ORIGINAL ARTICLE | ASIAN JOURNAL OF MEDICAL SCIENCES

Correlation of upper incisor–manubriosternal joint length with upper incisor–carinal length to predict airway length in the pediatric population: An observational study

Thomas T Vellapally[1], **Deepa Baskaran**[2], **Michelle Meril Reginald**[3]

[1]Assistant Professor, [2]Associate Professor, [3]Senior Resident, Department of Anesthesiology and Critical Care, St. Johns National Academy of Health Sciences, Bengaluru, Karnataka, India

Submission: 09-03-2025 Revision: 27-04-2025 Publication: 01-06-2025

ABSTRACT

Background: Short and variable length of the trachea precludes accurate placement of endotracheal tubes (ETTs) in the pediatric population. The incidence of malposition of the ETT in the pediatric population was reported to be 30–50% warranting repositioning. The manubriosternal joint (MSJ) and the carina lie in the same horizontal plane. This can be utilized as a guide during endotracheal intubation in children. **Aims and Objectives:** To evaluate the correlation between the incisor-MSJ (IMSL) length measured in extension and the incisor–carinal length (ICL) and to predict the airway length in the pediatric population. **Materials and Methods:** Fifty-seven children between the ages of 2 and 8 years were recruited for our study. The length of the IMSL was measured with a tape after inducing anesthesia with the neck fully extended. Following intubation with appropriately sized ETT, ICL was measured in neutral position as well as in flexion and extension using fiberscope and the corresponding measurements were taken. **Results:** There was a positive correlation between the two parameters. The mean ICL-N was 15.65±2.17 cm, and the mean IMSL distance in extension was 16.22±2.46 cm, which was found to be statistically significant with R^2=0.799 (P<0.001). The airway length can be estimated by the formula: ICL (neutral)=2.828+0.790×IMSL (extension). **Conclusion:** The IMSL length can be used as a simple and accurate reference for predicting the airway length and the depth of insertion of ETTs in the pediatric population.

Key words: Incisor–carina length; Incisor–manubriosternal joint length; Surface landmark; Pediatric intubation depth

Access this article online

Website:

https://ajmsjournal.info/index.php/AJMS/index

DOI: 10.71152/ajms.v16i6.4510

E-ISSN: 2091-0576

P-ISSN: 2467-9100

INTRODUCTION

Airway management is the bedrock of pediatric anesthesia. The appropriate depth of insertion of endotracheal tube (ETT) is one of the challenging aspects and of utmost importance as malposition carries serious ramifications. Deeper placement of endotracheal tube leads to endobronchial intubation, atelectasis, hypoxia and barotrauma, while a shallow placement can lead to inadvertent extubation and vocal cord trauma.[1] The incidence of malposition is 30–50% among the pediatric population warranting repositioning,[2] more often in children <10 years of age. The incidence of endobronchial placement is 10% in children <10 years and 30% in infants. This is attributed to the short length of the trachea, which leaves a very narrow margin of safety.

Measurement of the airway length is the most appropriate parameter to determine the position of the ETT to determine the depth of insertion. If the tracheal length is

Address for Correspondence:
Dr. Thomas T Vellapally, Assistant Professor, Department of Anesthesiology and Critical Care, St. Johns National Academy of Health Sciences, Bengaluru, Karnataka, India. **Mobile:** +91-9746717055. **E-mail:** tvthomas1985@gmail.com

known, the ETT should be placed at the midtracheal level[3] in infants and 2–3 cm above the carina allowing for a good margin of safety even during flexion or extension of the neck intraoperatively.[4]

Many formulae based on age, weight, and height[5,6] have been envisaged and age-based formula (age/2+12) is widely practiced. However, these formulae lack accuracy with malposition rate of 69% because growth in children is grossly nonlinear over the same range of age, gender, and weight warranting the need for predictors that are more accurate and individualized.[7,8] Furthermore, these formulae lack widespread validation as they are elucidated based on a sample population and there are no clinical follow-up studies.

