ORIGINAL RESEARCH PAPER
Volume - 15 | Issue - 02 | February - 2026 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr
INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

ACCURACY OF DEMOGRAPHIC-BASED FORMULAE FOR DETERMINING ENDOTRACHEAL TUBE INSERTION DEPTH IN CHILDREN: A FIBRE-OPTIC BRONCHOSCOPY–GUIDED ANALYTICAL STUDY

Anaesthesiology

Dr. Rajvinder Kaur SR Anaesthesiology ESIC Medical College and Hospital Ludhiana

Dr. Amandeep Kaur SR Anaesthesiology SKR Hospital and Trauma Centre, Pathankot

Dr Barkha Rani SR Anaesthesiology VMMC, Delhi

Dr Rama Chatterjee Senior Professor Department of Anaesthesiology, SMS Medical College, Jaipur, India

ABSTRACT

Background: Incorrect endotracheal tube (ETT) positioning in children can lead to serious respiratory and hemodynamic complications. Several demographic-based formulae are used to estimate ETT depth; however, their accuracy remains uncertain. Fibre-optic bronchoscopy (FOB) offers a direct and reliable method for confirming optimal tube placement.

Objectives: To compare the accuracy of demographic-based formulae (middle finger length, age, weight, and height) for predicting ETT insertion depth in children, using fibre-optic bronchoscopy as the gold standard.

Methods: This analytical cross-sectional study was conducted in 54 paediatric patients aged 5–10 years (ASA I–II) undergoing elective surgery under general anaesthesia. Fibre-optic bronchoscopy was used to position the ETT in the middle third of the trachea, which was considered the optimal depth (actual depth, AD). Predicted depths were calculated using formulae, accuracy and correlation with actual depth were analysed.

Results: The mean actual ETT depth was 16.34 ± 1.15 cm. The age-based method demonstrated the highest accuracy (85.2%), followed by the height-based method (51.9%), while the middle finger (40.7%) and weight-based (38.9%) methods were less accurate. All methods showed strong positive correlations with actual depth: MF ($r = 0.760$), AG ($r = 0.664$), WE ($r = 0.713$), and HE ($r = 0.740$), with $p < 0.001$ for all.

Conclusion: The age-based formula is the most reliable method for estimating ETT insertion depth in children aged 5–10 years, followed by the height-based formula. While all demographic methods correlated well with actual depth, middle finger and weight-based methods showed lower clinical accuracy.

KEYWORDS

Paediatric Anaesthesia, Endotracheal Tube Depth, Fibre-Optic Bronchoscopy, Airway Management, Demographic Formulae

INTRODUCTION

Accurate placement of the endotracheal tube (ETT) is a critical component of safe airway management, particularly in paediatric patients who have a shorter tracheal length and limited tolerance for malposition.[1] Distal intubation may result in endobronchial placement, atelectasis, pneumothorax, and hypoxemia, while proximal placement increases the risk of accidental extubation, aspiration, and subglottic injury.[2]

Various methods have been used to confirm ETT position, including auscultation, chest radiography, capnography, ultrasonography, and fibre-optic bronchoscopy (FOB).[3] Among these, FOB provides direct visualization of the tracheobronchial tree and allows precise confirmation of tube tip position without radiation exposure.[4]

Several demographic-based formulae have been proposed to estimate optimal ETT insertion depth, including age-, weight-, height-, and middle finger length–based methods. However, reported accuracy varies widely across studies, and most prior research has relied on radiographic confirmation rather than FOB.[5-8]

This study was therefore designed to evaluate and compare the accuracy of commonly used demographic-based formulae for estimating ETT insertion depth in children, using fibre-optic bronchoscopy as the gold standard.

MATERIALS AND METHODS

Study Design and Setting

This analytical cross-sectional study was conducted in the Department of Anaesthesiology, SMS Medical College and Attached Group of Hospitals, Jaipur, from November 2023 to February 2024, after approval from the Institutional Ethics Committee (CTRI/2023/11/059835).

