Clinical Research

# Accuracy of pediatric advanced life support method for predicting the depth of endotracheal tube in Indonesian children

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**ABSTRACT**

**BACKGROUND** The pediatric advanced life support (PALS) method can predict the depth of endotracheal tube (ETT) in pediatric patients easily, but it has limitations due to variations in the children's characteristics, especially the racial consideration. This study compared the accuracy of ETT depth prediction based on the PALS methods in Indonesian children.

**METHODS** Patients aged 0–12 years, who underwent elective surgery with oral intubation, were recruited consecutively based on their ages: 0–24 months and 25 months–12 years for this cross-sectional study in Cipto Mangunkusumo Hospital, Jakarta, Indonesia from June to August 2014. Bland–Altman analysis was used to compare the two measurement methods: PALS method to predict the ETT depth accuracy and auscultation method to confirm the position of the ETT. Furthermore, correlation analysis was done to examine the relationship of age, weight, height, and ETT internal diameter with ETT depth.

**RESULTS** 50 patients were recruited in each group. Bland–Altman test of ETT depth in the 0–24 months age group showed a 1.18 cm mean difference from confirmation using the auscultation method (limits of agreement −0.71 to 3.08). The 25 months–12 years age group showed a 1.11 cm mean difference with limits of agreement were −0.95 to 3.17 from confirmation using the auscultation method. Age and weight had the strongest correlation value to ETT depth in the 25 months–12 years age group ($R^2$ = 62.3%).

**CONCLUSIONS** The PALS method is inaccurate for predicting ETT depth in Indonesian children aged 0–12 years old compared with the auscultation method.

**KEYWORDS** endotracheal tube, pediatrics, resuscitation

The accuracy of endotracheal tube (ETT) placement and depth is crucial in pediatrics. Malposition of the distal end of the ETT could lead to higher morbidity and mortality.[1,2] Visual confirmation of the distal end of the tube can be performed by chest X-ray examination or bronchoscopy. However, these methods are impractical to perform as daily routine procedures because of the unavailability of the equipment at patient bedside, cost, and limited competent personnel.[2] These difficulties lead the airway practitioners to create prediction methods. Many publications proposed various methods to predict ETT depth in children, such as pediatric advanced life support (PALS), glottis landmark, and tracheal palpation.[1,3,4] The PALS method was first introduced in the 2010 PALS guidelines to predict ETT depth for children classified as 0–24 months and >2 years old.[5] This method is simpler and easier to use than the other prediction methods, particularly in emergencies. However, it has some limitations regarding children's characteristic variants, such as tongue size, glottic opening, and airway diameter.[1,4,6] Inspection of chest expansion and auscultation of breath sounds could be an alternative to confirm the tube's end.[5,7] This method is used in our institution as the primary standard to predict ETT depth in children. However, these methods are insufficiently reliable as they are more subjective and depend on operator expertise.

ETT depth in children is affected by age, height, weight, ETT internal diameter, craniofacial variant, head position, and fixation location.[8–11] As Malayan Mongoloid, Indonesian children have different skull anatomies, plate shapes, mandible and alveolar bone sizes, and shorter stature than American or European children.[8,11] This study aimed to compare the accuracy of ETT depth prediction based on the PALS in Indonesian children. This study also evaluated the contributing factors to predict ETT depth.

## METHODS

A cross-sectional study was conducted in pediatric patients aged 0–12 years who underwent elective surgery under general anesthesia with oral intubation at Cipto Mangunkusumo Hospital, Jakarta from October to December 2015. This study has been approved by the Ethics Committee of the Faculty of Medicine, Universitas Indonesia (No: 639/UN2.F1/ETIK/2015). All subjects had provided an informed consent from parents or related caregiver. The sample was obtained through consecutive sampling. The sample size was calculated using the formula for every independent variable to determine the correlation between independent and dependent variables. The minimum significant correlation (r) was 0.4, and the types 1 and 2 errors were 5% and 20%, respectively.

