

# THE 'BEST FIT' ENDOTRACHEAL TUBE IN CHILDREN

## - Comparison of Four Formulae -

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### Abstract

**Background:** Uncuffed endotracheal tubes are still being recommended by most pediatric anesthesiologists at our Institutes. Different algorithms and formulae have been proposed to choose the best-fitting size of the tracheal tube. The most widely accepted is related to the age of the child [inner diameter [ID] in mm = (age in yr/4) +4; the second is a body, length-related formula (ID in mm = 2 + height in cm/30); the third, a multivariate formula (ID in mm = 2.44 + age in yr × 0.1 + height in cm × 0.02 + weight in kg × 0.016)<sup>5</sup>; the fourth, the width of the 5<sup>th</sup> fingernail is used for ID prediction of the ETT (ID in mm = maximum width of the 5<sup>th</sup> fingernail).

The primary endpoint of this prospective study was to compare the size of the 'best fit' tracheal tube with the size predicted using each of the above mentioned formulae.

**Patients and Methods:** With Institutional Ethics Committee approval and parental consent, 27 boys, 23 girls, ASA I-III, 2-10 years, scheduled for different surgical procedures requiring general anesthesia and endotracheal intubation, were enrolled in the study. The size of 'best fit' endotracheal tubes in those children were compared. The internal diameter considered the 'best fit' by the attending pediatric anesthesiologist was compared to age-based, length-based, multivariate-based and 5<sup>th</sup> fingernail width-based formulae. For all tests, P < 0.05 was considered to be statistically significant.

**Results:** The mean (SD) IDs for the 'best fit', age-based, length-based, multivariate and 5<sup>th</sup> fingernail techniques were 5.31 (0.691), 5.54 (0.622), 5.82 (0.572), 5.71 (0.67) and 5.43 (0.821) mm, respectively.

**Conclusions:** The age-based and 5<sup>th</sup> fingernail width-based predictions of ETT size are more accurate than length-based and multivariate-based formulae in terms of mean value and case matching.

**Key Words:** pediatric, endotracheal tube, age, length, multivariate, 5<sup>th</sup> fingernail, formula

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## Introduction

Uncuffed endotracheal tubes are still being recommended for pediatric anesthesia in our Institutes. Smaller than ideal endotracheal tube size is not recommended because of increased incidence of tracheal tube replacement, less precise monitoring of respiratory mechanics and end-tidal CO<sub>2</sub>, increased pollution of the operating room and increased cost related to increased consumption of volatile agents, in addition to increased airflow resistance.

The endotracheal tube (ETT) itself poses more resistance to airflow, and this resistance is inversely proportional to the fourth power of the radius and directly proportional to the length; i.e., narrower and longer tubes show greater flow resistance<sup>1</sup>. This is of significant clinical importance for children during anesthesia or intensive care, and it suggests that the widest and shortest possible ETT should be used.

However, a tightly fitting endotracheal tube can easily result in decreased mucosal perfusion and subsequent edema, which can result in critical airway obstruction and associated syndromes, e.g. dyspnea, hypoxemia, and the potential need for invasive management. Even cartilage damage may occur, potentially resulting in permanent impairment and disability.

Anatomically, the larynx of a pediatric patient assumes a funnel shape with its narrowest part at the level of the cricoid ring, which cannot be seen during conventional laryngoscopy<sup>2</sup>.

Different algorithms and formulae have been proposed to choose the best-fitting size of the tracheal tube.

The most widely accepted of which is age based formula (ABF) (inner diameter [ID] in mm = (age in yr/4) + 4<sup>3</sup>. This calculation overestimates the correct size in more than one in four cases<sup>4</sup>.

Pediatric emergency physicians have suggested a body length-related formula (ID in mm = 2 + height in cm/30)<sup>5</sup>. However, selection of the correct tube size in children might be more complex, leading others to propose a multivariate prediction model (ID in mm = 2.44 + age in yr × 0.1 + height in cm × 0.02 + weight in kg × 0.016)<sup>6</sup>.

Finally, the 5<sup>th</sup> fingernail width can be used for prediction of the ID of the ETT (ID in mm = maximum

width of the 5<sup>th</sup> fingernail)<sup>7</sup>.

The primary endpoint of this prospective study was to compare the 'best fit' size of the tracheal tube with the size predicted using each of the above mentioned formulae.