Weiss et al.,[9] inferred that ETT marking guided placement was better than formulae. The sort of guide mark used, whether its horizontal or vertical, single or numerous, and distance from the ETT tip, varies among the manufacturers. However, it remains to be a reliable intubation depth marker for the anesthesiologists.[10]

The gold standards for the confirmation of the ETT tip position are chest radiography[11] and fiberoptic positioning. These are, however, cumbersome, time–consuming, and not practical in an intraoperative setup.

Some studies have analyzed the usefulness of external surface anatomy markers3 as a predictor of airway length and found them to be more accurate for pediatric population. Such studies, however, are less and have not been adequately researched among the Indian children. Manubrium sterni is on the same horizontal plane as the carina and would be more accurate measure of airway length.

We, in our study evaluated the correlation between incisor-manubriosternal joint distance in extension (IMSL[E]) and incisor-carinal length (ICL), and thereby derive an equation to predict the accurate depth of insertion of endotracheal tube in pediatric population.

Aims and objectives

Primary objective

To evaluate the correlation between incisor–manubriosternal joint (IMSL) length measured in extension and the ICL in neutral position and to derive a simple formula to predict the airway length.

Secondary objective

To measure the airway length in neutral, flexed, and extended neck position to assess the optimum position of ETT during neck movements.

MATERIALS AND METHODS

This was a prospective, observational study. The study was taken up after obtaining approval from the Institutional Ethics Committee (Ref No 344/2020), and the study was done in accordance with the Helsinki Declaration 1975.

Children aged between 2 and 8 years of age belonging to the ASA physical status 1 and 2 undergoing surgeries under general anesthesia were recruited for the study.

Children with
- Anticipated difficult airway (neck swelling and craniofacial anomalies)
- Cleft lip or palate surgery
- Low pulmonary reserve
- Rapid sequence induction
- Any congenital abnormalities affecting the body stature were excluded from the study.

On arriving at the operation theater, basic monitors including electrocardiogram, pulse oximeter, and non-invasive blood pressure were connected and baseline vital parameters were recorded. Patients were induced with either sevoflurane or with intravenous (IV) propofol (1–2 mg/kg) and were given IV fentanyl (2 mcg/kg) and IV atracurium (0.5 mg/kg) to facilitate muscle relaxation and ETT insertion. The patients were ventilated for 3 min and were intubated after adequate ventilation using an appropriate size ETT based on the Pellington's formula and was fixed onto the upper lip in the midline.

The upper incisor–manubriosternal length was measured using a standard metallic tape, first in neutral position, followed by flexion and extension of the neck. Neutral position in children under 8 years of age was achieved by placing a shoulder roll. The average elevation required was found to be 2.5 cm (25.4+6.7 mm) according to a study done by Nypaver et al., in 1994.[12]

An arbitrary line passing between superior orbital margin and the external auditory canal was used to estimate the degree of extension. The difference between this line in neutral position and in extended position was considered as the degree of maximal extension. The same procedure was done in case of flexion. Vital parameters were monitored carefully and maintained.

A 3.8 mm outer diameter bronchoscope (Ambu® aScope4) was inserted after disconnecting the ETT and advanced upto the carina with head in neutral position. The length from the carina to the proximal end of the ETT was noted (L1). The length from the upper incisor to the proximal end of the tube was measured by a member of the investigating team (L2). L1-L2 gave the ICL in neutral position. ICL was measured in flexed and extended position. The whole procedure did not exceed more than 30 s.

Vitals were monitored throughout the surgery, and the surgery was allowed to proceed. At the end of the surgery, patients were reversed adequately with neostigmine (0.05 mg/kg) and glycopyrrolate and extubated. Postoperatively, children were shifted to the post-operative unit and the vitals were monitored.

Sample size estimation

The reported correlation between upper incisor–carina length and upper IMSL length was 0.456 according to a study by Jain et al., in 2020.[13] Hence, to estimate and test the correlation coefficient at 1% level of significance and 90% power of the study, the study was conducted on 57 subjects (Table 1).

Statistical analysis

All categorical data were summarized as frequencies and percentages. The mean and standard deviation or median and interquartile range were used to describe continuous data. Chi-square test and Fisher's exact test were employed as tests of significance for qualitative data. Independent t-test was employed as a test of significance to identify the mean difference between two quantitative variables. Pearson's correlation or Spearman's correlation was employed to estimate the correlation between quantitative and qualitative variables. Multiple linear regression model was used to find the regression equation (Table 2). P-value (probability that the result is true) of <0.05 was considered statistically significant after assuming all the rules of statistical tests.