Subjects were divided into two age categories: 0–24 months and 25 months–12 years age groups to examine the differences of the airway anatomy development, particularly the length and diameter of the trachea. A total of 100 pediatric patients aged 0–12 years who underwent elective surgery with oral intubation were included in this study. Exclusion criteria were patients with abnormal airway anatomy (labioschisis, palatoschisis, and tracheoesophageal fistula) or mouth cavity diseases (tongue cancer, nasopharyngeal cancer, and abscess), patients with tracheal stricture or pushing due to mass, patients with pulmonary or respiratory diseases that make breath sounds inaudible (atelectasis and pleural effusion), or patients intubated via tracheostomy. Drop-out criteria were failed intubation on pediatric patients. Failed intubation was defined as three unsuccessful attempts, and the patient will be managed according to difficult airway protocols by the American Society of Anesthesiologists (ASA).

Predictive factors measured were the ETT internal diameter, age, height, and body weight. For the PALS method, the result was classified as accurate or inaccurate in predicting ETT depth with confirmation using the auscultation method. This method is considered accurate in predicting ETT depth when the difference between the two measurements is between the limits of agreement.

Preanesthetic visits were done to obtain demographic data (name, age, sex, weight, height, diagnosis, and ASA physical status), informed consent, and to conduct physical examination of the airway and lungs. In the operating room, the patient's head was propped up with a cloth so that the outer ear canals were in line with the sternal notch. A vital sign monitor was placed next to the patient. An ETT size suited to the patient's age was chosen. This study used the Magill ETT. Endotracheal intubation technique was performed after standard anesthesia induction. Atracurium of 0.6 mg/kg body weight was used as a neuromuscular blocking agent to facilitate endotracheal intubation. The distal end of the tube supposed to reach the right bronchus. The ETT's end in the trachea or bronchus was confirmed by chest expansion, with audible breath sounds from the chest, no projected breath sounds in the gastric area, and end-tidal carbon dioxide wave and value were displayed on the capnography.[9,12] Mechanical ventilation was set with inspiratory pressure of 15–18 cm $H_2O$ (weight <10 kg) and monitored by inspiratory pressure indicator or inspiratory pressure gauge. Respiratory rate was set in normal range according to the subject's age.[11]

After the tube's end reached the bronchus, the ETT was pulled proximally, approximately 0.5 cm every 5 secs, with the stethoscope membrane placed on the left chest. After a breath sound was heard, two senior physicians simultaneously re-performed auscultation by placing both stethoscope membranes on the right chest and then the left chest. The operator stopped pulling the tube when the lung sounds were equal and confirmed by the auscultation personnel; hence, the ETT position was assumed in the center of the trachea.

All the operators of this procedure had passed their competency level.

For subjects aged 8–12 years, the ETT was pulled further at 1.5 cm proximally from the determined point after the breath sounds were equal in both lungs. This process was done to ensure that the tip of the ETT was placed in the middle of trachea,[13] following the length of the trachea in that age group. ETT depth was measured from the distal end to the right/left corner of the lips. Then, the prediction of depth accuracy by PALS was calculated using the following formula: [age (in years)/2] + 12 (for oral ETT). For the 0–24 months age group, the age calculation was measured by dividing the age in months by 12 to obtain more precise measurements.

Data were analyzed using the SPSS software version 20 (IBM Corp., USA). Categorical data were presented in percentage (%), and numerical data were presented in mean and standard deviation (SD). Kolmogorov-Smirnov test was used for the normality test. Bland–Altman analysis was used to quantify the agreement between the two quantitative measurements by constructing limits of agreement between PALS prediction and auscultation confirmation. These statistical limits were calculated using the mean and SD of the differences between the two measurements. Pitman's test was obtained to show the difference in variance obtained from the analysis. Linear regression analysis was performed for the PALS measurement variables (weight, height, and ETT internal diameter). Spearman's correlation test was used to correlate variables (age, height, body weight, and ETT internal diameter) and endotracheal depth.

## RESULTS

A total of 100 subjects were enrolled, with 50 subjects each for the 0–24 months and 25 months–12 years age groups. Patient characteristics are shown in Table 1.

The ETT depths in Indonesian children aged 0–24 months were 10.94 ± 1.51 confirmed using the auscultation method and 12.12 ± 1.60 cm using the PALS method. Figure 1 shows the Bland–Altman test of the ETT depth for the 0–24 months age group between the PALS and auscultation methods. The mean difference between the two measurements was 1.18 (0.96) cm with limits of agreement were −0.71 to 3.08. Pitman's test showed that the correlation between the two methods was *r* = 0.81 with *p* = 0.48.

