Brazilian Journal of Anesthesiology 2023;73(5):584–588

Sociedade Brasileira de Anestesiologia

Brazilian Journal of ANESTHESIOLOGY

ORIGINAL INVESTIGATION

Comparison of four formulas for nasotracheal tube length estimation in pediatric patients: an observational study

Ashkan Taghizadeh Imani [a], Mehrdad Goudarzi [a], Niloufar Shababi [a,*], Behrang Nooralishahi [a], Alireza Mohseni [b]

[a] *Tehran University of Medical Sciences, Children's Medical Center, Anaesthesiology Department, Tehran, Iran*
[b] *Shahid Beheshti University of Medical Sciences, National Research Institute of Tuberculosis and Lung Diseases, Tracheal Diseases Research Center, Tehran, Iran*

Received 4 May 2020; accepted 2 April 2021
Available online 28 April 2021

KEYWORDS
Intubation;
Intratracheal;
Pediatric;
Infant;
Child;
Anesthesia

Abstract
Background: Correct endotracheal intubation results in better ventilation, prevents hypoxia and its possible damages, such as brain injury, and minimizes attempts for re-intubation. Up to now, several formulas have been published to estimate nasotracheal intubation tube length. This study aims to compare the accuracy of different suggested formulas to find the one that better estimates the tube insertion distance.
Methods: This cross-sectional retrospective study was carried out in 102 (51 female, 51 male) children who underwent cardiac surgery under general anesthesia. Inclusion criteria were correct nasotracheal intubation according to the postintubation chest X-ray (CXR). The estimated tracheal tube length was calculated by four different formulas. Pearson's correlation coefficient was used to find the correlations between the estimated length of each formula and the correct nasotracheal tube length. Also, linear regression was used to obtain a formula to estimate nasotracheal tube length by weight, height, and age.
Results: The formula L=3*tube size+2 had the best correlation with tube length (r = 0.81, Confidence Interval: 0.732–0.878, *p*-value < 0.001). Among demographic variables, height had the highest correlation coefficient with the tube length (r = 0.83, Confidence Interval: 0.788–0.802, *p*-value < 0.001). Therefore, considering the height as an independent variable and tube length as a dependent variable, using linear regression, the following formula was achieved for determining tube length: nasotracheal tube length = 0.1*Height+7.
Conclusions: The formula L=3*tube size+2 and the new suggested formula in this study can be used to estimate nasotracheal tube length in children under 4 years old. However, these formulas are only guides and require confirmation by auscultation and CXR.

* Corresponding author.
E-mail: niloufar.shababi@gmail.com (N. Shababi).

https://doi.org/10.1016/j.bjane.2021.04.021

Introduction

Every correct endotracheal intubation consists of three factors: appropriate tube size, correct tube length, and tube fixation in the correct position.[1] Major differences between the airways of pediatric and adult patients make endotracheal intubation more difficult in pediatrics. If the endotracheal tube is not introduced at a sufficient depth, accidental extubation and laryngeal injury may occur.[2] In contrast, if the endotracheal tube is placed too far, endobronchial intubation (mostly in the right bronchus) may occur, which can lead to overdistension and possibly pneumothorax.[3] On the other hand, the other lung is usually not adequately ventilated, and atelectasis may occur.[4–6] To confirm the position of the tip of the endotracheal tube immediately after intubation, pulmonary sound auscultation is recommended. However, the standard method of confirmation is evaluation of the position of the tip of the tracheal tube by chest X-ray (CXR).[7] In the past, several formulas and suggestions have been published to estimate tube length. Many more studies have suggested formulas for orotracheal intubation compared to estimation of the length of a nasotracheal tube (NTT).[8–11] In pediatric cardiac surgery, nasotracheal intubation – in comparison with orotracheal intubation – lowers the risk of tube movement during procedures such as transesophageal echocardiography. A nasotracheal tube is also better tolerated. However, the indications of nasotracheal intubation are controversial among medical centers.[12–15] In addition, a valid and accepted formula for estimation of NTT length is not available.[16–19] The main objective of this study is to compare the accuracy of four different suggested formulas in pediatric patients undergoing cardiac surgery.