## Patients and Methods

After obtaining Ethics Committee approval and parental written informed consent, 50 patients (27 boys, 23 girls), ASA I-III, median (range) age 6.0 (2.0-10.0) years, mean (SD) height 121.14 (17.73) cm and mean (SD) weight 21.35 (8.96) kg, scheduled to undergo different surgical procedures requiring general anesthesia with oro-tracheal intubation and lasting more than 45 minutes, were prospectively included. Exclusion criteria included known or suspected airway anomalies, the need for exceptional tracheal tube sizes known from previous anesthetic treatment, concurrent or recent upper respiratory tract infection and requirement of postoperative mechanical ventilation.

Monitoring consisted of noninvasive measurement of blood pressure, heart rate via electrocardiogram, hemoglobin oxygen saturation, end-tidal CO<sub>2</sub> values, and inspiratory and expiratory oxygen concentrations.

General anesthesia was induced by inhalation of sevoflurane in O<sub>2</sub> or propofol (2 mg/kg) as appropriate and maintained by fentanyl (1 µg/kg) and sevoflurane in an O<sub>2</sub>/N<sub>2</sub>O gas mixture. Tracheal intubation was performed after complete muscle paralysis by cisatracurium 0.15 mg/kg. The correct position of the tracheal tube was confirmed by capnography and by auscultation for bilateral breath sounds.

The tracheal tube size was chosen and selected as 'best fit' by the attending pediatric anesthesiologist if air leakage was satisfactory at a maximum of 20 cmH<sub>2</sub>O airway pressure<sup>8</sup>. The leak pressure was measured by carefully closing the pressure relief valve from the zero position until an audible air leak was obtained at the patient's mouth and/or over the larynx. For the purpose of air leak measurement, the head and body positions were standardized; the patient was supine with the head roughly in a neutral position to limit any impact on the leak test<sup>9</sup>. The ETT would be changed to a bigger size when air leak is excessive. Alternatively,

when there was resistance to the passage of the ETT into the trachea or when air leak was not detected, a smaller tube was placed.

Standardized respirator settings were applied: pressure-controlled ventilation, peak inspiratory pressure of 10-15 cmH<sub>2</sub>O to give tidal volume of 7-10 ml/kg, breathing frequency according to patient's age and PetCO<sub>2</sub>, fresh gas flow of 3 L/min.

At the end of the procedure, the tracheal tube was removed, and all patients were transferred to the recovery room for postoperative follow-up to assess post-extubation respiratory morbidities (croup, cough, sore throat, dyspnea, dysphonia or stridor).

For all patients, the size predicted by the above mentioned formulae was calculated preoperatively and recorded in a sheet that was not seen by the attending anesthesiologist. Because the calculated values might NOT be clinically applicable (0.5 multiples), we calculated the difference between the used and estimated sizes and considered the estimate to match the size actually used when the difference was between -0.5 and +0.5. We evaluated the proportions of matched cases using each method. Each value was approximated to the nearest 0.5 or 0.0 (e.g. 4.65 approximated to 4.5, 5.8 approximated to 6.0, and so on), and then the comparison of the means was repeated.

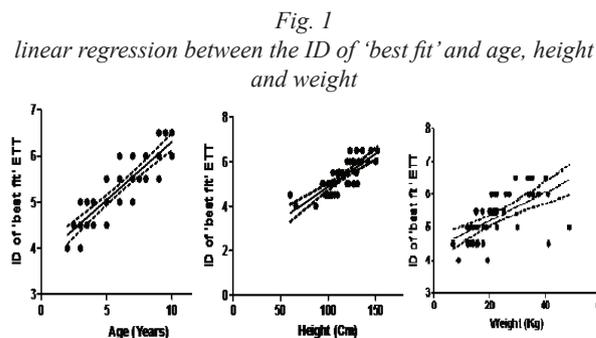
Data are presented as the mean ± standard deviation, numbers of cases (%) or median (range) as appropriate. All statistical tests were unpaired and two-tailed, and P < 0.05 was considered to be statistically

significant. The Mann-Whitney U-test was used for nonparametric variables, and the Fisher exact test was used for nominal variables.

Power analysis was done assuming that the true difference between the 'best fit' ETT ID mean and hypothetical average mean of the predicted IDs of all used formulae is 0.27, our study has an 80% power with a significance level (alpha) of 0.05 (two-tailed).