In the 25 months–12 years age group, the Bland–Altman test showed 1.11 (1.05) cm mean difference with limits of agreement were −0.95 to 3.17. Correlation between the two methods was *r* = 0.73 and *p* = 0.49 (*p*>0.05).

**Table 1.** Subject characteristics

| Characteristics | 0–24 months age group, mean (SD) (N = 50) | 25 months–12 years age group, mean (SD) (N = 50) |
|---|---|---|
| Age (months), median (min–max) | 11 (0–24) | 54 (30–144) |
| Male sex, n (%) | 27 (54) | 26 (52) |
| Body weight (kg)* | 6.9 (2.94) | 14.5 (8.5–40) |
| Height (cm) | 68.5 (14.73) | 105.5 (16.31) |
| BMI (kg/cm²)* | 14.2 (3.52) | 14.8 (7.35–25.6) |
| ETT internal diameter (mm), median (min–max) | 4 (3–5) | 5 (4–5.5) |
| ASA, n (%) | | |
| 1 | 7 (14) | 12 (24) |
| 2 | 28 (56) | 31 (62) |
| 3 | 11 (22) | 7 (14) |
| 4 | 4 (8) | 0 (0) |

*Data were presented as mean (SD) and median (min–max)
ASA=American Society of Anesthesiology; BMI=body mass index; ETT=endotracheal tube; SD=standard deviation

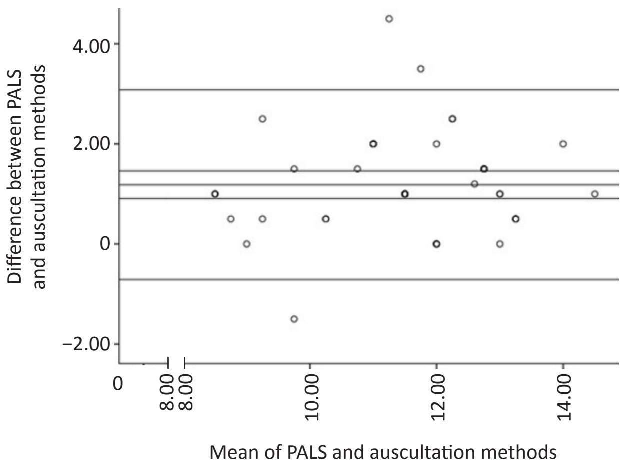


**Figure 1.** Bland–Altman test of endotracheal tube (ETT) depth for the 0–24 months age group between the pediatric advanced life support (PALS) and auscultation methods. Limits of agreement (reference range for the difference) = −0.71 to 3.08. Mean difference = 1.18 cm (95% confidence interval [CI] = 0.90–1.45) and range = 8.0–14.0. Pitman's test of difference in variance: *r* = 0.81, n = 50, *p* = 0.48

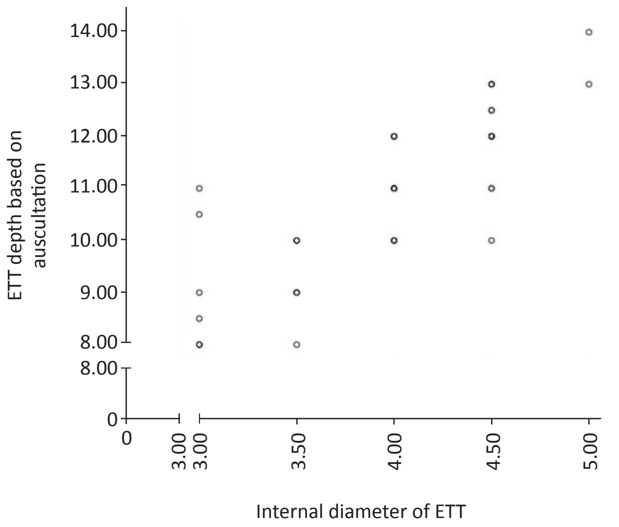


**Figure 2.** Scattered diagram between endotracheal tube (ETT) depth and ETT internal diameter (independent variable) for the 0–24 months age group