Study Population

Fifty-four paediatric patients aged 5–10 years, weighing 10–30 kg, and classified as ASA physical status I or II, scheduled for elective surgery under general anaesthesia, were enrolled.

Inclusion Criteria

- Age 5–10 years
- Weight 10–30 kg
- ASA I–II
- Elective surgery requiring oral endotracheal intubation

Exclusion Criteria

- Difficult airway
- Finger anomalies
- Tracheobronchial malformations
- Syndromic associations
- Acute respiratory infections
- Requirement for nasal intubation

Anaesthetic Technique and Measurements

After induction of anaesthesia, fibre-optic bronchoscopy was performed. The bronchoscope was advanced to the carina, and markings were taken at the level of the incisors at both the vocal cords and carina. The tracheal length was divided into three equal parts, and the ETT was positioned in the middle third of the trachea. This depth was recorded as the actual depth (AD).

Predicted ETT depths were calculated using:

- **Middle Finger (MF):** MF length (cm) × 3
- **Age (AG):** (Age/2) + 12
- **Weight (WE):** (Weight/2) + 8
- **Height (HE):** (Height × 0.1) + 5

Outcome Measures

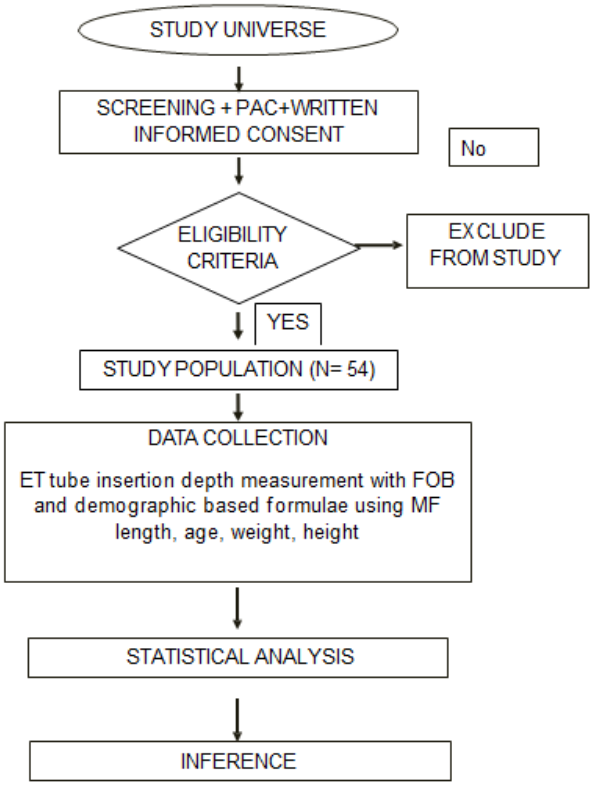
Primary outcome: Accuracy of each formula in predicting optimal ETT depth.

Secondary outcome: Correlation between predicted and actual depth.

Statistical Analysis

Data were analysed using Epi Info version 7.2.1.0. Continuous variables were expressed as mean ± SD. Categorical variables were expressed as frequency and percentage. Correlation was assessed using Pearson's correlation coefficient. A p value < 0.05 was considered statistically significant.

Study Flow Chart



RESULTS

Demographic Profile

The mean age was 7.53 ± 1.71 years, mean height 123.64 ± 11.11 cm, mean weight 20.42 ± 4.4 kg, and mean middle finger length 5.88 ± 0.49 cm. Most patients were ASA I (98.15%) and male (94.44%).

Table 1: Demographic Characteristics and ETT Depth Values Using Different Formulae in Age Subgroups

