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Modification of the "Tochen Formula" to Measure the Accuracy of Endotracheal Tube Depth in Orotracheal Intubation of Neonates with Birth Weight Below 1500 Grams or Gestational Age Below 32 Weeks

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ABSTRACT

Introduction: Accurate endotracheal tube (ETT) depth is crucial to prevent serious complications. The Tochen formula, commonly used in Indonesia, shows limitations in premature or low birth weight neonates due to a high rate of malposition. This study aimed to evaluate the accuracy of the Tochen formula and compare it with a modified formula for determining appropriate ETT depth in neonates weighing less than 1500 grams or with a gestational age below 32 weeks.

Methods: This retrospective cross-sectional study was conducted in the Neonatology Unit of RSCM between 1 January 2023 and 31 December 2024. Inclusion criteria were neonates with a birth weight under 1500 grams or a gestational age below 32 weeks who underwent orotracheal intubation and chest X-ray to assess ETT tip position.

Results: Only 22.2% of ETT placements using Tochen's formula were accurate, versus 77.8% using the modified formula ($p < 0.001$). Spearman analysis showed gestational age ($r = 0.996$, $p < 0.001$) and birth weight ($r = 0.792$, $p < 0.001$) significantly influenced ideal ETT depth. Linear regression found both factors to be significant predictors ($\beta = 0.081$ and 0.108, $p < 0.001$ and 0.008, respectively). The modified formula yielded improved accuracy, though ICC analysis = 0.941 indicated extremely good agreement with Tochen's.

Conclusion: Gestational age and birth weight significantly influence ideal ETT depth in group. The Tochen's formula is less accurate for this group. The proposed modification provides improved precision for ETT placement in next longitudinal study for improve validity. Nevertheless, the potential for type 1 error was noted in the significant statistical results.

Keywords: *Birth weight, Endotracheal tube, Gestational age, Tochen's formula*

1. INTRODUCTION

Accurate placement of the endotracheal tube (ETT) during neonatal intubation is essential to ensure effective ventilation and prevent complications such as mainstem bronchial intubation, hypoventilation, pneumothorax, or accidental extubation.[1] These risks are significantly heightened in very low birth weight (VLBW) and extremely preterm neonates, who possess shorter and more delicate airways.[2,3] Studies have shown that up to 50% of ETTs placed in this population are initially mispositioned leading to a potentially severe clinical consequences, including increased morbidity, prolonged ventilation, and higher rates of intensive care interventions.[4–6]

In clinical practice, the Tochen formula (ETT depth = weight in kg + 6 cm) is a simple and widely used method for estimating insertion depth.[7] However, this formula was originally developed for term or near-term neonates and does not adequately account for anatomical variability observed in preterm infants. In neonates with a birth weight under 1500 grams or a gestational age below 32 weeks, the formula tends to overestimate the required depth, thereby increasing the risk of right mainstem intubation.[8] Theoretically, this limitation affixes from the formula's assumption of a linear correlation between weight and tracheal length—an assumption that fails in the context of extreme prematurity.[8]

The rationale for this study lies in addressing a critical gap in neonatal airway management. Clinicians often rely on a formula that lacks precision for the population most at risk, resulting unrepeated tube repositioning, extended procedure time, and avoidable complications. Although several modified formulas have been proposed internationally—incorporating in gestational age, anatomical landmarks, or composite indices—there is limited evidence validating these alternatives in local clinical settings, such as in Indonesian neonatal intensive care units (NICUs). This underscores the urgent need for context-specific evaluation and refinement of existing methods.

Given the significant clinical impact of ETT misplacement and the theoretical limitations of the standard Tochen formula, particularly in preterm and VLBW neonates, this study aimed to evaluate the accuracy of the Tochen formula and compare it with a modified formula for determining the appropriate ETT depth in neonates weighing less than 1500 grams or with a gestational age below 32 weeks.