**Table 2.** Spearman's correlation test results in both groups

| Variables | 0–24 months age group | | 25 months–12 years age group | |
|---|---|---|---|---|
| | *r* | *p* | *r* | *p* |
| ETT internal diameter (mm) | 0.82 | **<0.001** | 0.68 | **<0.001** |
| Age (months) | 0.72 | **<0.001** | 0.63 | **<0.001** |
| Body weight (kg) | 0.76 | **<0.001** | 0.6 | **<0.001** |
| Height (cm) | 0.62 | **<0.001** | 0.58 | **<0.001** |

ETT=endotracheal tube

Spearman's correlation test for both groups showed a positive relationship between variables (age, height, body weight, and ETT internal diameter) and ETT depth. These results indicated that patient's age, height, body weight, and ETT internal diameter were related to ETT depth (Table 2). Higher measurements increased ETT depth. In the 0–24 months age group, ETT depth could be predicted using the following formula: ETT depth = 1.87 + (2.26 × ETT internal diameter) (Table 3; Figure 2).

Multivariate linear regression analysis with backward method showed that age and weight adequately explained ETT depth in the 25 months–12 years age group. Thus, the formula for ETT depth was as follows: ETT depth = [11.308 + (0.258 × age in years) + (0.45 × weight in kg)] ($R^2$ = 62.3%). All linear regression assumptions (linearity, normality, zero residue, no outlier residue, independent, constant, and homoscedasticity) were fulfilled.

**Table 3.** Formulas generated from linear regression analysis in the 0–24 months age group

| Variables | Formula to predict ETT depth | $R^2$ (%) |
|---|---|---|
| ETT internal diameter | 1.87 + (2.26 × ETT internal diameter) | 68.3 |
| Age | 9.43 + (0.14 × age in months) | 55 |
| Body weight | 8.16 + (0.40 × body weight in kg) | 60.6 |
| Height | 6.31 + (0.06 × body height in cm) | 41.7 |

ETT=endotracheal tube

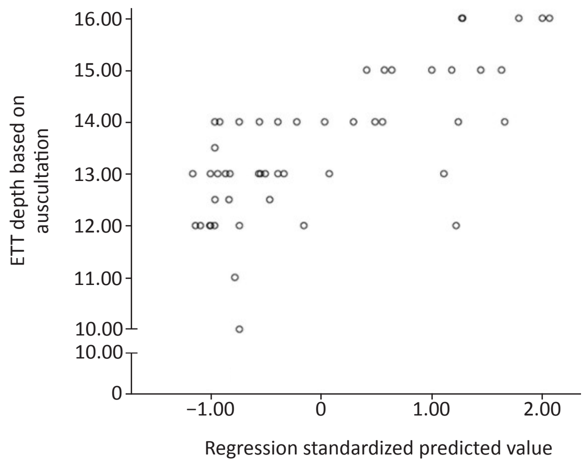


**Figure 3.** Scattered diagram between endotracheal tube (ETT) depth and regression standardized predicted value (independent variable) for the 25 months–12 years age group

## DISCUSSION

This study aimed to calculate the prediction of ETT depth among Indonesian children using the PALS method and then confirmed using the auscultation method. The Bland–Altman test in both groups showed that the PALS method was inaccurate for Indonesian children aged 0–12 years old. The fact that the PALS method was created in the Caucasian pediatric population may contribute to the result. However, the auscultation confirmation method showed high subjectivity, although it was validated by two people to reduce subjectivity. The auscultation method is not the gold standard for ETT depth confirmation, but it has been used in our institution for daily practice. However, many studies revealed that inspection of chest expansion and auscultation of breath sounds could be an alternative to confirm the tube's end.[2,5] Ideally, ETT depth should be evaluated visually using X-ray or bronchoscopy as standard methods in both children and adults. However, the lack of resources limits these examinations; hence, they are not used for daily routine and emergency cases. Ultrasonography is another alternative to evaluate ETT depth by measuring the distal end of the ETT to the upper border of the aortic arch[13] or visualizing the ETT's balloon filled with NaCl 0.9% at the suprasternal notch.[14]

The limits of agreement in the 0–24 months age group were −0.71 to 3.08, which shows the measurement using the PALS prediction method may be −0.71 cm above or 3.08 below the auscultation confirmation method. The mean difference between the two measurements was 1.18 cm. Therefore, the PALS method overestimated the ETT depth than the auscultation confirmation method since the difference between the two methods was higher than the minimum difference expected, which was 0.5 cm. The result of this study showed that the PALS method was inaccurate for Indonesian children aged 0–12 years old. It will cause a misplacement of ETT in the trachea that may lead to endobronchial intubation and endanger patient's life.

