Paediatrica Indonesiana

p-ISSN 0030-9311; e-ISSN 2338-476X; Vol.64, No.5 (2024). p.384-8; DOI: https://doi.org/10.14238/pi64.5.2024.384-8

Original Article

Measurement of leak volume as a diagnostic predictor of post-extubation stridor in pediatric patients

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Abstract

Background Endotracheal intubation can cause post-extubation stridor (PES). The PES may prolong the length of stay in the hospital and be associated with increased morbidity and mortality, particularly if re-intubation is necessary. The leak volume (LV) test is a simple method to detect airway edema.

Objective To evaluate the efficacy of LV and percent leak volume (PLV) in predicting PES.

Methods Inspired tidal volume (VTi) and expired tidal volume (VTe) were observed for six respiratory cycles during positive pressure ventilation before extubation. The average of the six VTi and six VTe values were recorded. The LV was the difference between average VTi and average VTe. The conversion of the ratio of LV to average VTi into percentage was defined as PLV. Both LV and PLV were analyzed to determine cut-off values in predicting PES.

Results Among 77 patients, 39 patients (50.6%) developed PES. Both LV and PLV showed a significant decrease in patients with PES.The ROC analysis showed that LV at a cut-off point of < 18.34 mL gave a sensitivity of 82.1% and specificity of 57.9%, whereas PLV < 13.83% yielded 79.5% sensitivity and 57.9% specificity for predicting PES. The LV and PLV had an area under the ROC curve of 0.770 (95%CI 0.665 to 0.874; P<0.001) and 0.706 (95%CI 0.59 to 0.821; P=0.01) respectively.

Conclusion Leak volume and percent leak volume can be used as markers to predict PES in pediatric patients. **[Paediatr Indones. 2024;64:384-8; DOI: https://doi.org/10.14238/pi64.5.2024.384-8**].

Keywords: *post-extubation stridor; leak volume; percent leak volume*

The incidence of post-extubation stridor (PES) in children ranges from 3.5-30.2%.[1, 2] The PES may increase the risk of adverse outcomes and prolong the length of stay in the pediatric intensive care unit (PICU), particularly if reintubation is required. Currently, it is difficult to predict which patients will develop PES after extubation. Cuff leak tests (CLT) were introduced as a simple method to predict PES, but many studies have questioned the applicability of CLT as a routine test because of varied specificity and sensitivity.[3] The presence or absence of audible air leaks from air leak tests has a low sensitivity in predicting PES in pediatric patients.[4] This study was conducted to assess the cut-off value of leak volume (LV) and percent leak volume (PLV) in predicting PES. The objective of this study was to evaluate the efficacy of LV and PLV in predicting PES in pediatric patients.

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Submitted November 10, 2022. Accepted October 14, 2024.

Methods

We conducted a prospective, observational study in the PICU of Queen Sirikit National Institute of Child Health, Bangkok, Thailand, between January 2019 and January 2020, with patients aged one month to 15 years old who were intubated for more than 24 hours and met the extubation criteria. The exclusion criteria were patients with congenital upper airway anomalies, unplanned extubation, a requirement of a tracheostomy tube, more than three attempts of intubation, and death before trial of extubation.

The measurement of LV was performed immediately before extubation. To measure the LV, the patient was suctioned intraorally and intratracheally, and put on pressure control mode. The endotracheal tube (ETT) cuff was deflated in patients intubated with cuffed ETT. Patients were ventilated with FiO2 40%, peak inspiratory pressure to deliver tidal volume (VT) at 8-10 cc/Kg, mechanical rate at 20 breaths/minute, and inspiratory time depending on age (infant 0.5 seconds, toddler 0.6-0.7 seconds, small child 0.7-0.8 seconds, child 0.8-1 seconds, and adolescent 1-1.2 seconds). Inspiratory and expiratory VT were determined. Both inspiratory and expiratory VT were observed over the six respiratory cycles. The average of the six VT in both inspiration and expiration were calculated. Leak volume was the difference between average VTi and average VTe. The PLV was obtained by the following formula:

$$PLV = \frac{\text{average inspiratory VT - average expiratory VT}}{\text{average inspiratory VT}}$$

Patients were evaluated immediately after extubation for signs and symptoms of PES. Patients were considered to have PES if they experienced respiratory distress characterized by inspiratory grunting, whistling, or high-pitched wheezing localized in the trachea or larynx that developed in 24 hours following extubation. Furthermore, they required medical intervention beyond humidified oxygen therapy, including steroid nebulization, adrenaline nebulization, non-invasive positive pressure ventilation, or reintubation.

