Original Article

Length of the middle finger of hand as a simple and reliable predictor of optimal size of uncuffed endotracheal tube in paediatric patients: An observational study

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ABSTRACT

Background and Aims: A recent study suggested middle finger length-based formula as a better predictive guide compared with age-based formula for selecting uncuffed endotracheal tubes (ETTs) in children. But that study did not meet sample size requirement. Thus, we primarily aimed to determine the accuracy of formula using length of the middle finger to determine the internal diameter of the uncuffed ETT and to compare its accuracy with the Cole's formula. As a secondary objective, we desired to compare its accuracy with some commonly used length and weight-based formulae. **Methods:** This prospective observational study included children aged up to 12 years posted for elective surgery under general anaesthesia. The length of the middle finger on the palmar aspect of the hand was measured in the preoperative period and the characteristics of the airway used were noted. A predefined criterion of optimal size of the uncuffed ETT was used. **Results:** A total of 139 patients were included in the final analysis. It was observed that the formula based on middle finger length can predict the optimal size of uncuffed ETT within an error of 0.5 mm in more than 90% instances and its predictive performance is better than Cole's formula. As a secondary outcome, we also observed that its accuracy is better than other formulae under evaluation. **Conclusion:** Formula based on middle finger length can be used as a predictor of optimal size of uncuffed ETT in paediatric patients and it is a better predictor than Cole`s formula.

Key words: Anaesthesia, child, fingers, general, intratracheal, intubation, predictive value of tests

INTRODUCTION

A recent study suggested that length of the middle finger of the hand may be a better predictor of the appropriate size of uncuffed endotracheal tube (ETT) in children compared to certain bedside clinical predictors.[1] Among different formulae based on length of the middle finger, the formula "middle finger length (cm) [round up to nearest 0.5] = internal diameter of uncuffed tracheal tube (mm)" was proposed to be clinically appropriate with an error of 0.5 mm ETT size.[1] Without describing any statistical reasoning, the authors chose to use a sample size of 80 patients based on previous similar studies.[1] Unfortunately, even after increasing the number of approached patients, due to the higher than predicted attrition rate, the authors could gather data from 76 patients and the study did not meet the stipulated sample size.[1]

Airway morphometric measurements are different in the Asian and Western population.[2] Thus, we questioned whether the relationship of middle finger length to the size of uncuffed ETT is valid in our

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population. Our hypothesis was that the above formula would have similar predictive accuracy (proportions in which the appropriate size ETT could be predicted with an error of 0.5 mm) in our population. Therefore, this study was designed to primarily determine the accuracy of this formula to determine the internal diameter of the uncuffed ETT and to compare it with the Cole's formula.[1] As a secondary objective, we desired to compare its accuracy with some commonly used length and weight-based formulae.[3-5]

METHODS

This single-centre prospective observational study was conducted from 3 October 2019 to 31 July 2020 in a medical college hospital in patients aged 1 month–12 years requiring endotracheal intubation for provision of general anaesthesia. Permission from Institutional Ethics Committee was obtained and the study was prospectively registered with Clinical Trials Registry-India (CTRI/2019/09/021383). Patients with finger or airway abnormalities, anticipated difficult airway, use of supraglottic airway devices or cuffed ETT, requiring nasal intubation or posted for emergency surgical procedures were excluded.

All consecutive patients meeting the inclusion criteria were eligible for inclusion. Discussion with the parents of included patients was held to obtain consent for inclusion in the study. Height was measured using a Mancloem™ 1.50m measuring tape. In younger patients, length was measured from the heel to the vertex of the head in supine position and was regarded as the height. Patients who could stand were asked to stand straight with their back towards the wall and foot and head touching the wall. A mark was made corresponding to the highest point of the patient's head. Height was measured from the floor to the above-mentioned mark. Weight (in kg) was measured with GVC deluxe personal analogue mechanical weighing scale™ calibrated to zero. Age was calculated in days from the date of birth to the day of the surgery. For measurement of the middle finger length, the hand was kept on a firm surface with the upper limb in anatomical position.[1] The length of the right middle finger on the palmar aspect from the crease of the metacarpophalangeal joint to the tip of the distal phalanx was measured with a Zhart vernier digital caliper (150 mm/6 inches) in centimetres up to the first decimal point [Figure 1]. The person collecting the above-mentioned data was not a part of the subsequent perioperative management. The

Figure 1: Measurement of the length of the middle finger

concerned surgical, anaesthesiology, and allied subject's teams were not informed about the study hypothesis or outcome measures.