RESULTS

Table 3 depicts the age distribution of the subjects, and the mean age of the subjects was 5.46±2.05 years.

The gender distribution of the subjects recruited is shown in Figure 1. There was a male preponderance in our sample.

In the study, the mean ICL-N was 15.65±2.17 cm and the mean IMSL-E was 16.22±2.46 cm with a difference of 0.57 cm as shown in Table 4. Pearson's test showed a positive strong correlation between IMSL (E) and ICL (neutral), which was statistically significant.

Figure 2 shows the scatter plot where the IMSL (e) is plotted in the X-axis and the ICL (n) is plotted in the Y-axis and the plot density corresponds to a positive correlation with R^2=0.7992.

Table 1: Sample size calculation

Regression methods	
Correlation coefficient	0.456
Power (1-beta) %	90
Alpha error (%)	1
1 or 2 sided	2
Required sample size	57

Table 2: Interpretation of correlation coefficient

Correlation coefficient (r)	Interpretation
0–0.3	Positive weak correlation
0.3–0.6	Positive moderate correlation
0.6–1.0	Positive strong correlation
0–(−0.3)	Negative weak correlation
(−0.3)–(−0.6)	Negative moderate correlation
(−0.6)–(1)	Negative strong correlation

Table 3: Age distribution of study subjects

Parameter	Variable	Value
Age (in years)	Mean	5.46
	SD	2.05
	Median	6.00
	Minimum	2.00
	Maximum	8.00

Table 4: Correlation between ICL (neutral) and IMSL (extension)

Variable	Value
Incisor–manubriosternal joint length (E) - mean+SD	15.65±2.17 cm
Incisor–carinal length	16.22±2.46 cm
Pearson's correlation	0.894
R^2	0.799
P-value	<0.001*

ICL: Incisor–carinal length, IMSL: Incisor–manubriosternal joint length, *Statistically significant

Table 5 shows the factors taken as inputs for Pearson's correlation coefficient. Linear regression analysis on the relation of single variable (IMSL) to ICL was done to derive the formula.

Formula derived is ICL (neutral)=2.828+0.790×IMSL (extension).

The ICL was measured in neutral, extended, and flexed neck positions, and the difference in airway length is shown in Table 6. The airway length decreased by 0.1.17 cm upon neck flexion and increased by 1.22 cm on extension.

DISCUSSION

In our study involving 57 children aged between 2 and 8 years, we found that the relationship between IMSL (E)

Table 5: Derivation of formula for calculating ICL neutral from IMSL at extension position of the neck

Constant	Unstandardized coefficients		Standardized coefficients	t	P-value	95.0% confidence interval for B	
	B	Standard error	Beta			Lower bound	Upper bound
	2.828	**0.876**		**3.227**	**0.002***	**1.072**	**4.583**
IMSJ-extension	0.790	0.053	0.894	14.795	<0.001*	0.683	0.897

ICL: Incisor–carinal length, IMSL: Incisor–manubriosternal joint length

Table 6: Comparison of measures of incisor–carinal length (ICL) with respect to different positions of neck among the study subjects

ICL (in cm)	Mean	SD	Median	Minimum	Maximum	P-value#
Neutral	15.65	2.17	15.30	9.00	19.30	-
Extension	16.77	2.75	16.50	10.20	26.00	<0.001*
Flexion	14.48	2.05	14.30	8.80	18.10	<0.001*