Mean and standard deviation were used to describe continuous data, and the proportion (%) was used to describe categorical data. Independent T-test, Mann-Whitney U test, and Chi-square test are used to analyze the data. The ROC curve was constructed with the area under curve analysis performed to detect the optimal cutoff value of LV and PLV to predict PES. The results were considered statistically significant if P value <0.05.

This study was approved by the Research Office and Ethics Committee Body of Queen Sirikit National Institute of Child Health, Bangkok.

Results

Seventy-seven patients were enrolled during the study period. Demographic and baseline characteristics of the patients are presented in **Table 1**.

The PES occurred in 39 (50.6%) out of 77 patients. Eight patients (10.3%) needed to be reintubated within one hour due to upper airway obstruction. The LV showed a significant difference between the two groups (P=0.007). Patients with PES had a mean LV of 14.04 (SD 14.22) mL, in comparison with patients without PES who had a mean LV of 95.12 (SD 21.92) mL. The mean PLV of patients with PES was 11.3 (SD 7.41) %, in comparison with

Table 1. Characteristics of study patients

Characteristics	N=77
Median age (range), years	1.33 (0.58-4.25)
Male gender, n(%)	48 (62.3)
Median body weight (IQR), kg	9.5 (7.17)
Type of endotracheal tube, n(%)	
Uncuffed	38 (49.4)
Cuffed	39 (50.6)
Median duration of intubation (range), hours	95 (53-169.5)
Patients who received steroids before extubation, n(%)	42 (54.5)

patients without PES was 16.6 (SD 15.02) %, with a significant difference (P=0.006). The comparison of LV and PLV between patients with PES and patients without PES are demonstrated in **Table 2**.

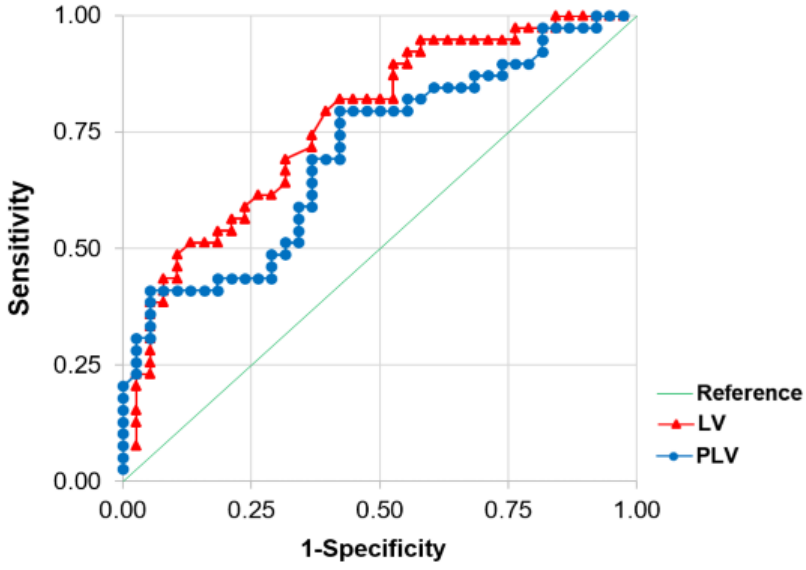
From the ROC curve, the diagnostic ability of LV and PLV in the detection of PES showed that LV < 18.34 mL had a sensitivity of 82.1%, a specificity of 57.9% with PPV, NPV, and accuracy 66.7%, 75.9%, and 70.1%, respectively. The PLV < 13.83% had a sensitivity of 79.5%, specificity of 57.9%, with PPV, NPV, and accuracy are 66%, 73.3%, and 68.8% respectively at a cut-off value of < 13.83% (**Figure 1** and **Figure 2**).

