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Validity of Three Formulas for Measuring Endotracheal Tube Insertion Depth in Children under Mechanical Ventilation

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Abstract

Background: In the process of intubation, inappropriate placement of the endotracheal tube can lead to hypoxemia, aspiration, insufficient ventilation, atelectasis, barotrauma and pneumothorax. The above complications may be difficult for a patient with severe disease to tolerate; especially when inappropriate placement is not detected by the specialist in the initial evaluation and the diagnosis lasts until the confirmatory chest x-ray is performed. This study evaluated the validity of three formulas in measuring the depth of endotracheal intubation in children under mechanical ventilation.

Methods: 60 intubated children aged 2 months to 12 years were included in this study. The patients were randomly divided into three study groups. Endotracheal tube length for each patient was calculated on the basis of the endotracheal tube length formulas (12 + age (years) / 2; endotracheal tube diameter * 3; and 5 + height (cm) / 10). The ideal depth of the endotracheal tube based on chest x-ray was measured as the median distance between the first thoracic vertebra (T1) and the carina in cm. The distance between the ideal depth of the endotracheal tube and the end location of the endotracheal tube was also measured and recorded.

Results: The mean age of the patients was 42.90 months and 58.3% of them were boys. The most common indication for intubation was pneumonia, along with respiratory distress (33.3%). Considering the difference in endotracheal tube depth between the two values calculated using the formula and chest X-ray equal to± 0.5 cm, formula 12 + (2 / age) in 55% of patients, formula 3 * endotracheal tube length in 70% patients and formula 5 + (10 / height) in 85% of patients, were correctly estimated endotracheal tube length. On the other hand, it was observed that in 15%, 45% and 40% of the patients, the formula predicted the correct length of the endotracheal tube for correct intubation without any difference while compared to the chest X-ray. In evaluating the results obtained from the formula and length of the endotracheal tube measured by chest X-ray, it was also observed that the formulas 12 + (2 / age), 3 * length of the endotracheal tube and 5 + (10 / height) were significantly correlated with CXR.

Conclusion: According to the obtained results, it can be concluded that the formulas used to estimate the depth of endotracheal tube placement in children have low accuracies compared to the gold standard of measurement (chest X-ray). Of course, in comparison to the three formulas (height, weight and diameter of the ETT), the height formula was more accurate than others.

Key Words: Children, Endotracheal Tube, Intubation, Respiratory Distress, Pediatric Intensive Care.

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1- INTRODUCTION

The endotracheal tube entered anesthesia in 1929 by Megil as a method of performing inhalation anesthesia and establishing an airway. Ayri developed this method for pediatric anesthesia. The endotracheal tube can be inserted through the mouth or nose into the endotracheal tube (1, 2).

Intubated endotracheal tubes (ETTs) are commonly used in children because they guarantee better ventilation and more accurate monitoring of ventilation parameters (3, 4). Also they closely monitor ventilation parameters, and reduce the number of ETT changes to prevent leakage and aspiration of stomach contents. However, cuff ETT has the potential to damage children's airways if placed improperly (5-7). Awareness of the effect of a child's age on the size of the larynx is essential for all physicians who deal with children's airways. In infancy, the trachea is funnel-shaped and the upper end is wider than the lower end, and becomes cylindrical with age. The developing airway anatomy is a major determinant of endotracheal intubation in patients less than 8 years of age (8). Endotracheal tube placement (ETT) is a complex process in children in terms of technique and in this regard, one of the main cases is the placement of endotracheal tube at the appropriate depth. In proper placement, the distal end of the endotracheal tube should be located between the end of the trachea and the carina. It also increases the risk of improper placement when the chip length is shorter (9). Formulas based on age and height of patients are helpful in estimating the appropriate depth of ETT placement, while a bunch of standard approaches such as audiography, capnography and CXR are also used to confirm the correct ETT depth placement (10). Other methods include end-tidal carbon dioxide monitoring to confirm esophageal intubation, and direct observation with direct bronchoscopy by an experienced operator, but this method is not available in many pediatric emergencies and is not feasible (11-13). More than 25% of adults who intubate outside the operating room have evidence of improper ETT placement in the CXR (14). Pediatric data also show similar results, with a high percentage of cases intubated outside the operating room associated with improper ETT placement. For example, 30% of intubated children in the emergency department and 13% of intubated children in the ICU are associated with improper ETT placement (15).

This study was conducted for the first time in Iran to determine the validity of the formulas for assessing the correct depth of endotracheal tube placement in children in comparison with the gold standard CXR.

2- MATERIALS AND METHODS

2-1. Sample collection

This study is a cross-sectional study on all children (2 months to 12 years) in need of intubation and candidate for mechanical ventilation in Tabriz Children's Hospital for 6 months. A total of 60 patients were included in the study; they were divided into 3 groups of 20 patients. All patients with tracheostomy, airway anomaly, and/or spinal anomaly were excluded from the study.

