Original Research Article

# ACCURACY OF DIFFERENT METHODS OF ENDOTRACHEAL TUBE SIZE ESTIMATION IN PAEDIATRIC PATIENTS: A COMPARATIVE RANDOMIZED STUDY

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**ABSTRACT**

**Background:** Endotracheal tube is frequently needed to change due to inappropriate endotracheal (ET) tube size estimation during intubation in padiatric patients. By using the correct estimation tool, we can avoid complications associated with ET tube changes. This study was aimed to investigate which of three commonly used methods (age based Penlington's formula, middle finger length and little finger anteroposterior diameter) for estimating correct ET tube size is better in prediction. Primary objective was to measure incidence of ET tube change in each group. Secondary objectives were to estimate correct estimation rate, pearson corelation coefficient for correct size estimation, and incidence of laryngospasm, bronchospasm, airway trauma and aspiration.

**Materials and Methods:** This comparative, randomized study involved 75 pediatric patients (ASA I-II, up to 5 years old) scheduled for elective surgery. Participants were randomly assigned to one of three groups for estimating endotracheal (ET) tube size: group-A (age-based formula), group B (middle finger length), and group C (little finger anteroposterior diameter). The ET tube used was considered the correct fit if delivery of adequate tidal volume was achieved along with presence of leak only between 11-24 cmH2O airway pressure. If a leak occurred at $\leq$10 cmH2O airway pressure, then the tube changed to 0.5mm larger in size. If no leak occurred at $\geq$25 cmH2O then the tube changed to 0.5mm smaller in size.

**Results:** The requirement of ET tube change was significantly low when ET tube size was predicted with middle finger length (16%) in comparison to age-based formula (36%) and diameter of little finger (32%). The proportion of correct size ET tube estimation was maximum in group B (84%) while it was 64% in both group A and 68% in group C. ET tube size estimated by middle finger length has better correlation with finally placed ET tube ($r=0.918$, $p<0.001$).

**Conclusion:** Based on this study it can be concluded that middle finger length is a better tool for ET tube size estimation as it is associated with less incidence of ET tube change.

**Keywords:** tracheal intubation, endotracheal tube, endotracheal tube size prediction, paediatric, re-intubation

## INTRODUCTION

Endotracheal tube is frequently required in children undergoing surgery to maintain airway patency and to provide positive pressure ventilation during general anesthesia.[1] Required size of ET tube for intubation varies from child to child, even two children with same age may have different size of ET tube requirement. So paediatric patient requiring endotracheal intubation presents unique challenge of estimating appropriate size ET tube, which is important for the prevention of various perioperative complications and injury in airway structure.[2]
Selecting the correct endotracheal (ET) tube size is a crucial step in pediatric anesthesia, as an initial incorrect choice is common. An oversized tube risks difficult insertion, mucosal ischemia, and subsequent edema, which can lead to postoperative airway obstruction and, in severe cases, permanent tracheal damage.[3-7] Conversely, an undersized tube compromises patient safety by increasing the risk of inadequate ventilation, accidental extubation, pulmonary aspiration, and unreliable gas monitoring, while also allowing anesthetic gas leakage.[7-9]
Traditional age-based formulas for estimating endotracheal (ET) tube size are often inaccurate due to the non-linear correlation between a child's age and airway growth. This study, therefore, evaluated the predictive success of three different methods in children up to five years of age: the standard age-based formula, middle-finger length, and the anteroposterior diameter of the little finger, to determine which provides the most reliable estimation.