2. METHOD

This retrospective cross-sectional study was designed to develop and evaluate the accuracy of a modified formula for predicting appropriate ETT depth in neonates. To ensure transparency and methodological rigor, the study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. Approval was obtained from the institutional review board (384/UN2.FI/ETIK/PPM.00.02/2025).

The study was conducted between 1 January 2023 and 31 December 2024 affals the Radiology Unit, Perinatology Ward, and Medical Records Division at the Kiara Center for Maternal and Child Health, Cipto Mangunkusumo National General Hospital (RSCM), Jakarta. Data were retrospectively collected from the hospital's neonatal intensive care unit registry.

The target population included all neonates classified of either extremely low birth weight or extremely preterm who underwent orotracheal intubation followed by thoracic radiographic imaging to assess ETT placement. The inclusion criteria specified neonates with a birth weight under 1500 grams or gestational age under 32 weeks, who had past intubation. Neonates with major congenital anomalies, such trisomy 13, trisomy 18, or cleft lip and palate, were excluded, with incomplete documentation in the medical record were excluded.

Subjects were recruited using a consecutive sampling method. The minimum sample size of 52 was estimated using a rule-of-thumb calculation testable for multivariable analysis

The primary outcome was the accuracy of ETT tip placement, as confirmed by post-intubation chest radiography. Independent variables included gestational age (weeks), birth weight (kilograms), and crown-heel length (centimeters), all assessed for their predictive relevance. Data were screened, cleaning, and analyzed using SPSS software version 27.0. The normality test was assessed using the Kolmogorov-Smirnov test. The Wilcoxon Rank Nm test and Chi square test were used to compare continuous and categorical variable, respectively. Spearman rank-order correlation assessed the association between biometric parameters and ETT depth. A multiple linear regression model was developed to generate a modified formula, with statistical significance set at a two-tailed p-value < 0.05 and a 95% confidence interval.

Intraclass Correlation Coefficient (ICC) and Bland-Altman analysis were used to evaluate the agreement between the modified and Tochen formula.

3. RESULTS

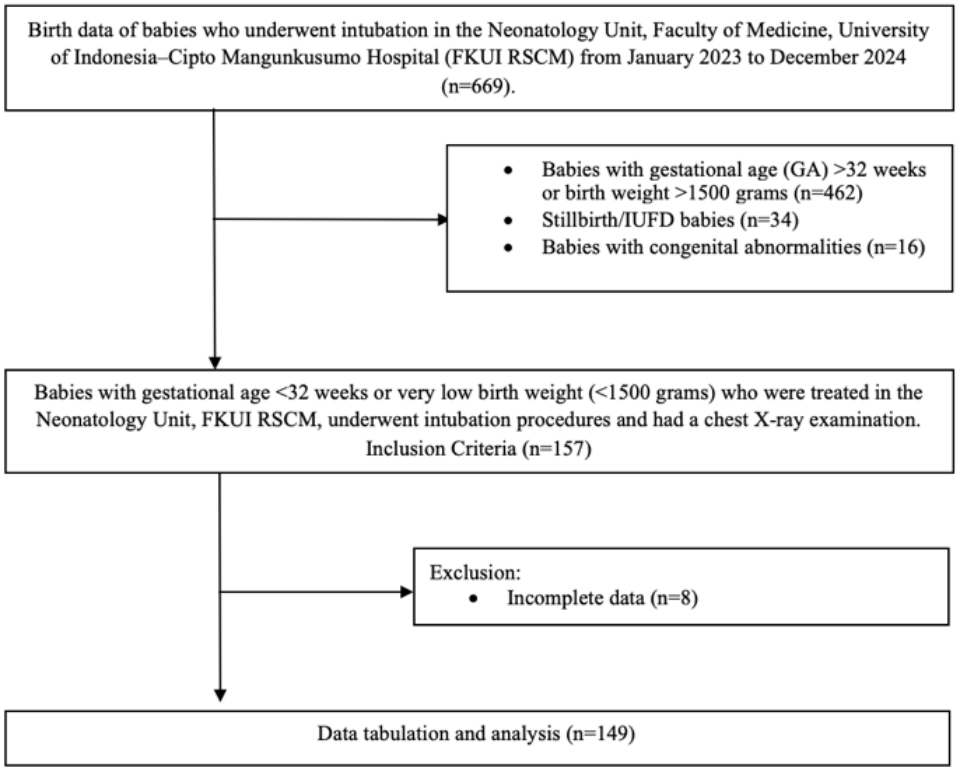

Figure 1. Flow diagram of inclusion and exclusion criteria for neonates who underwent intubation at the Neonatology Unit, FKUI RSCM.