Methods

This cross-sectional, retrospective study was carried out in patients who underwent cardiac surgery under general anesthesia in our hospital from January to December 2018. In our center, practice of the nasotracheal intubation for pediatric cardiac surgery is routine. After ethics committee approval and assignment of a specific code for each patient which was not directly associated with the patient's name or ID in medical records, patients' CXRs and medical records were evaluated. All patients had post-surgical CXRs. Inclusion criteria included correct nasotracheal intubation according to the CXR: the NTT tip must be introduced between the T1 upper border and the T2 lower border in neonates[18] and between T1 and T3 vertebral bodies in other pediatrics.[19] To prevent bias, two physicians independently evaluated the CXRs for inclusion criteria. If there was any disagreement, a radiologist was consulted to make the final decision. Patients with airway anomalies and abnormal anatomies were excluded from further analysis. Age, weight, height, sex, and NTT length (cm) and size (diameter, mm) were obtained from patients' medical records. NTT length was estimated by one of the following formulas[16,17,20] according to the patient's age or weight (Table 1).

Table 1 Recommended Formulas for NTT length estimation.

No.	Formula	Condition
1	10.5+(weight/2)[16]	age < 4 y/o
2	L=(3[a]tube size)+2[20]	weight > 3 kg
3	(a) 9+(weight/2)[17]	age < 1 y/o
	(b) 15+(age/2)[b] [17]	age >1 y/o
4	14+(age/2)[23]	–

[a] Weight (kg).
[b] Age (y).

Statistical analysis

To determine the total sample size required for the study, we used the previous study by Antona et al.,[16] evaluated the correlation between formulas and correct NTT length; the least correlation coefficient found was r = 0.30. This determines the largest required sample size to be n = 85 according to a previously suggested calculator for correlation sample size.[21] Our final analysis included 102 patients. We did not put the patients in subgroups based on age or weight; however, each formula had its own conditions according to the weight and age.[16,17,20] Pearson's correlation coefficient was used to find the correlation between each formula and the correct NTT length obtained from medical records, which had correct nasotracheal intubation according to CXR. In addition, Pearson's correlation coefficient (r) was used to find the correlations between patient demographics (age, weight, and height) and NTT length obtained from medical records. Correlation coefficient was considered good if > 0.7, moderate if 0.5–0.7, and poor if < 0.5. Then, linear regression was used to obtain a formula to estimate NTT length by weight, height, and age. All analyses were performed using SPSS v.22. A p-value < 0.05 was considered significant.

Result

During this study, 141 patients underwent nasotracheal intubation. Thirty-one patients were excluded due to incomplete medical records, and the remaining 110 cases were examined for study eligibility. Finally, 102 patients (51 female, 51 male) were eligible and included in the final analysis. Two patients had airway anomalies, and six CXRs did not meet the inclusion criteria. The patients' age ranged from 2 days to 4 years. Eighty-two patients (80.4%) were ≤ 1 year-old (Table 2).

Table 3 shows the correlation among 4 suggested formulas and the correct tube length. Formula 2 ''L=(3*tube size)+2''[20] had the highest correlation coefficient with tube length, while formula 3b ''15+(age/2)''[16] was poorly correlated.

To determine a new formula according to the data obtained in this study, we first examined the correlation between age, weight, and height of the patients and the length of correct intubation. According to Table 4, height had the highest correlation coefficient with tube length. The relationship between height and NTT length is shown in Figure 1. Therefore, considering height as an independent

Table 2 Children patients' characteristic.

N (patients)	Gender (boys/girls)	Age (months)	Weight (kg)	Height/length (cm)
102	51/51	8 (12.2) (2 days–4 years)	5.90 (4.07) (2.20–22)	64.46 (17.11) (40–127)

The data are presented as mean (SD) and (range).

Table 3 Correlation between suggested NTT length by formulas and correct tube length.

Formula	Participants	Pearson's correlation coefficient (r)	95% Confidence Interval	*p*-value	Concordance level
Formula 1[16]	99	0.583	0.304–0.895	< 0.001	**moderate**
Formula 2[20]	70	0.816	0.732–0.878	< 0.001	**good**
Formula 3a[17]	78	0.599	0.478–864	< 0.001	**moderate**
Formula 3b[17]	24	0.455	0.125–791	0.026	**poor**
Formula 4[23]	102	0.637	0.458–0.824	< 0.001	**moderate**

Table 4 Correlation between age, weight, and height with tube length.