2-2. Method

All patients were randomly divided into 3 groups. After the initial examination and intubation consent from the parents, intubation was performed; then the patients' lungs were listened and after ensuring the proper functioning of the endotracheal tube, they were connected to a ventilator and CXR was performed.

The length of the endotracheal tube is, generally, designed for each patient based on the following formulas:

A) 2/age (year)+12=Tracheal tube length

B) Tracheal tube diameter *3=Tracheal tube length

C) 10/Height(cm)+5=Tracheal tube length

It should be noted that in order to calculate the diameter of the endotracheal tube in this study, the formula of age/4 +4 has been used. The ideal depth of the endotracheal tube based on CXR was measured as the median distance between the first thoracic vertebra (T1) and carina based on cm. The distance between the ideal depth of the endotracheal tube and the end location of the endotracheal tube was also measured and recorded.

2-3. Data Analysis

The obtained data were analyzed by SPSS version 21. Patients' demographic information was analyzed using descriptive analysis; and Pearson's correlation test will be used to evaluate the alignment between the results obtained from the calculated formulas and the ideal length based on CXR. ROC Analysis will also be used to assess validity. The items obtained by CXR will be considered as the gold standard in the two categories of proper and inappropriate ETT placement. Then the results obtained by the formulas based on the ROC Curve are reviewed and the results will be presented with CI95% and Area under Curve and calculation of sensitivity, specificity, positive predictive value and negative predictive value. A p-value of less than 0.05 will be considered statistically significant.

3- RESULT

In this study, 60 children were examined; they aged between 12 months and 12 years, and were candidates for mechanical intubation and ventilation. The mean age of the patients was 42.90 months, and 58.3% of them were boys. A comparable pattern was seen in the demographic and physical characteristics of all 60 patients (**Table 1**).

Table-1: Demographic characteristics of the patients

Variable	Value
Frequency (n=100)	
Age, mean±SD (months)	42/90 ± 39/4 8(2/5 -144)
Male: female	35(58.3):25(41.7)
Weight, mean±SD (kg)	14/89 ± 9/2 9(4 -50)
Height, mean±SD (cm)	90/96 ± 28/9 5(50 -150)

The highest frequency of intubation indication in patients with respiratory distress + pneumonia was 33.3%. Intubation failure was observed in 6 patients, which was once in 5 patients and twice in one patient. The frequency of success in intubation of patients was more than 90%. Also, the size of endotracheal tube No. 4 was used more than other endotracheal tubes. Intubation failure was observed in 6 patients, which was once in 5 patients and twice in one patient. The frequency of proper ETT placement in the studied patients with the difference of ± 0.5 cm (**Fig. 1**) was more successful in group C, as compared to the other groups (26.33).

In the present study, considering the difference in ETT depth between the two values calculated by the formula and chest graph equal to ± 0.5 cm, the age formula in 55 patients, the endotracheal tube length formula in 70% of patients, and the height formula in 85% of patients had accurate estimates of endotracheal tube length.

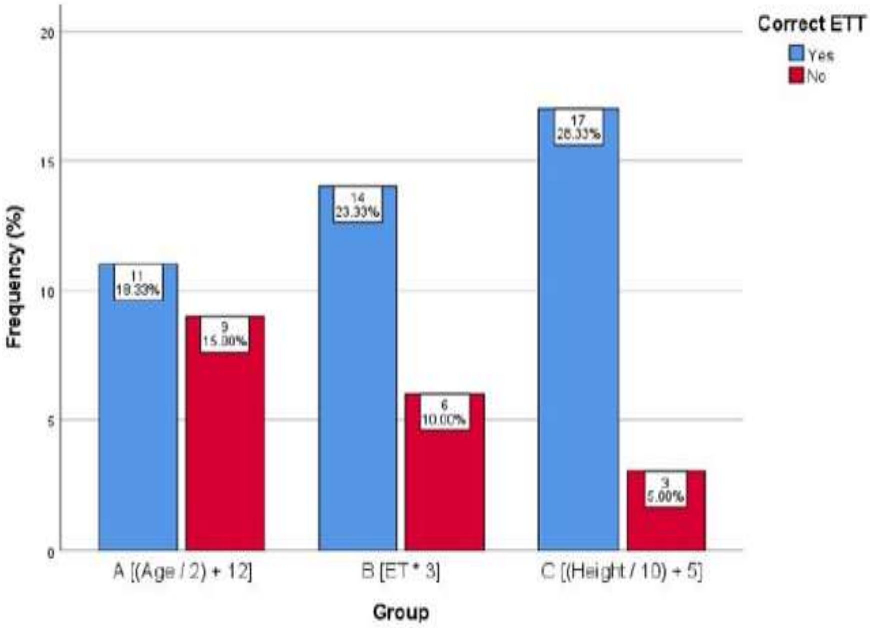

Fig. 1: frequency of proper ETT placement with a difference of ±0/5 cm

The frequency of appropriate ETT replacements in the studied patients with no difference with CXR in all 3 groups includes more cases of failure, with the highest percentage of failures belonging to group A (**Fig. 2**). It was observed that in 15%, 45% and 40% of the patients, respectively, belonging to groups A, B, and C, the formula was matched with the correct endotracheal tube length for correct intubation without any difference with chest x-ray.