Discussion

The PES is a life-threatening complication that occurs immediately after extubation. Depending on the severity, it may require treatment ranging from nebulization with racemic epinephrine to reintubation. Many studies have been conducted to estimate the incidence of PES and showed a wide range of results ranging from 3.5-30.2%.[1,2] We found that the incidence of PES in our study was 50.6%, which is higher than in other studies. The high variance observed among the published studies may be because of different underlying medical conditions, the

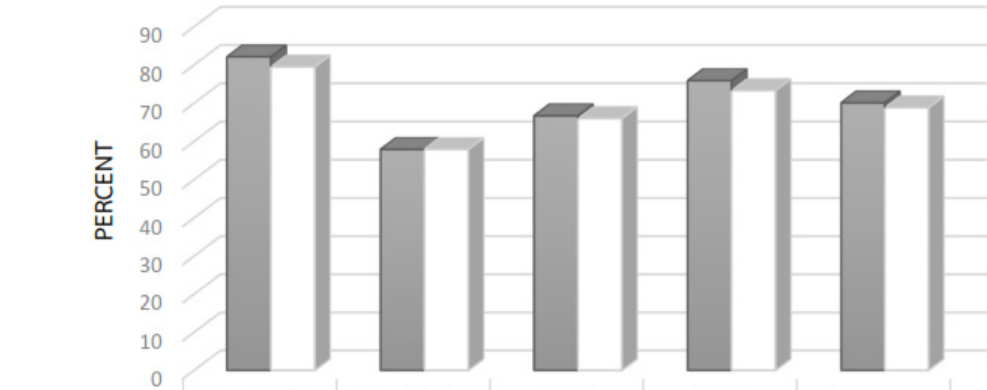
Table 2. The leak volume and percent leak volume of patients with or without PES

Variables	Patients with PES (n=39)	Patients without PES (n=38)	P value
Mean LV (SD), mL	14.04 (14.22)	95.12 (21.92)	0.007
Mean PLV (SD), %	11.3 (7.41)	16.6 (15.02)	0.006



Test	Cut-off	AUC	95%CI	p-value
LV	≤ 18.34 ml	0.770	(0.665, 0.874)	< 0.001
PLV	≤ 13.83 %	0.706	(0.59, 0.821)	0.001

Figure 1. The ROC curve for the predictive value of LV and PLV in predicting PES



	Sensitivity	Specificity	PPV	NPV	Accuracy
LV ≤ 18.34 ml	82.1	57.9	66.7	75.9	70.1
PLV ≤ 13.83%	79.5	57.9	66	73.3	68.8

Figure 2. Comparison of sensitivity, specificity, PPV, NPV, and accuracy between the cut-off value of LV and PLV in predicting PES

number of days on ETT and mechanical ventilation, the degree of airway edema, and the use of steroids before extubation.[5]

It is important to identify the patients at risk for PES. We proposed the measurement of LV and PLV as a simple method for predicting the occurrence of PES in pediatric patients. LV and PLV are the quantitative assessments to measure the air leak around the ETT. We reported LV < 18.34 mL as the threshold value for predicting PES in our study patients. This threshold had a sensitivity of 82.1%, specificity of 57.9%, PPV of 66.7%, NPV of 75.9%, and accuracy of 70.1%. A PLV < 13.83% yielded 79.5% sensitivity, 57.9% specificity, 66.0% PPV, 73.3% NPV, and 68.8% accuracy for predicting PES.

Theoretically, when no laryngeal edema exists, there is an air leak around the ETT. In contrast, laryngeal edema can cause airway narrowing and decrease expiratory flow into the upper airway, suggesting potential airway obstruction after extubation.[6] The lower value of the LV and PLV, the higher the risk for PES. The LV and PLV were comparatively lower in the PES group than the non-PES group, with statistically significant differences. This study supports the use of LV and PLV as a simple method to predict PES in pediatric patients.

Several tests have been proposed for the evaluation of risk for PES. A previous retrospective review of 105 PICU patients who had an air leak test (ALT) performed prior to extubation, reported that ALT at >20 mm Hg to be a more sensitive predictor of PES in older patients (>7 years) than in younger patients (< 7 years).[7] The ALT measurement requires positive pressure to produce an audible air leak around ETT, which may be affected by interobserver variability and head positioning.[8, 9]

Laryngeal ultrasonography, including laryngeal air column width difference measurement, has been proposed as a reliable method of predicting the occurrence of PES. Results from a previous study showed that laryngeal air column width difference at a cut-off point < 0.8 mm had high sensitivity in predicting PES.[10] Although laryngeal ultrasound is a good tool for predicting PES because it correlates very well with bronchoscopic images, proper training, and experience are required to ensure accurate measurement of air column width.[11]

Limitations of this study include the small number of pediatric patients, most of whom were young children.

Patients with PES had significantly smaller LV and PLV than those without PES. These findings suggest that LV and PLV measurements prior to extubation can help identify patients at increased risk for developing PES.

Conflict of interest

None declared.

Funding acknowledgment

The authors received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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