Characteristics	5 – 6 years	6 – 7 years	7 – 8 years	8 – 9 years	9 – 10years
Height (cm)	111 ± 4.52	117.45± 6.95	122.67± 5.39	126.67± 6.67	135.79 ± 7.9
Weight (kg)	16.49 ± 1.95	17.91 ± 2.8	19.28 ± 1.92	21.44 ± 3.61	25.03 ± 3.88
MF length (cm)	5.4 ± 0.3	5.58 ± 0.38	5.87 ± 0.28	6.02 ± 0.33	6.35 ± 0.4
Tracheal length (cm)	7.31 ± 0.6	7.86 ± 0.59	7.93 ± 1.2	8.08 ± 0.57	8.99 ± 0.61
Carina to ETT tip (cm)	3.36 ± 0.25	3.64 ± 0.42	3.82 ± 0.62	3.91 ± 0.46	4.05 ± 0.3
Depth AD (cm)	15.51 ± 1.04	15.67 ± 0.98	15.87 ± 0.71	17 ± 0.87	17.27 ± 0.82
Depth MF (cm)	16.2 ± 0.89	16.74 ± 1.13	17.6 ± 0.84	18.07 ± 0.99	19.04 ± 1.19
Depth AG (cm)	14.69 ± 0.13	15.04 ± 0.19	15.67 ± 0.16	16.18 ± 0.13	16.86 ± 0.18
Depth WE (cm)	16.25 ± 0.98	16.96 ± 1.4	17.64 ± 0.96	18.72 ± 1.8	20.52 ± 1.94
Depth HE (cm)	16.1 ± 0.45	16.75 ± 0.7	17.27 ± 0.54	17.67 ± 0.67	18.58 ± 0.79

The middle finger (MF) length was 5.4 cm (± 0.3) in the youngest group and 6.35 cm (± 0.4) in the oldest group. Tracheal length was 7.31 cm (± 0.6) in the 5-6 years age group and 8.99 cm (± 0.61) in the 9-10 years age group. The distance from the carina to the ETT tip was 3.36 cm (± 0.25) in the 5-6 years age group and 4.05 cm (± 0.3) in the 9-10 years age group.

Fibre-Optic Bronchoscopy Measurements- Mean tracheal length: 8.11 ± 0.93 cm, Mean incisors-to-carina distance: 20.1 ± 1.41 cm and Mean actual ETT depth (AD): 16.34 ± 1.15 cm.

Accuracy of Demographic Formulae

Table 2: Accuracy of ETT Placement by Different Methods in Age Subgroups

Formulae	Accuracy	5 – 6 years	6 – 7 years	7 – 8 years	8 – 9 years	9 – 10 years
MF	Accurate	5 (45.5%)	5 (50%)	1 (11.1%)	7 (77.8%)	4 (26.7%)
	Proximal	0	0	0	0	0
	Distal	6 (54.5%)	5 (50%)	8 (88.9%)	2 (22.2%)	11 (73.3%)
AG	Accurate	7 (63.6%)	8 (80%)	9 (100%)	7 (77.8%)	15 (100%)
	Proximal	4 (36.4%)	2 (20%)	0	2 (22.2%)	0
	Distal	0	0	0	0	0
WE	Accurate	7 (63.6%)	5 (50%)	1 (11.1%)	5 (55.6%)	3 (20%)
	Proximal	0	0	0	0	0
	Distal	4 (36.4%)	5 (50%)	8 (88.9%)	4 (44.4%)	12 (80%)
HE	Accurate	6 (45.5%)	4 (40%)	1 (11.1%)	8 (88.9%)	9 (60%)
	Proximal	0	0	0	0	0
	Distal	5 (45.5%)	6 (60%)	8 (88.9%)	1 (11.1%)	6 (40%)

Table no.2 shows that accuracy of MF method was highest in 8-9 years age group (77.8%), followed by 6-7 years (50%) and 5-6 years (45.5%) and was lowest in 9-10 years (26.7%) and 7-8 years (11.1%). AG method was 100% accurate in 9-10 years and 7-8 years followed by 6-7 years (80%) and 8-9 years (77.8%) and was minimum in 5-6 years (63.6%). WE method was more accurate in 5-6 years (63.6%), 8-9 years (55.6%), 6-7 years (50%), and was lower in 9-10 years (20%) and 7-8 years (11.1%). HE method was more accurate in 8-9 years (88.9%), and 9-10 years (60%), followed by 5-6 years (45.5%), 6-7 years (40%), and was lowest in 7-8 years (11.1%)

The age-based formula was the most accurate (85.2%), followed by the HE method (51.9%), while the MF method (40.7%) and WE method (38.9%) were less accurate.