This study analyzed birth data of babies who underwent intubation in the Neonatology Unit at FKUI RSCM from 1 January 2023 to 31 December 2024 (n=669). From the total, 462 babies with gestational age over 32 weeks or birth weight above 1500 grams, 34 stillbirths or intrauterine fetal deaths (IUFD), and 16 babies with congenital abnormalities were excluded. The inclusion criteria focused on babies with gestational age under 32 weeks or very low birth weight (under 1500 grams) who received intubation and underwent chest X-ray examinations while being treated in the Neonatology Unit, resulting in 157 eligible cases. Of these, 8 were excluded due to incomplete data, leading to a final dataset of 149 babies for tabulation and analysis.

As shown in Table 1, the majority of ETT placements were inaccurate, with 79.3% too shallow and 20.7% too deep. Accurate placements were more common in neonates with median (1.1 kg vs. 1.5 kg) and gestational age (27 vs. 28.5 weeks). IUGR was more prevalent in the accurately placed group (62%) than in the accurate group (14.7%).

Table 1. Demographic Characteristics (n = 149)

Variable	ETT Placement Accuracy	
	Accurate (n=33)	**Inaccurate (n=116)**
Placement Depth		
Too Deep	–	24 (20.7%)
Too Shallow	–	92 (79.3%)
Sex, n (%)		
Female	13 (39.4%)	54 (46.6%)
Male	20 (60.6%)	62 (53.4%)
Birth Weight (kg)	1.1 (0.4 – 2.4)	1.5 (0.4 – 2.5)

Variable	ETT Placement Accuracy	
	Accurate (n=33)	**Inaccurate (n=116)**
Median (Min–Max)		
Gestational Age (weeks)	27 (24 – 38.8)	28.5 (24 – 39.1)
Median (Min–Max)		
< 32 weeks, n (%)		
1500 – 2499 g	7 (21.2%)	37 (31.9%)
1000 – 1499 g	2 (6%)	15 (13%)
400 – 999 g	14 (42.8%)	24 (24.9%)
Birth Length (cm)	38.5 (31 – 41)	38.8 (31 – 42)
Median (Min–Max)		
Male	32 – 41	32 – 42
Female	31 – 41	31 – 41
IUGR, n (%)	8 (62%)	17 (14.7%)

Based on the correlation analysis, gestational age ($r = 0.996$, $p < 0.001$) and birth weight ($r = 0.792$, $p < 0.001$) mowed a statistically significant association with ideal endotracheal tube (ETT) depth, whereas sex, birth length, and IUGR were not significantly correlated (Table 2). Subsequent linear regression analysis identified gestational age and birth weight as significant predictors of ETT depth. The regression coefficients were 0.081 (95% CI: 0.070–0.093, $p < 0.001$) for gestational age and 0.108 (95% CI: 0.029–0.187, $p = 0.008$) for birth weight, with a constant value of 4.057 (Table 3). Based on these findings, a modified formula was developed to estimate ETT depth: ETT depth (cm) = 4.057 + (0.108 × birth weight in kg) + (0.081 × gestational age in weeks).

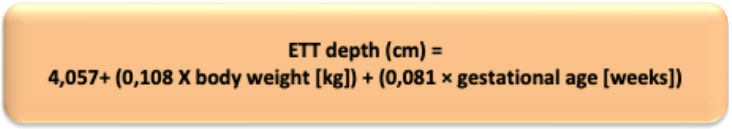

Figure 2. The modified formula based on linear regression.