Patients were placed supine on the operating table and underwent anaesthesia as per the preference of the consulting anaesthesiologist. The choice of airway was at the discretion of the consultant anaesthesiologist. If a supraglottic airway or a cuffed ETT was chosen, the patient was excluded from subsequent analysis. Trachea was intubated with direct laryngoscopy using an uncuffed ETT (Sterimed, India). After confirmation of tracheal placement by continuous demonstration of expiratory carbon dioxide and bilateral chest auscultation, the adjustable pressure limiting valve was closed (Mindray A5 anaesthesia machine). The inspiratory pressure was gradually increased with constant monitoring of the peak airway pressure (Paw) and haemodynamics. A stethoscope was placed near the oral isthmus to detect leak around the ETT. If leak was detected at Paw of 15 cm H_2O or less, the ETT was changed to the next larger size. If no leak was detected at Paw of 30 cm H_2O or more or there was resistance while passing the tube, the ETT was changed to the next smaller size.[6] The anaesthesia team was briefed about the protocol for choice of size of ETT. The consultants were asked if they used any specific formula to predict the size of ETT required.

Ritchie-Mclean *et al*. reported that middle finger length (cm) rounded up to nearest 0.5 cm could predict the correct size of ETT within 0.5 mm in 89.5% (95% confidence interval 80.3-94.8%) patients.[1] To correctly predict the ETT size up to nearest 0.5 mm in 90% patients, with a margin of error of 5% (confidence level of 95%), 130 patients were required. They also reported that Cole's formula could predict the internal diameter of the ETT to the nearest 0.5 mm in 50% patients.[1] To detect an additional increase of 40% with the power of 90% and a confidence interval of 95%, 23 patients are required. Therefore we intended to obtain complete data from 130 patients for our study. To account for an estimated dropout of 20%, we intended to include 156 patients.

The pertinent data was collected and tabulated in the Excel Spreadsheet (Microsoft Windows 10, USA). Nominal variables are presented as absolute numbers and percentages. The central tendency and dispersion of continuous variables are presented as mean, standard deviation, coefficient of variation, median, intra-quartile range and range. The correlation between age, height, weight and middle finger length was measured with Pearson's correlation coefficient and the respective scatter plot generated using Microsoft Excel. Co-efficient of determination between size of appropriate ETT and age, height, weight and the middle finger length were calculated and relevant scatter plots were created using Statistical Package for the Social Sciences (SPSS) version 21.0, IBM, USA. Similarly, the coefficient of determination between the age, weight, height and the middle finger length-based formulae with the optimal sized ETT was measured. Bootstrapping with 1000 re-sampling was carried out for multiple regression analysis for prediction of internal diameter of uncuffed ETT by age, height and weight. Bootstrapping was also used to compare the models based on Cole's formula and the other height and weight-based formulae. The predicted accuracy is presented with proportions. For comparison of the predictive accuracy between two formulae, z-score test for two populations was used. A value of $P < 0.05$ was considered statistically significant.

RESULTS

Among the 371 patients evaluated for possible inclusion in our study, 139 patients were included in the final analysis [Figure 2]. In 129 patients, trachea could be intubated in the first attempt with the tube chosen by the consultant anaesthesiologist fulfilling the criteria based on leak pressure, whereas the ETT needed to be changed in nine patients (6.47%). Intubation of the trachea needed two attempts in one patient and the trachea could be intubated with the tube size chosen during the first attempt. In none of the instances, the consultant anaesthesiologist used any specific predictive formula.