Formula	Participants	Pearson's correlation coefficient (r)	95% Confidence Interval	*p*-value	Concordance level
Age	102	0.776	0.677–0.862	< 0.001	**good**
Weight	102	0.600	0.330–0.883	< 0.001	**moderate**
Height	102	0.836	0.788–0.802	< 0.001	**good**

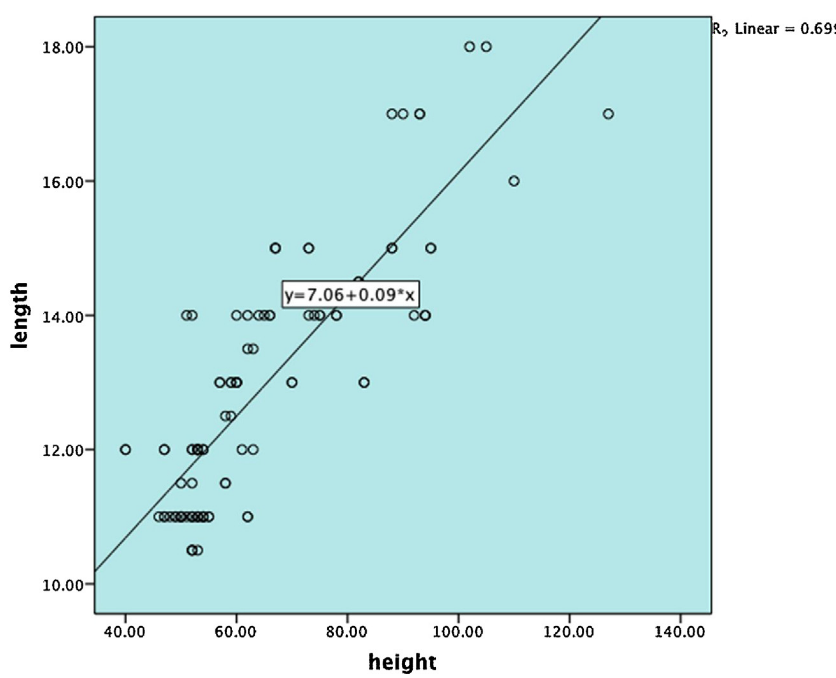

Figure 1 Scatter Plot between nasotracheal tube length (cm) and child's height (cm).

variable and tube length as a dependent variable, using linear regression, the following formula for determining tube length was obtained:

$$\text{Nasotrachealtubelength} = 0.09 * \text{height} + 7.06;$$

$$\text{height(cm)};$$

$$\text{SimplifiedFormula} : \text{Nasotrachealtubelength} =$$

$$0.1 * \text{height} + 7; \text{height(cm)}$$

Discussion

This study compares the accuracy of previously suggested formulas predicting correct NTT length in pediatrics and suggests a new formula based on the child's height to estimate NTT length. According to variability in the length of the airway in children of the same age or weight, suggested formulas (based on age or weight) may not be sufficiently reliable.[22]

In a prospective study, Antona et al.[16] evaluated the concordances of formulas 1 ''10.5+(weight/2)'',[16] 2 ''L=(3*tube size)+2'',[20] and 4 ''14+(age/2)''[23] with correct NTT length in the pediatric intensive care unit. Formula 4 ''14+(age/2)''[23] showed a moderate correlation with correct tube length (r = 0.58). Moreover, in our study, this formula showed a moderate correlation (r = 0.63). The similarity can result from almost similar mean age (8 months in this study, and 12.3 months in the study by Antona et al.). This correlation demonstrates that formula 4 ''14+(age/2)'' (23) (as an age-based formula) is not reliable for children in a low age group.

Formula 1 ''10.5+(weight/2)''[16] showed good correlation with correct NTT length (r = 0.89) in the study by Antona et al., but in our study, the formula showed a moderate correlation (r = 0.58). Different mean weight (5.9 kg in ours and 8.3 in the study by Antona et al.) can be a probable cause. This different result can be explained by different methodologies. Our study was retrospective, but Antona et al. followed their patients prospectively. Also, we evaluated children undergoing cardiac surgery, but in their study, Antona et al. enrolled children who had been admitted to ICU. These different underlying conditions may also affect the final results.

Formula 2 ''L=(3*tube size)+2''[20] showed a good correlation with correct NTT length in both the study by Antona et al. and our study (r = 0.75 and 0.71, respectively). It can be concluded that this formula is more accurate compared to others.