## MATERIALS AND METHODS

Following approval from the institutional ethical committee (1584/Ethics/19), this prospective study was conducted between 2019 and 2020 at our tertiary care center. We enrolled 75 pediatric patients (ASA physical status I-II, aged up to 5 years) scheduled for elective surgery requiring general anesthesia. Exclusion criteria included known difficult airway, recent respiratory infection, finger or tracheal malformations, or a procedural need for nasal intubation or tracheostomy.
Randomization was performed using computer-generated numbers, and allocation was concealed using the sealed envelope technique. To prevent bias, a research anesthesiologist who was not involved in patient intubation or data collection managed the recruitment and randomization process. Participants were randomly allocated to one of three groups, each corresponding to a different ET tube size estimation method-
**Group A:** ET tube size estimation was done by using age-based formula where internal diameter of ET tube (mm) = Age in years /3 + 3.5
**Group B:** ET tube size estimation was done by measuring length of middle finger where internal diameter of ET tube (mm) = Middle finger length in centimetres.
**Group C:** ET tube size estimation was done by using the anteroposterior diameter of the little finger at distal interphalangeal joint of right hand where internal diameter of ET tube (mm) = anteroposterior diameter of the right little finger at distal interphalangeal joint.
Estimation of ET tube size was done by researcher anaesthetist in preoperative area using three different above-mentioned parameters. In calculating the ET tube size, children < 6 months were taken as 0.5 year and those between 6 months and 1 year were considered 1 year and so on. Since the calculated values may not be multiple of 0.5, they were approximated to the nearest 0.5 or 0.0. ET tube used in our institution were uncuffed ET tubes manufactured by Romsons®. The length of the middle finger was measured on the palmar aspect from the crease of the metacarpophalangeal joint to the tip of the distal metacarpal in centimetres using a measuring tape. The anteroposterior diameter of little finger was measured by using a vernier calliper at distal interphalangeal joint.
In operating room intravenous access was established under sevoflurane sedation, if already not secured in ward. Standard monitors (pulse-oximeter, electrocardiogram, non-invasive blood pressure and $EtCO_2$) were attached and used during intraoperative period. General anesthesia was induced with fentanyl (2 µg/kg), propofol (2-3 mg/kg) and intravenous muscle relaxant atracurium (0.5mg/kg) was given to achieve required relaxation for intubation. After that child was oxygenated with positive pressure ventilation for 4 minutes by ayres T-piece then the first trial of intubation was carried out using an uncuffed ET tube whose size was already calculated according to method of group A, B or C.
Immediately after placement of the tube in the trachea, leak test was done by connecting ET tube to the ventilator (Drager Fabius Plus) on pressure control mode with a inspiratory pressure set at 25 cm $H_2O$, positive end expiratory pressure set at zero, gas flow at 3 L/min and respiratory rate at 20 breath per minute. Then inspiratory pressure was gradually decreased to know the value at which leak was continued to auscultate over trachea. The tube size used was considered as small to fit if there was audible leak at or below 10 cm $H_2O$ airway pressure and ventilator was unable to generate tidal volume of 7 ml/kg. In that case, the tube was changed to larger (0.5 mm more) than previous one.
If endotracheal tube was unable to pass through glottis or resistance was felt during ET tube insertion at glottic or subglottic level, then smaller size tube (0.5 mm less) was chosen. If there was no audible leak above an airway pressure of 25 cm $H_2O$ then tube was considered as large to fit and it was changed to tube having 0.5 mm I.D. smaller size and this was recorded as a tube change incidence. This process was continued until endpoint of the study was

reached where leak occurred only at an airway pressure between 11 to 24 cm H2O.

In this study primary objective was to measure incidence of ET tube change in each group. Secondary objectives were to estimate correct estimation rate, pearson corelation coefficient for correct size estimation, and incidence of laryngospasm, bronchospasm, airway trauma and aspiration.

**Sample size and statistics:**

Assuming type-I error of 5% and power of study 90%, sample size was calculated based on a previous study conducted by Subramanian S et al. The sample size calculated comes out to be 23 which was round of to 25 subjects in every group.

Interpretation and analysis of obtained results was carried out using software Microsoft office Excel 2010 and Statistical package for social science (SPSS) version 22. Qualitative data was expressed using range, frequencies, and percentages whereas mean and standard deviation expressed quantitative data. Comparison of efficacy of different modalities for prediction of ET tube size was done by using Pearson's correlation coefficient. To find the significant difference between the bivariate samples in independent groups, the unpaired sample t-test was used. To find the significance in categorical data, Chi-square test was used. In all the above statistical tools, the probability value of 0.05 or less is considered as statistically significant.