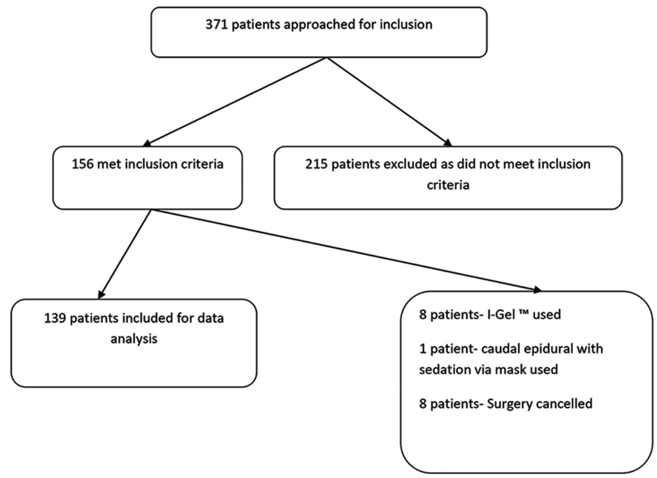

Figure 2: Flow chart of patient selection in our observational study

The demographic details of the patients included age, weight, height, gender and length of the middle finger [Table 1]. We calculated the proportions of patients in whom the optimal size of ETT was correctly predicted and predicted within an error of 0.5 mm for each of the formulae [Table 2]. The proportions in which a potentially too large (more than 0.5 mm) tube was predicted was also calculated [Table 2]. The Z score and P value for hypothesis testing between middle finger length-based formula and other predictive formulae for the exact tube size and a tube size within 0.5 mm error was calculated [Table 2]. We graphically evaluated the instances where the size of ETT used was similar to that predicted by different formulae [Figure 3].

Age, weight, height and middle finger lengths are continuous variables whereas the size of ETT is a discrete variable. However, there appeared to be a linear relationship between these continuous and discrete variables. We carried out a linear regression analysis between internal diameter of tube used (dependent variable) and age, height, weight and middle finger length (independent variable). The coefficient of determination (R2) of internal diameter of ETT used and the age, height, weight and middle finger length was 0.712, 0.793, 0.740 and 0.859 respectively.

The coefficient of determination (R2) between the tube size judged to be optimal and that predicted by the formula based on length of the middle finger, Cole's formula, the length based formula (30L + 2), the weight-based formula (10Wt + 3.5) and the length based formula (3L + 2.5) was 0.862, 0.803, 0.802, 0.805 and 0.803, respectively.

We evaluated the performance of 5 models based on the predictive formulae under evaluation [Table 3].

The regression equation calculated after bootstrapping was

“Internal diameter of uncuffed ETT = 1.017 + [0.788 X middle finger length (cm)]”.

DISCUSSION

We observed that the formula "middle finger length (cm) [round up to nearest 0.5] = internal diameter of uncuffed tracheal tube (mm)" can predict the optimal size of uncuffed ETT within an error of 0.5 mm in more than 90% instances and its predictive performance is better than Cole's formula. As a secondary outcome, it was observed that its accuracy is better than other formulae under evaluation.

In our study, there is a statistically significant correlation between size of uncuffed ETT and various morphometric variables. Thus we investigated whether these robust correlations translate into useful aids in the clinical context.[1] We therefore examined the accuracy with which these different formulae could predict the optimal size of uncuffed ETT. As there may be more than one optimal tube size and since it is more acceptable clinically to use a comparatively smaller sized ETT than one of a larger size, we examined the accuracy of these formulae in those contexts.[1] The instances where both the predicted and actual size of uncuffed ETT was similar was highest for the formula based on middle finger length. This formula not only could predict the optimal sized uncuffed ETT but also its use could prevent the use of a larger sized uncuffed ETT. Similar finding was observed by Ritchie-McLean *et al*.[1] But still in a sizeable proportion, the suggested uncuffed ETT was bigger irrespective of the formula used. Though the frequency of such predictions differs among the formulae, studies by Ritchie-Mclean *et al*. and us are underpowered to provide a conclusion if these differences are statistically significant.

Since birth and till early adulthood, the upper and the lower respiratory tract undergo major changes and there is a wide variability of growth pattern.[7,8] This may have resulted in the observed variability of performance of the predictive formulae. Most of these formulae require some form of mathematical calculations and the requirement of solving of mathematical equation may limit their day-to-day clinical use. The formula based on length of middle finger does not involve any such calculation and thus can be very attractive for the clinician.

We used bootstrapping to achieve a more precise estimation of the predictive performance of the formulae. The root mean square error and the mean absolute error for middle finger length were least among all the formulae evaluated in this study. The size of the uncuffed ETT predicted by the regression equation obtained by Ritchie-McLean *et al*. is one size larger than the equation obtained by us.[1] This may be because the length of finger in our population is shorter than those in the study by Ritchie-McLean *et al*. Unfortunately, the data on middle finger length has not been mentioned by them in the published manuscript.