In a prospective study conducted on patients who were candidates for elective surgery or dental procedures under general anesthesia, Kemper et al.[10] calculated the percentage of tube tips that had been placed in the correct position. They reported that 92% of tube tips were placed in the correct position using formula 4 ''14+(age/2)''.[23] This formula was the second best among the suggested formulas in our study. This difference can result from different mean ages. In the study by Kemper et al., the mean age was 5 years, whereas in our study, it was 8 months. It can be concluded that formula 4 ''14+(age/2)''[23] is not accurate enough to estimate correct NTT length in lower ages. However, different methodologies may be a possible cause. We analyzed the correlation coefficient of different formulas with actual and correct NTT length in children who were correctly intubated. Kemper et al. reported the frequency and percentage of correct nasotracheal intubations using different formulas. They also reported that by using formula 1 ''10.5+(weight/2)'',[16] 57% of tube tips were placed in the correct position; this was the least accurate formula among the suggested formulas. Moreover, in our study, formula 1 ''10.5+(weight/2)'',[16] showed moderate correlation with correct NTT length (r = 0.58). This shows that formula 1 ''10.5+(weight/2)''[16] is not reliable. It should be noted that this formula is suggested for children < 4 years-old, while in Kemper et al. study, the mean age was 5 years-old and it is expected that fewer children were < 4 years-old.

Kemper et al. reported that 64.5% of tube tips were placed in the correct position using formula 2 ''L=(3*tube size)+2'',[20] which was the fourth-best among suggested formulas. However, in our study, this formula showed a good correlation (r = 0.81). Several factors, including the type of study, patients, and analysis, can be possible causes. In the study by Kemper et al., all tube tips (100%) were placed in the correct position using formula 3a ''9+(weight/2)''.[17] Thus, this formula showed the best results among the suggested formulas. However, Kemper et al. assessed only seven cases with ages < 1 year using this formula, thus making the result unreliable. In our study, this formula showed a moderate correlation (r = 0.59). Formula 3b ''15+(age/2)''[17] showed that 85% of tube tips had been placed correctly; thus, this was the third-best among suggested formulas in the study by Kemper et al. In our study, this formula showed a poor correlation (r = 0.49) with correct tube length. This formula is used for children > 1 year-old, and the difference can be explained due to the participation of fewer children > 1 year-old in our study.

The new formula suggested in this study (tube length=height*0.1+7) is a simple way to estimate NTT length. We could not find previous studies estimating NTT length based on height. This formula can be calculated quickly, and it is not difficult to memorize. The child's height is easily measurable and is available in the patient's medical records. Moreover, parents can recall their child's height simply and correctly. Height compared to age is less affected in conditions such as failure to thrive, malnutrition, and prematurity; these factors make height more reliable than weight.[24] The formula can be used in patients under 4 years of age because all cases in this study were equal to or lower than 4 years of age. The estimated tube length must be confirmed by immediate respiratory sound auscultation and postintubation CXR after surgery. Previous formulas had several limitations. For example, it seems that the use of age in children under one year is not appropriate, and Formula 4 ''(14 + age/2)''[23] calculates the tube length for all children < 1 year-old around 14 cm, which seems to be incorrect. Although it is recalled by parents easily and quickly and is simply available in patients' medical records, weight has some limitations. Weight cannot be used in older pediatrics because the airway does not grow proportionally with weight gain.[16] Also, in failure to thrive, weight is easily affected.[24]

Formulas based on the size of the tracheal tube are not affected by a child's nutritional status. However, using different tube sizes in the same patients, the length of the tracheal tube varies, which limits the use of this formula. Besides, there is more than one way to predict tube size. Many ill or toxic patients who require intubation are suffering from conditions that lead to airways narrowing such as infection, edema, and local injury due to previous intubation. In these situations when a smaller tracheal tube is needed, this size-based formula is not reliable.[20]

This study has some limitations. First, only a few cases were over one year old. We evaluated cardiac surgery cases who were mostly suffering from congenital heart disease; thus, they should undergo surgery as soon as possible at earlier ages (under one year). This did not lead to a major bias in our final results and conclusions because the evaluated formulas have their own conditions according to the patients' age and weight. However, our suggested formula should be evaluated in different studies with more children > 1 year-old to confirm its accuracy. Second, cases with congenital airway anomalies and abnormal anatomies were not evaluated, and the result cannot extend to these children. It should be considered that this study was retrospective, and most of the cases were under one year of age. We recommend that future studies prospectively evaluate new formula and previous formulas in children over 1 year old – for instance, children who require general anesthesia for dental procedures.