The ETT depth is defined as the distance between fixation on the lip's corner and 0.5 cm above the carina. Thus, it is affected by tracheal length (distance of the larynx and carina) and fixation distance (distance of the lip's corner and larynx).[3] Craniofacial variations such as mandibular and alveolar bone prominence in the Mongoloid race, including Indonesian children, can affect the distance between the lip's corner and larynx. Studies regarding these craniofacial variations and tracheal lengths have not been done before. Neunhoeffer et al[15] showed that ETT depth was 1 cm longer than the PALS prediction, whereas Pak et al[6] stated that ETT depth in Korean children was 1 cm shorter. Boensch et al[3] stated that the correct position for the ETT's end is 0.5 cm or more above the carina.

The result for the 0–24 months age group showed that the ETT internal diameter was the strongest variable to correlate ($R^2$ = 68.3%) with ETT depth. The variables used to predict ETT depth were constant and ETT internal diameter. This result followed the PALS method that used the same variables and ETT internal diameter to predict ETT depth in 0–24 months old children. The strong correlation might be due to the domination of transversal and anteroposterior diameter variations in that age group.[16]

Meanwhile, the 25 months–12 years age group showed that age and weight were the strongest variables to correlate ($R^2$ = 62.3%) with ETT depth. The variables used to predict ETT depth were constant, age (years), and weight (kg). The result is in accordance with Pak et al[6] and Hunyady et al[9] that revealed that age is more related to tracheal length than height in >5 years old children; therefore, we can assume that ETT depth will increase in accordance with the patient's age and weight.

However, height is a factor that affects ETT depth because the trachea grows longer along the with the height.[6] Indonesian children have shorter stature than American children in every age classification (0–12 years old);[11] hence, they might have shorter trachea, which leads to a shorter ETT depth compared with the PALS prediction of ETT depth. Thus, the PALS method overestimated ETT depth in the children.

In contrast to Hunyady et al,[9] Pak et al,[6] and Neunhoeffer et al,[15] this study showed that height and weight had a lower correlation value toward ETT depth. This result explained that height and weight could not predict ETT depth (Table 2) and take other factors into consideration. The result might also be caused by differences in subjects' age range and nutrition status in each study. The researchers did not set any limitation to diseases that could affect the subject's nutritional status (e.g., digestive tract diseases) to include more varied subjects. Thus, the height and weight data obtained were varied and close to the real population.

As head position can affect ETT depth, all subjects' heads were propped up with a cloth so that the ear canals were in line with the sternal notch. This process was done to eliminate bias due to head position. Head extension would place the distal end of the ETT proximally, which will cause the ETT to dislodge, whereas flexion would place the distal end toward the bronchus that will lead to endobronchial intubation.[4,6,17]

In children >8 years old, the ETT was pulled 1.5 cm proximally from the fixation point when equal lung sounds were heard to ensure that the tip of ETT was placed in the middle of the trachea. This method was based on the rationale that the airway of 8-year-old children was similar to that of adults.[18] However, this method resulted in airway leakage and led to ineffective ventilation. In this age group, we used the Magill ETT with a cuff. The procedures were performed before cuff inflation. The leakage might be caused by tracheal length difference between the subjects and adults.

A limitation of this study includes the position of ETT tip that was not confirmed using bronchoscopy, which is the gold standard for confirming the position of ETT tip in the trachea. We confirmed the position of ETT by the auscultation method as the standard method in our institution. However, this method was subjective, although we had two competent operators to reduce bias.

In conclusion, the PALS method is an inaccurate tool to predict ETT depth in Indonesian children aged 0–12 years because it will lead to a misplacement of the ETT. In predicting ETT depth in children 0–24 months old or based on age and weight, we suggest to use prediction formulas of ETT internal diameter which is more accurate for children aged 25 months–12 years old.

**Conflict of Interest**

The authors affirm no conflict of interest in this study.

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