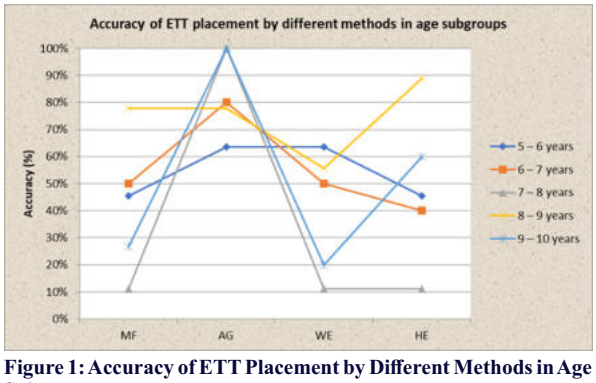


Figure 1: Accuracy of ETT Placement by Different Methods in Age Subgroups

Table 3: Demographic Characteristics and ETT Insertion Depth Values Using Different Formulae and 95% Confidence Interval

Characteristics	Mean ± SD	Mean depth of insertion	95 % Confidence interval
Height (cm)	123.64 ± 11.11	17.36 ± 1.11	17.06-17.66
Weight (kg)	20.42 ± 4.4	18.21 ± 2.2	17.61- 18.81
MF length (cm)	5.88 ± 0.49	17.63 ± 1.47	17.23- 18.03
Age (years)	7.53± 1.71 years	15.77 ± 0.86	15.54- 16.00
Actual depth of insertion		16.34 ± 1.15	16.03-16.65

The table No. 3 summarizes the characteristics of the study participants, including height, weight, MF (Middle Finger) length, and age. For each characteristic, the mean and standard deviation (SD) are provided, along with the mean depth of insertion of endotracheal tube and its 95% confidence interval.

- Height: The average height of participants was 123.64 ± 11.11 cm, with a mean depth of insertion of 17.36 ± 1.11 cm (95% CI: 17.06, 17.66).
- Weight: Participants had an average weight of 20.42 ± 4.4 kg, with a mean depth of insertion of 18.21 ± 2.2 cm (95% CI: 17.61,

18.81).
- MF Length: The mean MF length was 5.88 ± 0.49 cm, with a corresponding mean depth of insertion of 17.63 ± 1.47 cm (95% CI: 17.23, 18.03).
- Age: The average age of the participants was 7.53 ± 1.71 years, with a mean depth of insertion of 15.77 ± 0.86 cm (95% CI: 15.54, 16.00).
- Actual Depth of Insertion: The overall actual depth of insertion was 16.34 ± 1.15 cm (95% CI: 16.03, 16.65).

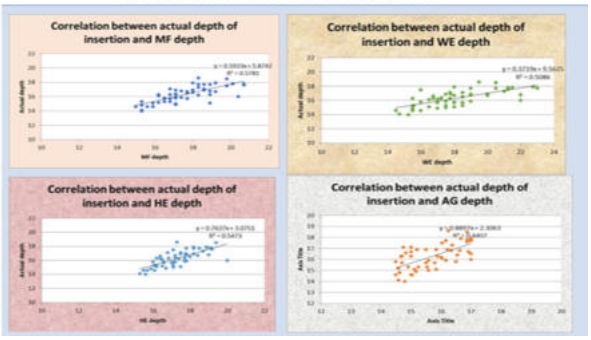
Correlation with Actual Depth

Table 4: Correlation of Actual Depth of Insertion With Depth by Different Methods

Method	Correlation coefficient (r)	P value	Interpretation
MF	0.760	<0.001	Strong positive correlation
AG	0.664	<0.001	Strong positive correlation
WE	0.713	<0.001	Strong positive correlation
HE	0.740	<0.001	Strong positive correlation

A strong positive correlation (p<0.001) was seen between the actual depth of insertion with depth predicted by MF (r=0.760), by AG (r=0.664), by WE (r=0.713), and by HE (r=0.740).