In most of our cases, the consultants were able to choose the appropriate sized ETT without using any

Table 1: Demographic details of patients

Parameter	Mean±SD*	CV†	Median	IQR‡	Range
Age (days)	1455.97±1315.94	90.4	1013	274-2494	32-4704
Weight (kg)	12.607±7.45	59.1	10.3	7-17	2-35
Height (cm)	94.09±27.02	28.7	90	71-117	41-163
Length of middle finger (cm)	4.558±1.12	24.5	4.4	3.6-5.5	2.7-7.8
Gender	Total number (percentage)				
Female	41 (29.5)				
Male	98 (70.5)				

*Standard deviation, †Coefficient of Variation, ‡Inter quartile range

Table 2: Accuracy of the predictive formulae

Morphometric formula	*n*/Total (Proportion, 95% CI*) correct	*n*/Total (Proportion, 95% CI*) correct within 0.5 mm	*n*/Total (Proportion 95% CI*) potentially too big (>0.5 mm
Length of middle finger (cm) [Corrected to nearest 0.5 cm]	52.52% (43.88-61.05%)	91.37% (85.41-95.46%)	3.60% (1.18-8.19%)
Cole’s formula[(age/4) + 4.0]	46.04% (37.56-54.70%), *P* 0.28†	69.78% (61.43-77.28%), *P*<0.00001†	7.91% (4.02-13.72%)
Body length (cm)/30+2	47.48% (38.95-56.12%), *P* 0.40†	74.82% (66.76-81.79%), *P* is 0.00024†	7.91% (4.02-13.72%)
Weight based formula [Weight (kg)/10+3.5]	46.76% (38.26-55.41%), *P* 0.40†	71.94% (63.70-79.23%), *P*<0.00001†	7.91% (4.02-13.72%)
3 Length (m) + 2.5	49.64% (41.06-58.24%), *P* 0.63†	80.58% (73.01-86.09%), *P*<0.0096†	9.35% (5.07-15.46%)

*Confidence Interval, †*P* value of length of middle finger based formula compared with respective formula

