹⁾. Patients with clinical stridor were subjected to flexible bronchoscopy (FFB) size 2.1 (manufactured by PENTAX). The findings were classified according to the CALI classification

system: acute laryngeal injuries are categorized as mild, moderate, or severe depending on where on the part of larynx they occur and what kind of tissue they affect ⁽¹²⁾. Measurements were performed on eight children from outpatient clinic before the study to examine inter-observer and intra-observer repeatability, the radiologist and the intensivist blinded to each other's data made the measurements on each subject. The same observer evaluated the intra-observer repeatability between the observations. Pediatric radiologist stored and updated the measurements and photos produced by skilled intensivist.

Ethical Approval:

The study was approved by the Ethics Committee of Faculty of Medicine, Cairo University and an informed written consent was taken from each parent of children in the study. This work was carried out following The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical Methods

With the aid of the SPSS program (Statistical Package for Social Science) version 24 and NCSS 12, LLC, USA, the obtained data were computerized and statistically evaluated. Using the Shapiro Walk test, the distribution of the data was examined for normality. Frequencies and relative percentages were used to depict qualitative data. The difference between the qualitative

variables was calculated using the chi square and Fisher exact tests. The median and range were used to express quantitative data. Whitney Mann for variables with non-normal distribution and the U test was employed to determine the difference between quantitative variables in two groups. (ROC) curve was created to enable the comparison of various testing methodologies and the determination of threshold values for test findings and it was used to calculate the areas under ROC curves and their standard errors. The Areas under ROC curves and their standard errors were determined using the method of Centor and compared using the normal distribution with correction for correlation of observations derived from the same cases. A larger area under ROC curve (AUC) indicates superior test performance, with 1 representing 100% sensitivity and specificity and 0.5 representing no discriminatory utility.

RESULTS

The study included 50 critically ill mechanically ventilated children from the ICU of Cairo University Children Hospital.

The median weight was 5.5 kg and males represented 56% of the study population. The median pSOFA was 5 on admission to the ICU. The most frequent etiology for ventilation was pneumonia 40% followed by coma of several etiologies: status epilepticus, septic encephalopathy or CNS infections (Table 1).

Table (1): Demographic characteristics of the study population on admission

Variable		Total N=50	
		N	%
Age in months		4.5 (1.0 to 120.0)	
Weight in Kg		5.5 (2.0 to 35.0)	
Sex	Female	22	44.0%
	Male	28	56.0%
Vitals	HR (beat/minute)	148 (87 to 190)	
	RR (number/minute)	40 (20 to 65)	
	Systolic BP (mmHg)	100 (70 to 142)	
	Diastolic BP (mmHg)	58 (40 to 96)	
	Temp (°C)	37.0 (36.4 to 100.0)	
	Saturation%	99.0 (37.4 to 100.0)	
pSOFA		5 (2 to 12)	
Fluid balance in ml		-4 (-2400 to 350)	
Fluid balance % of body weight		-0.045 (-45.1 to 5)	
Cause of admission	Asthma	1	2.0%
	Guilliane barre syndrome	1	2.0%
	Renal failure	1	2.0%
	Bronchiolitis	2	4.0%
	Cardiogenic shock	2	4.0%
	Hypovolemic shock	3	6.0%
	Post-operative	3	6.0%
	Coma	8	16.0%
	Septic shock	8	16.0%
	Pneumonia	21	42.0%

The incidence of PES was 18%. There was evidence of longer duration of intubation prior to the extubation in the stridor group. Median of 6 days in no stridor group compared to 12 days in the stridor group (p value=0.023). The air column width ratio was higher in no stridor median value of 1 (0.82 to 1.11) compared 0.82 (0.70-0.86) (p value < 0.001) (Table 2).

Table (2): Comparison of Post-intubation data as regard development of PES

		No stridor N=41		Stridor N=9		
Duration of intubation in days		6 (2 to 31)		12 (5 to 30)		0.023
Post-intubation US, mm		14 (9 to 27)		14 (11 to 20)		0.703
Pre-extubation US, mm		13 (8 to 27)		12 (9 to 14)		0.099
Air column width ratio		1.0 (0.82 to 1.11)		0.82 (0.70 to 0.86)		<0.001
Air column width ratio median value	< Median 0.95	15	36.6%	9	100.0%	0.001
	≥ Median 0.95	26	63.4%	0	0.0%	
Air column width ratio ROC value	≤0.86	1	2.4%	9	100.0%	<0.001
	>0.86	40	97.6%	0	0.0%	

We calculated the specificity and sensitivity of air column width ratio in the evaluation of stridor. A value < 0.86 had a sensitivity of 100% and specificity of 97.5% in prediction of PES (Table 3 and Figures 1 and 2).

Table (3): The Area under the ROC curve (AUC) of air column width ratio as a predictor of PES and extubation failure

	Cut-Off	Sensitivity % 95% CI	Specificity % 95% CI	PPV 95% CI	NPV 95% CI	AUC 95% CI	P
Post- extubation stridor	≤0.86	100 66.4 - 100.0	97.56 87.1 - 99.9	90 56.5 - 98.4	100	0.989 0.909 - 1.00	<0.001
Extubation failure	≤0.86	66.67 29.9 - 92.5	90.24 76.9 - 97.3	60 34.7 - 80.9	92.5 83.0 - 96.9	0.78 0.641 - 0.885	0.004