Table 2. Factors Influencing the Ideal Final Depth of Endotracheal Tube in Neonates

Variable	ETT Accuracy (r)	p-value
Sex	0.065	0.431
Gestational age	0.996	< 0.001
Birth weight	0.792	< 0.001
Birth length	0.092	0.263
IUGR	0.001	0.990

Table 3. Linear Regression Analysis of Factors Influencing the Ideal Final Depth of Endotracheal Tube in Neonates

Variable	Regression Coefficient	95% CI	p-value
Constant	4.057	–	–
Gestational age	0.081	0.070 – 0.093	< 0.001
Birth weight	0.108	0.029 – 0.187	0.008

As shown in Table 4, the modified formula resulted in significantly more accurate ETT placements compared to the Tochen formula, with 75.2% of neonates achieving correct depth using the modified formula versus only 22.1% with the Tochen formula ($p < 0.001$). Incorrect placements were more common with the Tochen formula (77.9%), predominantly due to shallow insertions (79.3%), in contrast the modified formula reduced the overall inaccuracy to 14.8%, with a more balanced distribution between excessively deep (35.1%) and shallow (64.9%) placements. Table 5 further demonstrates that among neonates with accurately positioned ETTs, the median final depth using the Tochen formula was 6.7 cm (range 5.2–7.4 cm), while the modified formula produced a deeper and more consistent placement with a median of 8.0 cm (range 6.8–9.0 cm).

Table 4. Comparison of Final Ideal ETT Depth Accuracy Between the Tochen Formula and the Modified Formula

Variable	Tochen Formula n (%)	Modified Formula n (%)	p-value
Accurate	33 (22.1%)	112 (75.2%)	$p < 0.001^c$
Inaccurate	116 (77.9%)	37 (14.8%)	
– Too deep	24 (20.7%)	13 (35.1%)	
– Too shallow	92 (79.3%)	24 (64.9%)	

Table 5. Comparison of Final ETT Depth in Patients with Accurate ETT Placement.

	Tochen Formula	Modified Formula
Accurate placement	6.7 cm (5.2 – 7.4 cm)	8.0 cm (6.8 – 9.0 cm)

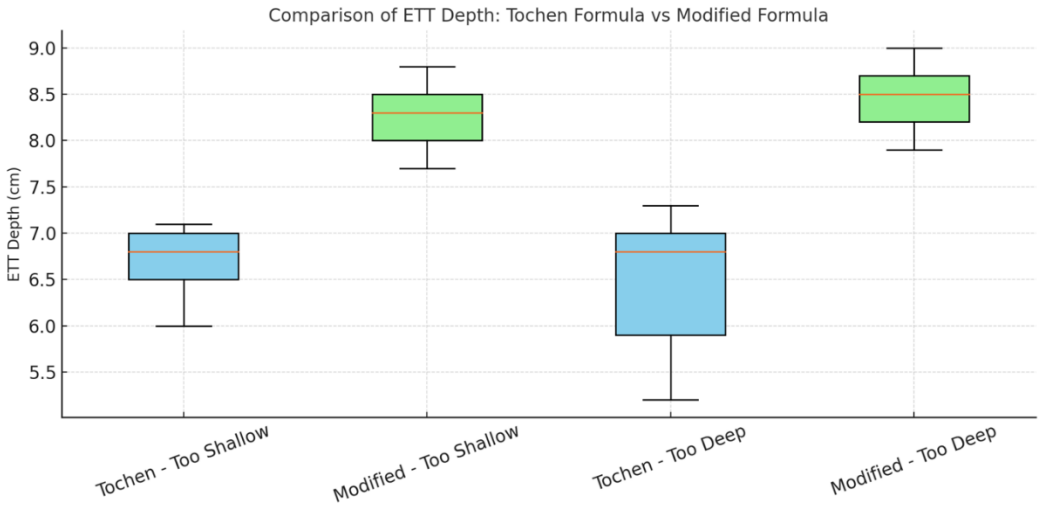

Figure 2. Comparison of ETT Depth Errors: Tochen vs Modified Formula.