**Results**

Non parametric correlation using spearman rank with no gaussian assumption showed that the 'best fit' ETT ID has a strong correlation with age (r = 0.872, P < 0.001) with 95% CI 0.880 to 0.927 and height (r = 0.804, P < 0.001) with 95% CI 0.673 to 0.886, and moderate correlation with weight (r = 0.675, P < 0.001) with 95% CI 0.482 to 0.806 (Figure 1). The p-values shown here describe the likelihood of no correlation (r = 0) and do not describe the strength of the association.



*Table 1  
Comparison of 'best fit' ETT with that predicted by age-based, length-based, multivariate-based and 5<sup>th</sup> fingernail width formulae*

'best fit'	N. of cases	Age (years)	Age-predicted size	Length-predicted size	Multivariate-predicted size	5 <sup>th</sup> fingernail width-predicted size
4	2	2.25 (2.0-3.0)	4.56 ± 0.269	4.65 ± 0.354	4.42 ± 0.071	4.0 ± 0.00
4.5	11	4.05 (2.5-7.0)	4.92 ± 0.205	5.30 ± 0.457**	5.09 ± 0.386**	4.82 ± 0.603
5	10	4.85 (3.0-7.0)	5.337 ± 0.566	5.75 ± 0.448*	5.49 ± 0.404	5.15 ± 0.337
5.5	13	6.65 (5.0-9.0)	5.66 ± 0.321	5.92 ± 0.263**	5.77 ± 0.273	5.38 ± 0.363
6	9	8.22 (6.0-10)	6.06 ± 0.391	6.22 ± 0.228	6.34 ± 0.365	6.22 ± 0.755
6.5	5	9.7 (9.0-10)	6.42 ± 0.112	6.57 ± 0.383	6.72 ± 0.29*	6.6 ± 0.418
Total	50	6.13 (2.0-10)	5.54 ± 0.622	5.82 ± 0.572**	5.71 ± 0.67*	5.43 ± 0.821

Data are presented as number, mean ± SD, or mean (range). N. = number, \* = p < 0.05, \*\* = p < 0.001

The mean (SD) IDs for the ‘best fit’, age-based, length-based, multivariate and 5<sup>th</sup> fingernail techniques were 5.31 (0.691), 5.54 (0.622), 5.82 (0.572), 5.71 (0.67) and 5.43 (0.821) mm, respectively, with the mean SD of the total fit used tube of 5.31(0.691) (Table 1). The differences were statistically significant for length-based and multivariate-based formulae (Table 2).

Table 2  
Match between ‘best fit’ and predicted size.

	‘best fit’ = size predicted	best fit’ < size predicted	best fit’ > size predicted
Age-based	11 (22)	29 (58)	10 (20)
Length-based	3 (6)	44 (88)	3 (6)
Multivariate-based	0 (0)	41 (82)	9 (18)
5 <sup>th</sup> fingernail-based	24 (48)	15 (30)	11 (22)

Data are number (%)

Furthermore, after approximation of the predicted sizes for each formula as described above, no changes were observed. Number of matching cases between the size of ‘best fit’ and predicted size by each formula is summarized in Table 2. Number of matching cases between the size of ‘best fit’ and approximated predicted size by each formula is summarized in Table 3.

Table 3  
Matching between ‘best fit’ and approximated predicted size

	‘best fit’= size predicted	best fit’ < size predicted	best fit’ > size predicted
Age-based	43 (86)	7 (14)	00
Length-based	30 (60)	20 (40)	00
Multivariate-based	29 (58)	21 (42)	00
5 <sup>th</sup> fingernail-based	46 (92)	3 (6)	1 (2)

Data are number (%)

## Discussion

In 1971, Brown emphasized the proper selection of uncuffed ETT for use in the pediatric population in order to avoid related problems and complications<sup>10</sup>. Since the human body build and structure are different across populations, the predicted size of the ‘best fit’ ETT calculated for children of various countries does

not remain consistent, even when using the same formula. Wang et al, demonstrated that body height had the best correlation to the size of an uncuffed oral ETT in Chinese children, in contrast to Caucasians<sup>5</sup>. Hofer et al, concluded that endotracheal tube size selection using the Broselow tape appeared to match the size of the tube used better than the ABF; the results in a European sample of children are comparable to the US data<sup>11</sup>. In Japan, Shima et al, concluded that endotracheal tube size was most correlated with body length, followed by body weight, tracheal size in X-ray photograph and age<sup>12</sup>. King et al, concluded that neither the 5<sup>th</sup> finger width nor the 5<sup>th</sup> finger diameter could accurately predict proper endotracheal tube size in most children. It was indicated that a more accurate estimation could be made using the ABF. That study did not examine length-based and multivariate-based formulae<sup>7</sup>.