## RESULTS

A total of 86 pediatric patients were screened for eligibility. Of these, 11 were excluded for not meeting the study criteria, leaving 75 patients who were enrolled and randomly assigned in equal numbers to one of three groups, as illustrated in the study flow diagram [Figure 1].

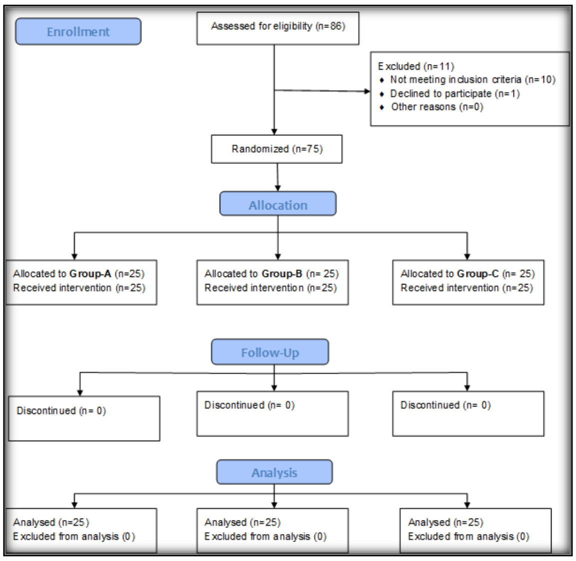


**Figure 1**

Patients in all the three groups are comparable with each other in baseline demographic profile such as age, height and weight. Groups are also comparable in distribution of gender, ASA grade and type of surgery as shown in [Table 1].

**Table 1: Demographic parameter of study groups.**

| Variable | Group A (n=25) | Group B (n=25) | Group C (n=25) | t-value | p-value |
|---|---|---|---|---|---|
| Age in yr (mean+sd) | 1.83±1.25 | 2.15±1.45 | 1.89±1.29 | 0.41 | 0.66 |
| Height in cm | 76.6±13.72 | 78.48±10.7 | 76.48±11.77 | 0.21 | 0.814 |
| Weight in kg | 8.82±3.44 | 10.08±3.62 | 8.82±3.54 | 1.07 | 0.349 |
| Gender | 10/15 | 8/17 | 11/14 | 0.79 | 0.675 |
| ASAI/II | 18/7 | 19/6 | 17/8 | 0.397 | 0.820 |
| Type of surgery Genitourinary/ Abdominal | 11/14 | 13/12 | 10/15 | 0.753 | 0.686 |

Maximum cases where ET tube change needed were from group A (36%) and group C (32%) while in group B only in 16% cases tube change was required. This difference was statistically significant (p=0.025) as shown in [Table 2].

**Table 2: Number of endotracheal changes in each group.**

| Number of ET tube changes | Group A (n=25) | Group B (n=25) | Group C (n=25) | Chi sq | p-value |
|---|---|---|---|---|---|
| 0 | 16(64%) | 21(84%) | 17(68%) | 2.77 | 0.025 |
| 1 | 8(32%) | 4(16%) | 7(28%) | | |
| 2 | 1(4%) | 0(0%) | 1(4%) | | |
| 3 | 0 | 0 | 0 | - | - |

The proportion of correct size tube estimation was maximum in group B (84%) while it was 64% in group A and 68% in group C. Proportion of under sized ET tube estimation was much frequent in group A (24%), whereas proportion of oversized ET tube estimation was much frequent in group C (32%). The proportion of accuracy of ET tube size estimation was significant among the groups (p=0.009) as shown in [Table 3].

**Table 3: Rate of correct endotracheal tube size estimation in groups**

| Variable | Group A (n=25) | Group B (n=25) | Group C (n=25) | Chi sq | p-value |
|---|---|---|---|---|---|
| Correct size estimation | 16(64%) | 21(84%) | 17(68%) | 13.58 | 0.009 |
| Over size estimation | 2(8%) | 2(8%) | 8(32%) | | |

| | | | | | |
|---|---|---|---|---|---|
| Under size estimation | 7(28%) | 2(8%) | 0(0%) | | |

Pearson correlation coefficient, which shows quality of corelation between estimation method and correct ET tube size was best with middle finger length method (r=0.918). It was 0.810 and 0.858 with group A and group C respectively as shown in [Table 4].