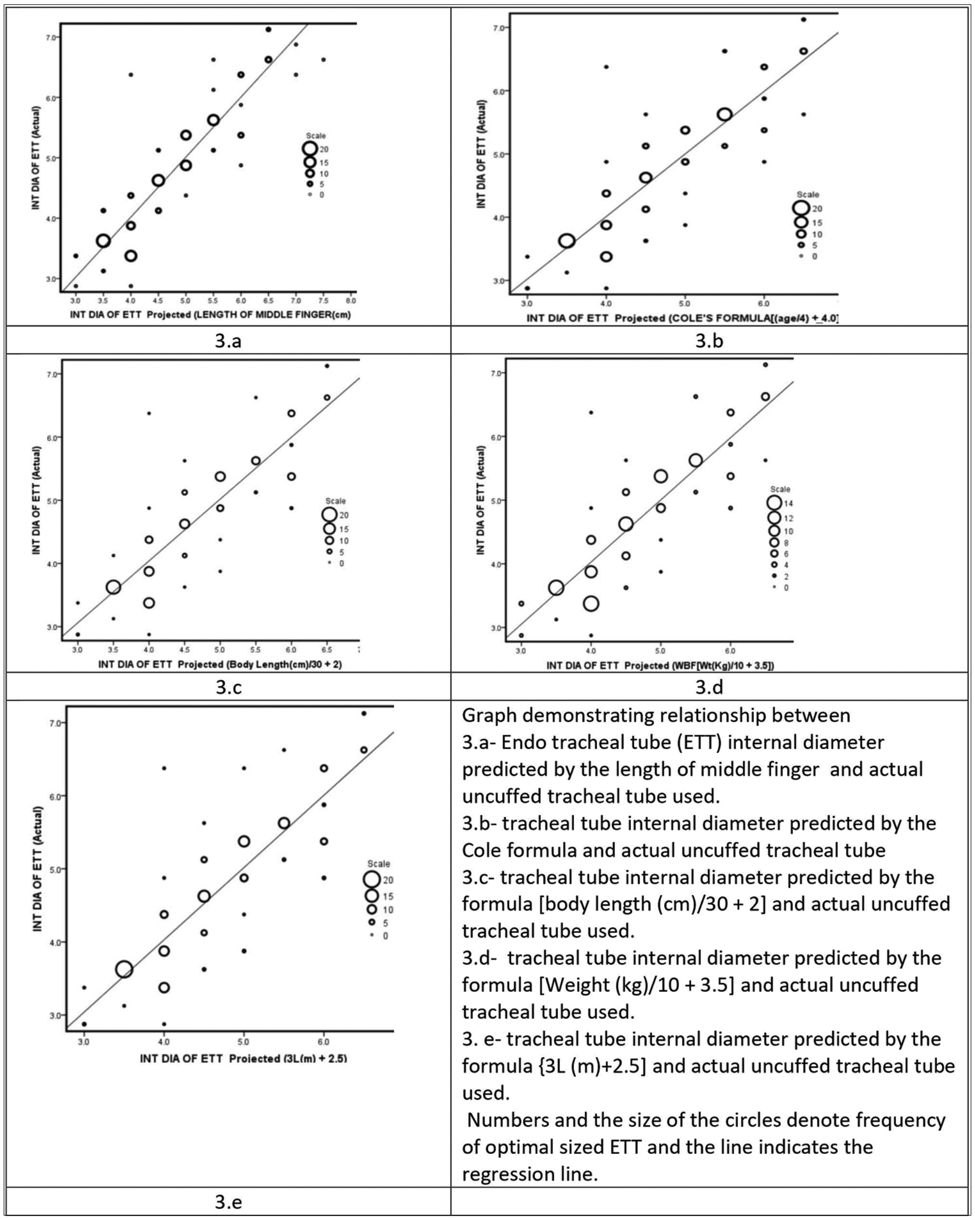

Figure 3: Relationship of internal diameter of uncuffed ETT and the size predicted by different formulae

predictive formula. This has also been observed in other studies.[1] Thus, the clinical relevance of our study may be questioned. Novice trainee students are almost always asked to choose an appropriate-sized tube, and they may not be able to predict it as precisely as a seasoned anaesthesiologist. Moreover, this simple formula will also help those who infrequently care for a paediatric patient.

Most of the bedside clinical predictors of size of ETT are based on some gross morphometric variables.[1,3-5] They may be no longer commonly in use among experienced clinicians and the reported predictive performance varies among formula and studies. Most have rather low predictive performance.[1] In our experience, length and weight-based formulae are used minimally. Though the usefulness of these formulae can be questioned, these formulae may still be valuable for the novice practitioners.

The strength of our study lies in the use of stricter criteria to define the appropriate ETT size, a sample population that is of appropriate size to validate the findings of Ritchie-Mclean *et al*. and the possibility of greater generalisability with possible extension of the analysis to a non-Caucasian population. Moreover, we created many simulated samples to allow a more statistically accurate estimate of the summary

Table 3: Summary of linear regression analysis of five predictive models after bootstrapping

Predictive formula	Constant	B	Standard Error	*t*	R^2	RMSE*	MAE†	Significance	95% confidence interval for β	
									Lower bound	Upper bound
Length of middle finger (cm) [rounded to 0.5 cm]	1.017	0.788	0.104	7.592	0.862	0.3969	0.28268	0.001	0.58	1.048
Cole's formula[(age/4) +4.0]	4.91	0.724	1.062	0.682	0.803	0.4738	0.337032	0.352	-2.348	1.282
Body length (cm)/30+2	1.92	0.053	0.253	0.208	0.802	0.4746	0.334694	0.674	-2.851	1.528
Weight based formula [Wt (kg)/10+3.5]	10.986	2.607	1.912	1.363	0.805	0.4714	0.343016	0.273	-7.589	1.357
3L (m) + 2.5	5.15	1.261	1.502	-0.84	0.803	0.4737	0.336237	0.424	-4.398	1.592

*Root Mean Square Error, †Mean Absolute Error

statistics. Nonetheless, the findings of our study must be inferred in the context of many inherent limitations. We assumed that one single-sized ETT is suitable for every patient, which may not always be the case.[1] Though we used ETT of the same manufacturer, we did not measure the external diameter of each used tube although there may be difference in outer diameter for ETT with same internal diameters. Our study findings cannot be generalised as we did not include patients with skeletal dysplasia and our patient population characteristics may not be representative of the paediatric surgical population as a whole. Apart from the formulae considered for our study, there are many other predictors that have been proposed in the literature and we did not include them.[9-15] Nonetheless, we have included some of the most commonly used formulae for prediction of size of ETT in the paediatric population.

Though we used bootstrapping, a multisite study will give a more robust evidence of performance of this simple and hassle-free formula. Ultrasonography based predictors are gaining more attention, seem to be more accurate and it is possible that access to ultrasonography will increase in our country in the future.[9-12] Apart from ultrasonography, radiography and three-dimensional printer-based predictors have also been evaluated recently.[13-15] It will be interesting to compare them with these newly described predictive parameters. As the interest in cuffed ETTs has gained momentum, and the formulae for such tubes are different, comparison of middle finger length with such formulae would be interesting.[16]

CONCLUSION

The study concludes that internal diameter (in mm) of uncuffed ETT prediction based on the middle finger length (in cm) rounded to the nearest 0.5 is an accurate method to determine the optimal size of uncuffed ETT in paediatric patient and a better alternative than Cole's formula.

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Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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