#Paired t-test. *Statistically significant

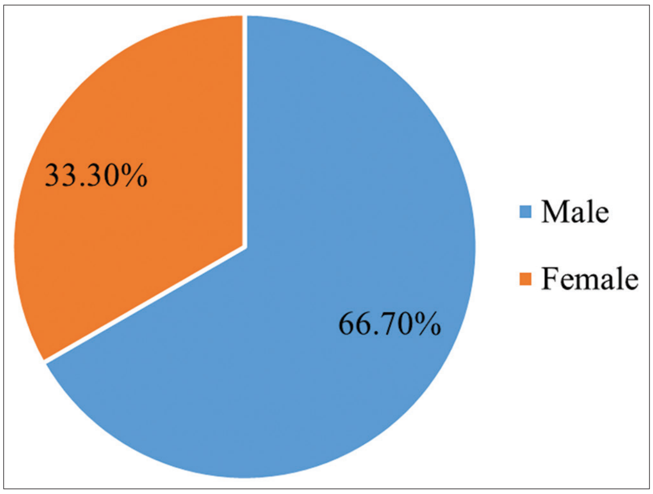

Figure 1: Pie diagram showing the distribution of study subjects based on gender

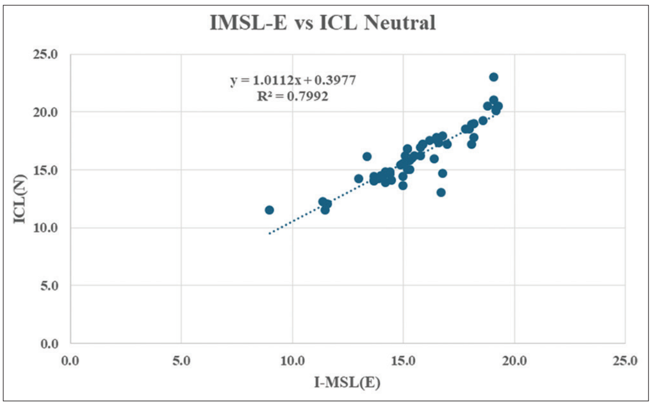

Figure 2: Scatter plot showing a positive correlation between incisor–carinal length (neutral) and incisor–manubriosternal joint length (extension)

measured as a surface marker strongly correlated with the ICL measured using fiberscope in neutral position.

Furthermore, we found that the airway length decreased by 1.17 cm on flexion of the neck and increased by 1.2 cm on neck extension. This implies that the endotracheal tip when placed 2 cm proximally to the carina (ICL minus 2 cm) would be a safe depth of insertion.

There are several ways of estimating the optimal depth of insertion of ETT. Clinicians widely use clinical methods of auscultation of bilateral breath sounds, palpation of the tube in the suprasternal space, and deliberate endobronchial placement and subsequent withdrawal.[14] These methods have been proven to be unreliable, and the malposition rates are high.

The anatomical structures of the airway and their growth are age dependent with changes in size, shape, and length and vary based on the nutritional status and development in the same age group.[15] Shorter length of the trachea in children often predisposes to malposition of the endotracheal tube, warranting the need to place the tip of the ETT to a predetermined depth, to avoid migration during movement of the head.[2]

Among all parameters, the external surface reference of IMSL is more representative of the airway length as the MSJ lies in the same horizontal plane as the carina. The angle of Louis can be easily palpated at the level of insertion of the 2nd rib to the MSJ, and this plane corresponds to the 4th vertebral level and passes through the plane of bifurcation of the trachea.[16] When a rigid bronchoscope is inserted with head in full extension, the upper airway comes in an almost straight line with the trachea and carina. Therefore, the IMSL measured in extension can be considered a more accurate representation of the real airway length. This was the reason to measure the IMSL in extended position.

We found a strong positive correlation between IMSL and ICL (Table 4 and Figure 2). From this, we inferred that assuming the relationship linear, the I-MSL (E) can be a surrogate measure of the airway length. The IMSL (E), unlike generic variables like age, is individualized variable and hence more reliable.

Our results were similar to that of Jain et al.13, who found a positive correlation between the two parameters. The difference in correlation compared to our study can be attributed to the difference in the demographics of the study population and methodology. Furthermore, for practical ease, we have used a metallic tape to measure the distance instead of compass, and this also might have contributed to the difference in the obtained measurements.

However, Lee et al.,[16] in their study on correlation between IMSL and ICL in 50 children, also found a strong positive correlation with a R^2=0.98. They also found a positive correlation among adults; Mukherji et al.,[17] similarly in a study on adult population, also found the IMSL E to be correlating significantly with the ICL. Although these observations cannot be extrapolated in children, the fact that IMSL E is indeed a reliable reference across age group and demographics can be inferred.