The comparison between the Modified Formula and the Tochen Formula for estimating ETT depth demonstrated a high level of agreement. As illustrated in the Bland-Altman plot (Figure 3), most data points fall within the limits of agreement, indicating minimal bias between the two methods. Furthermore, the ICC analysis revealed a strong correlation, with an ICC value of 0.941 and a 95% confidence interval ranging from 0.918 to 0.957, which was statistically significant ($p < 0.001$) (Table 6). These findings suggest that the Modified Formula provides highly consistent measurements when compared to the Tochen Formula.

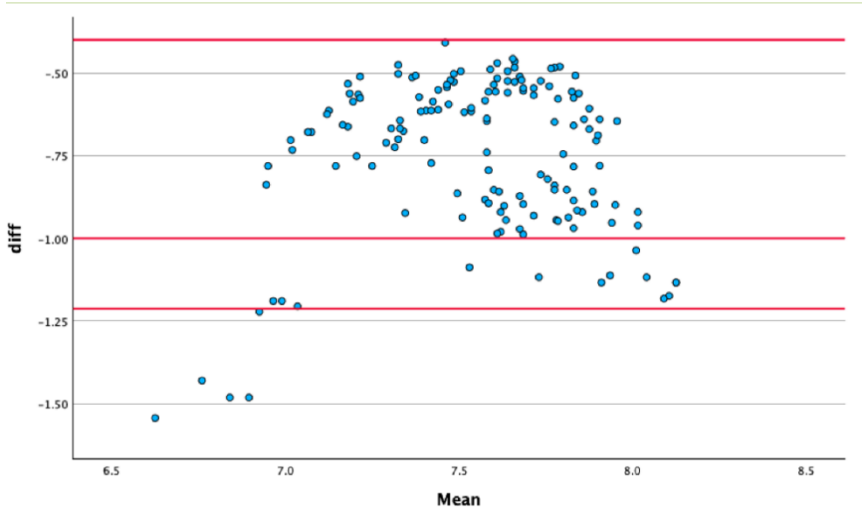

Figure 3. Bland-Altman Plot Comparing ETT Depth Estimates between Modified and Tochen Formulas

Table 6. ICC between Modified Formula and Tochen Formula

ICC Type	ICC Value	95% CI	Lower Bound	Upper Bound	p-value
Mean of Measures	0.941		0.918	0.957	< 0.001

4. DISCUSSION

This study highlights the limitation of the conventional Tochen formula in predicting ETT depth neonates. The traditional formula, ETT depth = BW (kg) + 6 cm, does not take into account key factor such as GA, BW, and tracheal length, factors that are essential ensuring proper ETT positioning. It assumes a standard tracheal length across preterm infants, which is inappropriate, especially for those born before 32 weeks of gestation, the trachea is significantly shorter. This limitation increases the chance of ETT malposition resulting in either shallow or deep, placement and consequently raises the likelihood of complications such as ineffective ventilation or airway injury. Therefore, there is an urgent need to modify the formula to account for these physiological differences in neonates, particularly in the highly vulnerable population of preterm infants.

Findings from this study revealed a low accuracy rate for the Tochen formula, with only 22.1% of ETT placements being correct. The remaining 77.9% were mispositioned, with the majority being either too shallow (61.8%) and a smaller proportion too deep (16.1%). These data confirm the inadequacy of the standard formula, in account for anatomical variability related to weights and gestational ages. Such inaccuracies were immediate clinical risks, including poor ventilation, hypoxia, and, in severe cases, mortality.[9,10] Therefore, these results reinforce the need for a more precise method of estimating ETT depth, one that integrates both GA and BW to improve clinical outcomes, particularly among preterm neonates in critical care settings.