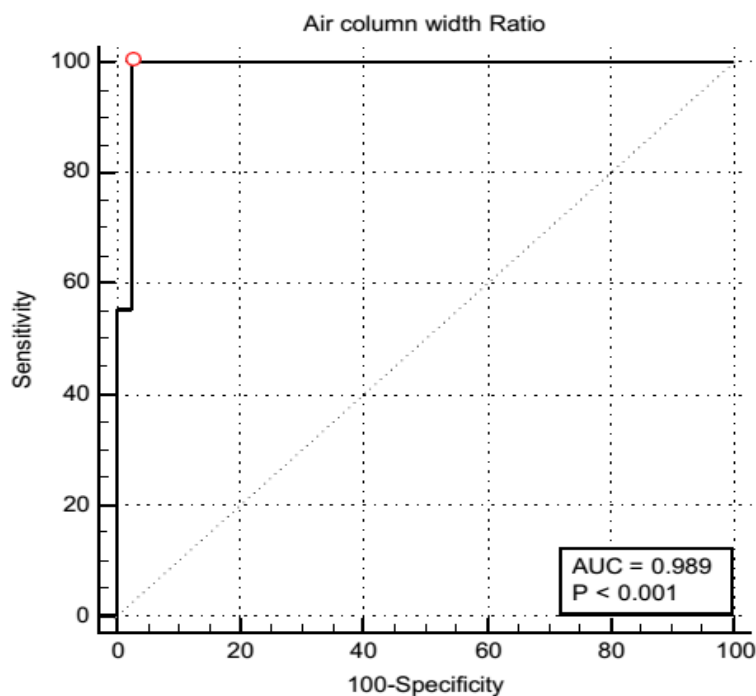


Figure (1): The Area under the ROC curve (AUC) of air column width ratio as a predictor for PES

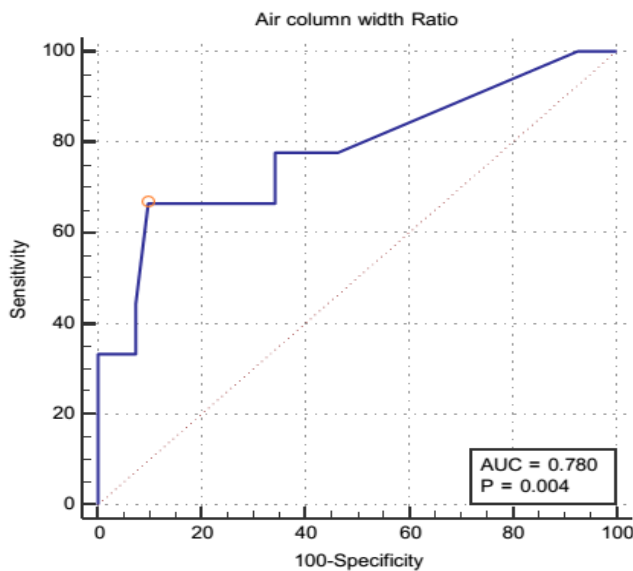


Figure (2): The Area under the ROC curve (AUC) of air column width ratio as a diagnostic marker for extubation failure.

We did an upper endoscopy examination using FFB for the nine patients who developed post-extubation stridor despite therapeutic interventions with pulse methylprednisolone and inhaled epinephrine to prevent the possible stridor predicted by laryngeal ultrasound. Three of them had moderate laryngeal trauma and the other six had mild trauma and hyperemia according to the CALI classification system (Table 4).

Table (4): Flexible bronchoscopy findings of nine patients with post extubation stridor

Bronchoscope (CALI classification)	Mild	6	12.0%
	Moderate	3	6.0%

DISCUSSION

Clinicians are often challenged with prediction of PES since cannot be predicted by spontaneous breathing trial (13).

The airway ultrasound is considered an emerging tool of care in pediatric critical care (14). Adults’ studies use the laryngeal air column width, which is measured with a single view at the level of the vocal cords, to predict PES (12). The frequency of stridor was 18% in our study, some reports gives a range from (11% to 41.2%) (11, 15, 16).

In our study, laryngeal ultrasound could predict stridor at a cutoff point < 0.86 mm with good sensitivity and specificity, which is close to **El Amrousy et al.** (11) which found for predicting PES in intubated anaesthetized children, a cutoff value of less than 0.8 mm produced sensitivity of 93%, specificity of 86%, and accuracy of 91%. (11).

However, 55% of their population was postoperative children while our patients had acute medical non-surgical illness.

Few other variable reports are available from adult literature, when compared to non-PES patients, **Ding and**

colleagues (8) found that patients with PES had considerably reduced air column width and ACWD. **Mikaeili et al.** (17) discovered that LACWD had low sensitivity (50%) and low specificity (57%) at a cutoff point of 0.85 mm. Also ACWD was reported to have a better prediction for PES when compared to cuff leak test (1). **Samprathi et al.** (18) hypothesized that the IPFS (intracricoid peritubular free space) could be estimated by cricoid ultrasound and could predict post extubation airway obstruction.

Only the longer the duration of ventilation and number of intubation attempts was the significant risk factor among other investigated criteria for PES in our group of patients. Also, **Nascimento et al.** (14) found no differences regarding age, weight, size of tube, only the risk was related to duration of ventilation greater than 3 days (15). Others found a correlation between stridor and number of intubation days (1).

El Amrousy et al. (11), said that patients with stridor experienced traumatic intubations much more frequently than patients without.

Regarding age, gender, and mortality, there was no discernible difference between the two groups with and without stridor. Contrary to what was stated in the literature, newborns and male sex were thought to be risk factors for PES (19).

There is significant correlation between air column width ratio and number of organ failure, p-SOFA score, number of intubations attempts and duration of intubated.

CONCLUSION

Our study has documented a possible ability of laryngeal ultrasound ACWR to predict the development of PES.

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Conflict of interest: The authors declared that there was no conflict of interest.

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