Using linear regression analysis, we derived a formula to calculate the airway length.

Formula derived is ICL (neutral)=2.828+0.790×IMSL (extension), which can be simplified as 2.8+0.8×IMSL.

Our formula was closest to that derived by Lee et al.,[16] (4+0.8×IMSL) who have validated the formula in a test sample. We, however, have not validated it in this study.

Our secondary objective was to measure the airway length in neutral, flexed, and extended positions of the neck to understand the change that occurs during movements, and we inferred that the airway length increased by 1.2 cm on extension and decreased by 1.17 cm on flexion (Table 6). The ETT displaced by 0.9 cm at 30° flexion and 1.7 cm at 45° extension according to a study by Sugiyama et al.[18] Similarly, Yan et al[19] conducted a study and found that the ETT tip migrated by 1.099 cm and 0.947 cm upon extension and flexion, respectively. This observation has a strong clinical significance. This change in length implies that it is optimal and safe to place the ETT tip 2 cm proximal to the carina with adequate margin of safety during flexion or extension.

The strength of the study is that the parameter IMSL is simple to measure in the operation theater routinely and the formula 2.8+0.8×IMSL can be put to use in day-to-day practice, to predict the length of airway. Based on our observations, the tip of the ETT should be placed 2cm above the carina to prevent inadvertent complications due to tube migration.

Limitations of the study

Our study has some limitations. Our study did not include other anthropometrics like height. Many studies have shown a positive correlation between airway length and height and incorporation of height along with IMSL would have improved accuracy of the equation. Our study included children between 2 and 8 years, a more uniform cohort and our results cannot be extrapolated to neonates and infants. We have derived an equation from the model cohort but have not applied it to a test cohort which would have enhanced the validity and reproducibility. There are studies on gender-specific analysis. Since we had lesser representation of females (Figure 1) than males, we could not make a gender-specific analysis. The degree of extension and flexion have not been measured or standardized, which could affect the accuracy of the results.

CONCLUSION

The accurate depth of insertion of ETT without too many manipulations remains an Achilles heel of pediatric intubations. Although various parameters of growth are being analyzed to reliably measure airway length, we found that the length between the incisor and manubrium sterni in children is a reliable predictor of the airway length and the depth of insertion of ETT in the pediatric population.

ACKNOWLEDGMENT

The authors would like to thank the pediatric patients, parents and faculty of St Johns National Academy of Health Sciences, Bengaluru for their co-operation.

REFERENCES

1. Shim JG, Lee EK, Oh EJ, Cho EA, Park J, Lee JH, et al. Predicting the risk of inappropriate depth of endotracheal intubation in pediatric patients using machine learning approaches. Sci Rep. 2023;13(1):5156.
   https://doi.org/10.1038/s41598-023-32122-5
2. Logia P, Theagrajan A, Raghuraman MS and Prabhu M. New formula for depth of insertion of endotracheal tube in children: A prospective observational study. Indian J Pediatr. 2024;91(2):125-130.
   https://doi.org/10.1007/s12098-022-04206-z
3. Song IK, Kim SH, Ryu J, Lee E, Oh HM, Kim EH, et al. Prediction of the midtracheal level based on external anatomical landmarks: Implication of the optimal insertion depth of endotracheal tubes in pediatric patients. Pediatr Anesth. 2016;26(12):1142-1147.
   https://doi.org/10.1111/pan.12996