In contrast to these findings, our results show that the ‘best fit’ ETT mean size is not significantly different from that predicted by age-based and 5<sup>th</sup> fingernail width formulas, but it is significantly different from that predicted by length-based and multivariate formulas. Davis et al, compared the ABF with the length-related formula. In agreement with our finding, it was concluded that the ABF was reliable and easily applied and accepted for routine anesthesia in their pediatric population<sup>3</sup>. Koichi et al, concluded from a retrospective analysis of 1301 charts from Japanese children undergoing pediatric surgery, that the ABF was applicable to Japanese children. However, it was recommended that three sizes should be available before endotracheal intubation<sup>13</sup>. In a recently published study on a weight-based formula (WBF) for tracheal tube size in children, it was found that the WBF was statistically inferior to the ABF in selecting the best tube size for children. However, when inaccurate the conventional ABF tended to underestimate while the WBF tended to overestimate the appropriate size of tracheal tube in pediatric anesthesia<sup>14</sup>.

In conclusion, the selection of the ETT as ‘best fit’ by observing the air leak test is subjective and may not be very accurate. Moreover, this is a descriptive study performed in a single institution and only a larger multicenter prospective study would be able to validate the results, especially with regard to the

different formulae used for predicting the adequate size of an uncuffed ETT. We believe that the age-based and 5<sup>th</sup> fingernail width-based formulae for predicting

of ETT size are more accurate than length-based and multivariate-based formulae among our children.

## References

1. ANSGAR B, ULRICH B: Airway management in infants and children. Best Practice & Research. *Clinical Anaesthesiology*; 2005, 19:675-79.
2. KARSLI CH, ISAAC LA, ROY WL: Induction of anesthesia, in Bissonnette B, Dalens BJ (eds): *Pediatric Anaesthesia Principles and Practice* (ed 1). New York, NY, McGraw-Hill, 2002, pp. 483-527.
3. DAVIS D, BARBEE L, RIRIE D: Pediatric endotracheal tube selection: a comparison of age-based and height-based criteria. *AANA J*; 1998, 66:299-303.
4. MOSTAFA SM: Variation in subglottic size in children. *Proceedings of the Royal Society of Medicine*; 1976, 69:793-95.
5. WANG TK, WU RS, CHEN C, CHANG TC, HSEIH FS, TAN PP: Endotracheal tube size selection guidelines for Chinese children: prospective study of 533 cases. *J Formos Med Assoc*; 1997, 96:325-29.
6. ECK JB, DE LISLE DEAR G, PHILLIPS-BUTE BG, ET AL: Prediction of tracheal tube size in children using multiple variables. *Paediatric Anaesth*; 2002, 12:495-98.
7. KING BR, BAKER MD, BRAITMAN LE, SEIDL-FRIEDMAN J, SCHREINER MS: Endotracheal tube selection in children: a comparison of four methods. *Ann Emerg Med*; 1993, 22:530-34.
8. MURAT I: Cuffed tubes in children: a 3-year experience in a single institution. *Paediatric Anaesth*; 2001, 11:748-49.
9. SCHWARTZ RE, STAYER SA, PASQUARIELLO CA: Tracheal tube leak test-is there inter-observer agreement? *Can J Anaesth*; 1993, 40:1049-1052.
10. BROWN ES: Resistance factors in pediatric endotracheal tubes and connectors. *Anesth Analg*; 1975, 50:355-60.
11. HOFER CK, GANTER M, TUCCI M, KLAGHOFFER R, ZOLLINGER A: How reliable is length-based determination of body weight and tracheal tube size in the pediatric age group? The Broselow tape reconsidered. *Brit J Anaesth*; 2002, 88:283-85.
12. SHIMA T, ANDOH K, AKAMA M, HASHIMOTO Y: The correct endotracheal tube size for infants and children. *Masui*; 1992, 41:190-93.
13. TAKITA K, MORIMOTO Y, OKAMURA A, KEMMOTSU O: Do age-based formulae predict the appropriate endotracheal tube sizes in Japanese children? *J Anaesth*; 2001, 15:145-48.
14. EIPE N, BARROWMAN N, WRITER H, ET AL: A weight-based formula for tracheal tube size in children. *Paediatric Anaesth*; 2009, 19:343-48.