Figure 2: Correlation between actual depth of insertion



DISCUSSION

This study demonstrates that among commonly used demographic-based formulae, the age-based method [(age/2) + 12] provides the most accurate estimation of ETT insertion depth in children aged 5–10 years when validated against fibre-optic bronchoscopy. Puneet Khanna et al [9] in 2021 studied age-based demographic formula [age/2 + 12] to calculate ET tube insertion depth in children aged 1-4 years. Their study reported 58 % of accurate placements according to age-based formula but in the present study, 85.2 % accurate placements were observed. This difference might be due to the difference in age group considered for the studies.

The height-based method also showed moderate accuracy (51.9%) and a strong correlation with actual depth.

In contrast, middle finger and weight-based methods demonstrated lower accuracy and a tendency toward distal placement. Although these methods correlated well with actual depth, their clinical reliability appears limited, especially when used in isolation.

A major strength of this study is the use of fibre-optic bronchoscopy as the gold standard, which allows direct visualization of the ETT tip and avoids radiation exposure associated with chest radiography.

Limitations

- Single-centre study with a relatively small sample size
- Gender imbalance (predominantly male patients)
- Limited age range (5–10 years), restricting generalizability
- Head–neck position variability during FOB could not be strictly standardized

CONCLUSION

In conclusion, the findings of this study indicate that the Age method is the most reliable approach for determining endotracheal tube (ETT) depth in paediatric patients, followed closely by the Height method using. In contrast, the Middle finger and Weight method were found to be less accurate. Notably, all methods exhibited a strong positive correlation with the actual depth of insertion, suggesting that each approach has some utility. However, the Age method's superior accuracy makes it the preferred choice for clinicians seeking to ensure optimal ETT placement in children.

Acknowledgements

The authors acknowledge the Department of Anaesthesiology, SMS Medical College, Jaipur, and all participating patients and staff for their support.

Conflicts of Interest

None declared.

Funding

No external funding.

REFERENCES

1. Vezzani A, Manca T, Brusasco C, et al. Diagnostic value of chest ultrasound after cardiac surgery: a comparison with chest X-ray and auscultation. J Cardiothorac Vasc Anesth. 2014;28(6):1527–32.
2. Pattnaik SK, Bodra R. Ballotability of cuff to confirm the correct intratracheal position of the endotracheal tube in the intensive care unit. Eur J Anaesthesiol. 2000;17(9):587–90.
3. Varshney M, Sharma K, Kumar R, Varshney PG. Appropriate depth of placement of oral endotracheal tube and its possible determinants in Indian adult patients. Indian J Anaesth. 2011;55(5):488–93.
4. Morgan GA, Steward DJ. Linear airway dimensions in children: including those from cleft palate. Can Anaesth Soc J. 1982;29(1):1–8.
5. Matsuoka W, Ide K, Matsudo T, Kobayashi T, Nishimura N, Nakagawa S. The occurrence and risk factors of inappropriately deep tip position of microcuff pediatric endotracheal tube during PICU stay: a retrospective cohort pilot study. Pediatr Crit Care Med. 2019;20(10):e510–e515.
6. Zamudio MA, Casas FD. El uso del ultrasonido en el manejo de la vía aérea. Rev Colomb Anestesiol. 2015;43(4):307–13.
7. Fortas F, Loi B, Centorrino R, Regiroli G, Ben-Ammar R, Shankar-Aguilera S, et al. Enhanced INSURE (ENSURE): an updated and standardised reference for surfactant administration. Eur J Pediatr. 2022;181(4):1269–75.
8. Varshney M, Sharma K, Kumar R, Varshney PG. Endotracheal tube positioning in children: comparison of age-, height-, and weight-based formulae. Indian J Anaesth. 2012;56(5):476–81.
9. Khanna P, Garg H, Ray BR, Singh A, Kundu R, Sinha R. Accuracy of predictive equations in guiding tracheal intubation depth in children: A prospective study. Pediatric Anesthesia. 2021 Dec;31(12):1304-9.
10. Kim KO, Um WS, Kim CS. Estimation of tracheal length and optimal endotracheal tube depth in children. Anesth Analg. 2010;110(3):745–8.