4. Zhuang P, Wang W and Cheng M. Effect of head position changes on the depth of tracheal intubation in pediatric patients: A prospective, observational study. Front Pediatr. 2022;10:998294.
https://doi.org/10.3389/fped.2022.998294
5. Zhuang PE, Lu JH, Wang WK and Cheng MH. A new formula based on height for determining endotracheal intubation depth in pediatrics: A prospective study. J Clin Anesth. 2023;86:111079.
https://doi.org/10.1016/j.jclinane.2023.111079
6. Ross PA, Abou-Zamzam A and Newth CJ. Height best predicts the optimal insertion length of orotracheal tubes in children. Intensive Care Med. 2024;2(1):6.
https://doi.org/10.1007/s44253-024-00032-7
7. Volsko TA, McNich NL, Prough DS and Bigham MT. Adherence to endotracheal tube depth guidelines and incidence of malposition in infants and children. Respir Care. 2018;63(9):1111-1117.
https://doi.org/10.4187/respcare.06024
8. Khanna P, Garg H, Ray BR, Singh A, Kundu R and Sinha R. Accuracy of predictive equations in guiding tracheal intubation depth in children: A prospective study. Paediatr Anaesth. 2021;31(12):1304-1309.
https://doi.org/10.1111/pan.14301
9. Weiss M, Knirsch W, Kretschmar O, Dullenkopf A, Tomaske M, Balmer C, et al. Tracheal tube-tip displacement in children during head-neck movement--a radiological assessment. Br J Anaesth. 2006;96(4):486-491.
https://doi.org/10.1093/bja/ael014
10. Goel S and Lim SL. The intubation depth marker: The confusion of the black line. Paediatr Aneesth. 2003;13(7):579-583.
https://doi.org/10.1046/j.1460-9592.2003.01103.x
11. Zaytseva A, Kurepa D, Ahn S and Weinberger B. Determination of optimal endotracheal tube tip depth from the gum in neonates by X-ray and ultrasound. J Matern Fetal Neonatal Med. 2020;33(12):2075-2080.
https://doi.org/10.1080/14767058.2018.1538350
12. Nypaver M and Treloar D. Neutral cervical spine positioning in children. Ann Emerg Med. 1994;23(2):208-211.
https://doi.org/10.1016/s0196-0644(94)70032-x
13. Jain A, Wadhwa B and Saxena KN. Preventing inadvertent endobronchial intubation: Upper incisor to manubriosternal joint length as a predictor of airway length in children. Paediatr Anaesth. 2020;30(11):1240-1244.
https://doi.org/10.1111/pan.14023
14. Bednarek FJ and Kuhns LR. Endotracheal tube placement in infants determined by suprasternal palpation: A new technique. Pediatrics. 1975;56(2):224-229.
15. Chou CH, Tai CL, Lin KL, Wu SC, Chiang MH, Huang HW, et al. A new formula to predict the size and insertion depth of cuffed nasotracheal tube in children receiving dental surgery: A retrospective study. Sci Rep. 2023;13(1):12585.
https://doi.org/10.1038/s41598-023-39793-0
16. Lee BJ, Yi JW, Chung JY, Kim DO and Kang JM. Bedside prediction of airway length in adults and children. Anesthesiology. 2009;111(3):556-560.
https://doi.org/10.1097/ALN.0b013e3181af6496
17. Mukherjee S, Ray M and Pal R. Bedside prediction of airway length by measuring upper incisor manubrio-sternal joint length. J Anaesthesiol Clin Pharmacol. 2014;30(2):188-194.
https://doi.org/10.4103/0970-9185.130011
18. Sugiyama K and Yokoyama K. Displacement of the endotracheal tube caused by change of head position in pediatric anesthesia: Evaluation by fibreoptic bronchoscopy. Anesth Analg. 1996;82(2):251-253.
https://doi.org/10.1097/00000539-199602000-00006
19. Yan S and Zhang H. Impact of changes in head position during head and neck surgery on the depth of tracheal tube intubation in anesthetized children. BMC Anesthesiol. 2020;20(1):124.
https://doi.org/10.1186/s12871-020-01033-7

Authors' Contributions:
TTV- Manuscript preparation and submission of article; coordination and manuscript editing, and manuscript revision; **DB**- Definition of intellectual content, concept design, clinical protocol, literature survey, prepared first draft of manuscript, data collection, data analysis; **MMR**- Literary survey, implementation of the study protocol, data collection, and preparation of figure.

Work attributed to:
Department of Anesthesiology, St. Johns National Academy of Health Sciences, Bengaluru, Karnataka, India.

Orcid ID:
Dr. Thomas T Vellapally - https://orcid.org/0000-0001-7311-9860
Dr. Deepa Baskaran - https://orcid.org/0000-0001-8662-7362
Dr. Michelle Meril Reginald - https://orcid.org/0009-0009-0631-4610

Source of Support: Nil, **Conflicts of Interest:** None declared.