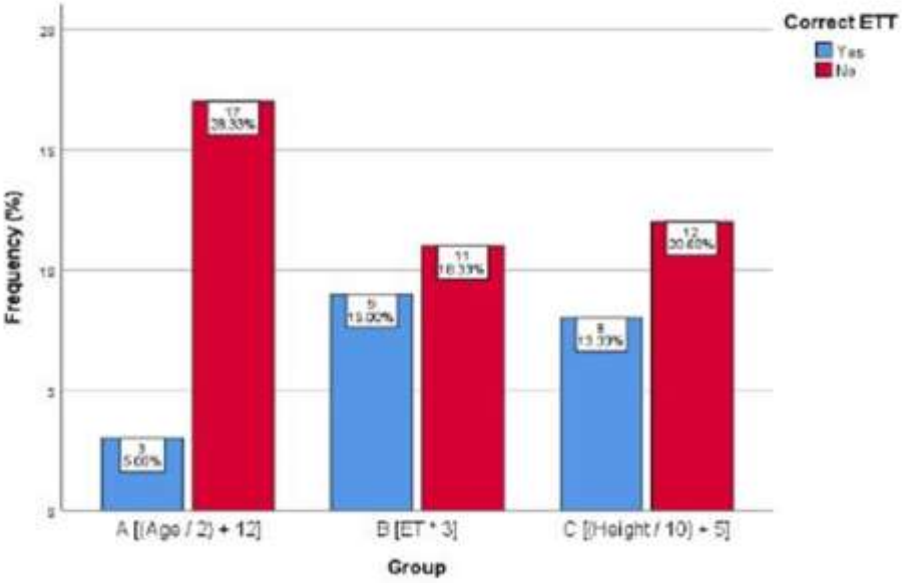

Fig. 2: Frequency of appropriate ETT replacements with no difference with CXR

Pearson's correlation coefficients (**Table 2**) revealed a strong correlation between the length of the endotracheal tube calculated and two formulas (3* endotracheal tube diameter (r=0.966)) and age/2 (r=0.966)). In addition, a much stronger correlation was found between group C and the length of the endotracheal tube (r= 0.982).

Table-2: Pearson correlation test results evaluating the relationship between endotracheal tube length calculated by the formula and endotracheal tube length measured by CXR

Group	Pearson correlation	P-value
(age/2)+12	0.966	0.001
Tracheal tube diameter3*	0.966	0.001
(Height/10)+5	0.982	0.001

4- DISCUSSION

In pediatric candidates of intubation and mechanical ventilation, decisions about the correct choice of size and especially the depth of placement of the endotracheal tube must be made carefully; because a placement that is too deep or less than the standard can lead to very serious complications (16) , such as hypoxemia, insufficient ventilation, atelectasis, barotrauma, and pneumothorax. Numerous methods and formulas have been introduced to estimate the depth of endotracheal tube placement in children, among which the most common male formulas are based on the height, weight and diameter of the endotracheal tube. In the present study, all three formulas have been investigated (17). The results indicated that height is a very ideal variable for calculating the depth of ETT. This finding is in line with the results obtained from the study by Morgan et al., reporting that the length of the endotracheal tube increases linearly with respect to patients' height. In another study by koshy et al., this rate was stated to be 25% for the height formula and in the study by santos et al., it was 56.7% (19, 20). It seems that the difference between these results and ours are related to the age range of the patients studied. In the above study, children under 4 years old were studied, while in our study, children between 2 months and 12 years of age were evaluated. In Akhgar et al.'s study, a new formula based on ultrasound measurements was used to assess the depth of endotracheal tube placement in adults. In this formula, the entrance distance of the endotracheal tube from the mouth to the suprasternal notch and also the distance of the carina to the suprasternal notch were measured and the depth of the endotracheal tube was estimated from all of these measurements.The results of this study demonstrated that out of 91 patients studied, the rate of intubation failure with the standard technique was 9.9%, reduced to 1.1% if the formula was used (21).

The main limitation of the present study is the low sample size, which despite the calculation by the formula, seems limited. Another limitation of the present study is the uniqueness of the study, which seems to lead to the involvement of patients' anthropometric characteristics in the results.

5- CONCLUSION

According to the obtained results, it can be concluded that the formulas for estimating the depth of endotracheal tube placement in children have low accuracies compared to the gold standard of measurement (CXR). Of course, compared to the three formulas of height, age and diameter of the endotracheal tube, the height formula has been more accurate than the others.

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