**Table 4: Pearson correlation coefficient of correct tube size estimation by different methods**

| S. no. | Correlation sets | Pearson correlation | P-value |
|---|---|---|---|
| 1 | Size estimated by age vs finally placed size | 0.810 | 0.001 |
| 2 | Size estimated by middle finger length vs finally placed size | 0.918 | 0.001 |
| 3 | Size estimated by little finger width vs finally placed size | 0.858 | 0.001 |
| 4 | Overall | 0.849 | 0.001 |

Laryngospasm at the time of extubation was observed in one case each in group A and group C, which was resolved by injection propofol. Similarly, one case of bronchospasm was noted in group A and group B as shown in [Table 5].

**Table 5: Incidence of various adverse events in groups.**

| Variable | Group A (n=25) | Group B (n=25) | Group C (n=25) | Chi sq | p-value |
|---|---|---|---|---|---|
| Laryngospasm | 1(4%) | 0(0) | 1(4%) | 2.33 | 0.67 |
| Airway trauma | 0(0) | 0(0) | 0(0) | - | - |
| Bronchospasm | 1(4%) | 1(4%) | 0(0) | 2.33 | 0.67 |
| Aspiration | 0(0) | 0(0) | 0(0) | - | - |

## DISCUSSION

Appropriate endotracheal tube size estimation is one of the important tasks for the paediatric anaesthetist and other personal involved. Oxygen reserve is low in younger children than adult so intubation process must proceed rapidly otherwise oxygen desaturation occurs quickly.[13] Inappropriate size endotracheal tube whether it is too large or too small can cause complications like airway injury, leak around tube and lung aspiration. Therefore, the selection of the correct tube is critical in this pediatric age group.[14]

In the present study, patients in all the three groups were comparable with each other in baseline demographic profile. We found that ET tube size estimated by middle finger length has better correlation with best fit ET tube size. The requirement of ET tube change was significantly low when middle finger length was used to estimate ET tube size in comparison to either age-based formula or diameter of little finger. The superiority of middle finger length to determine the internal diameter of uncuffed endotracheal tube size in paediatric patients was also documented in a study done by S Ritchie-McLean et al. They included 108 children aged up to 12 years presenting for elective surgery and require anaesthesia with a tracheal tube. They used middle finger length and age-based formula for selection of appropriate ET tube size. They concluded that this estimation method was associated with less the number of attempts of ET tube placement.[15]

In the present study correlation between ET tube size estimated and final ET tube size placed was maximum in group B (r=0.918, p=0.001). Similar results were found in previous study where they linear regression analysis showed value of 0.841, suggesting that 84% of the variation in tracheal tube size can be accounted for by the length of the middle finger with $p < 0.001$.[15]

Adverse events like laryngospasm, airway trauma, bronchospasm and aspiration were similar in all group indicating that ET tube change is not always associated with increase in incidence of above-mentioned events.

This study has several limitations. First, its single-center design may limit the generalizability of our findings to other clinical settings. Second, our methodology relied on the assumption that a single, predetermined size of uncuffed endotracheal tube (ETT) is suitable for each patient, which may not account for individual anatomical variations. Furthermore, the results may not be transferable to ETTs from other manufacturers, as the outer diameter can differ significantly across brands. Lastly, the findings cannot be applied to children with hand or finger deformities, as this population was not included in our study.

## CONCLUSION

Our study revealed that estimating endotracheal tube size based on middle finger length is associated with a lower incidence of tube exchanges due to improper fit (i.e., significant air leak or inability to insert). Furthermore, middle finger length demonstrated a stronger correlation with the optimal ET size compared to other estimation methods. Based on these findings, we conclude that middle finger length is a reliable and potentially superior tool for estimating ETT size in children under five years of age.

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