Conclusion

The formula ''L=3*tube size+2'' and the new suggested formula in this study – ''L=0.1*height+7'' – can be used to estimate nasotracheal tube length in children under 4 years of age. However, these formulas are only guides and require confirmation by auscultation and CXR.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Luten R. Accurate endotracheal tube placement in children: depth of insertion is part of a process. Pediatr Crit Care Med. 2005;6:606–8.
2. Khatami SF, Parvaresh P, Behjati S. Common complications of endotracheal intubation in newborns. Iran J Neonatol IJN. 2011;2:12–7.
3. Divatia J, Bhowmick K. Complications of endotracheal intubation and other airway management procedures. Indian J Anaesth. 2005;49:308–18.
4. Levy FH, Bratton SL, Jardine DS. Routine chest radiographs following repositioning of endotracheal tubes are necessary to assess correct position in pediatric patients. Chest. 1994;106:1508–10.
5. Niwas R, Nadroo AM, Sutija VG, et al. Malposition of endotracheal tube: association with pneumothorax in ventilated neonates. Arch Dis Child Fetal Neonatal Ed. 2007;92:F233–4.
6. Mainie P, Carmichael A, McCullough S, et al. Endotracheal tube position in neonates requiring emergency interhospital transfer. Am J Perinatol. 2006;23:121–4.
7. Gupta PK, Gupta PK, Jain M, et al. Postprocedural chest radiograph: impact on the management in critical care unit. Anesth Essays Res. 2014;8:139–44.
8. Pek JH, Tan EM, Hao Y, et al. Comparison of formulae for orotracheal intubation depth in the paediatric population. Ann Acad Med Singapore. 2018;47:138–42.
9. Boensch M, Schick V, Spelten O, et al. Estimation of the optimal tube length: systematic review article on published formulae for infants and children. Anaesthesist. 2016;65:115–21.
10. Kemper M, Dullenkopf A, Schmidt AR, et al. Nasotracheal intubation depth in paediatric patients. Br J Anaesth. 2014;113:840–6.
11. Murphy MC, Donoghue VB, O'Donnell CPF. Randomised trial of estimating oral endotracheal tube insertion depth in newborns using suprasternal palpation of the tip or weight. Arch Dis Child Fetal Neonatal Ed. 2020;105:196–200.
12. Greene NH, Jooste EH, Thibault DP, et al. A study of practice behavior for endotracheal intubation site for children with congenital heart disease undergoing surgery: impact of endotracheal intubation site on perioperative outcomes-an analysis of the society of thoracic surgeons congenital cardiac anesthesia society database. Anesth Analg. 2019;129:1061–8.
13. Moore BM, Blumberg K, Laguna TA, et al. Incidental sinusitis in a pediatric intensive care unit. Pediatr Crit Care Med. 2012;13:e64–8.
14. Shukla HK, Hendricks-Munoz KD, Atakent Y, et al. Rapid estimation of insertional length of endotracheal intubation in newborn infants. J Pediatr. 1997;131:561–4.
15. Hauser GJ, Muir E, Kline LM, et al. Prospective evaluation of a nonradiographic device for determination of endotracheal tube position in children. Crit Care Med. 1990;18:760–3.
16. Antona M de la S, López-Herce J, Rupérez M, et al. Estimation of the length of nasotracheal tube to be introduced in children. J Pediatr. 2002;140:772–4.
17. Lau N, Playfor SD, Rashid A, et al. New formulae for predicting tracheal tube length. Paediatr Anaesth. 2006;16:1238–43.
18. Blayney MP, Logan DR. First thoracic vertebral body as reference for endotracheal tube placement. Arch Dis Child Fetal Neonatal Ed. 1994;71:F32–5.
19. Koshy T, Misra S, Chatterjee N, et al. Accuracy of a chest X-Ray-based method for predicting the depth of insertion of endotracheal tubes in pediatric patients undergoing cardiac surgery. J Cardiothorac Vasc Anesth. 2016;30:947–53.
20. Yates AP, Harries AJ, Hatch DJ. Estimation of nasotracheal tube length in infants and children. Br J Anaesthesia England. 1987;59:524–6.
21. Hulley SB, Cummings SR, Browner WS, et al. Designing clinical research: an epidemiologic approach. 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2013. p. 79. Appendix 6C.
22. Weiss M, Balmer C, Dullenkopf A, et al. Intubation depth markings allow an improved positioning of endotracheal tubes in children. Can J Anaesth. 2005;52:721–6.
23. Davenport HT. Paediatric Anaesthesia. 3rd edn. London: Heinemann Medical Books; 1980.
24. Levine DA. Normal Growth. In: Marcdante KJ, Kliegman RM, editors. Nelson Essentials of Pediatrics. Philadelphia: Elsevier Saunders; 2015. p. 10–2.