The literature strongly supports the need for a modified Tochen formula that better accounts for neonatal differences. This findings align with prior research by Chung (2018), by Takeuchi (2020), and Kempley (2008), which emphasize the importance of the importance of incorporating gestational age and birth wight into depth prediction, particularly in neonates with birth weights under 1500 grams, significantly increases the risk of respiratory complications, such as atelectasis, hypoventilation, and pneumothorax.[8,11,12] These complications arise from either over-inflation of one lung or insufficient ventilation, which is more likely when ETT placement is too shallow or too deep. The inability of the original Tochen formula to consider variations in tracheal length based on GA and BW further exacerbates the problem. Therefore, adapting the formula to include these factors would improve the precision of ETT placement and reduce the incidence of such life-threatening complications in neonates.

In the regression analysis conducted in this study, both gestational age and birth weight were found to have a statistically significant effect on ETT depth. The regression coefficient for GA was 0.108 ($p < 0.001$), indicating that as the gestational age increases, the required ETT depth also increases due to the longer tracheal length. Similarly, birth weight showed a significant correlation with ETT depth, with a regression coefficient of 0.081 ($p = 0.008$). The result suggests that infants with higher birth weights require deeper ETT placement.[8,13] These findings are crucial, as they suggest that both GA and BW should be incorporated into the modified formula to enhance its accuracy.

From a clinical standpoint, the implications of this study are significant for improving neonatal care in the NICU. The study proposes the development of a web application and an Excel-based tool to automate the calculation of ideal ETT depth based on input values of birth weight and gestational age. These tools would enable healthcare professionals to quickly and accurately determine the correct insertion depth for each infant, thereby improving patient outcomes. Accurate ETT depth calculation may reduce the time spent re-positioning, minimize the risk of complications, and ultimately improve ventilation and oxygenation in neonates. Furthermore, the study advocates for the practical standardization of ETTs with specific markings for preterm infants weighing less than 1500 grams, which would assist clinicians during emergency intubation, particularly in settings where mobile radiology is not available. By implementing these recommendations, neonatal care can become safer, more efficient, and more consistent across diverse clinical environments.

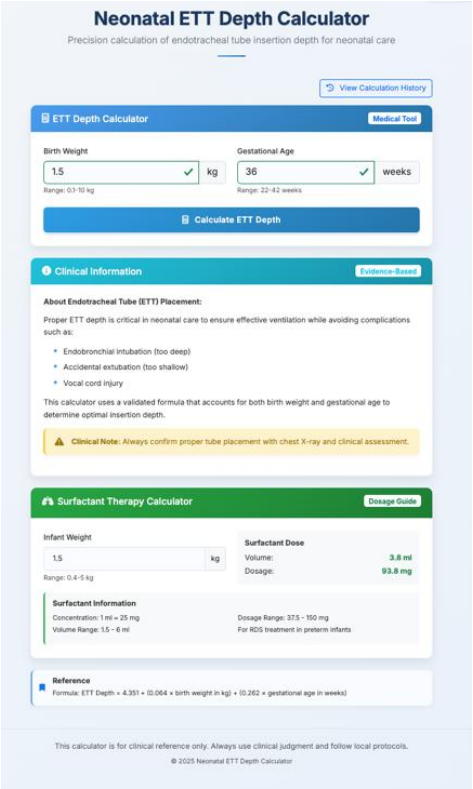

Figure 4. Web based application design.

Calculator for neonatal intubation (<32 weeks or weight < 1500 grams)

Birth weight	1000	gram		ETT depth
Gestational age	30	weeks		7.378 cm

Figure 5. Application design using *Microsoft Excel*.

Study Limitations

This study has several limitations that should be acknowledged. First, its retrospective relied on secondary data from medical records, which maybe incomplete or inconsistent. The limitation is evident in the exclusion of eight subjects due to missing data. Second, as the study is not prospective, there was limited control over independent variables and the measurement process, increasing the potential for bias in data collection and recording. In addition, the significant p-value reported in Table 4, when compared to findings in Table 5 may reflect clinically inappropriate placement, raising the possibility of a type 1 error, where the null hypothesis is incorrectly rejected despite statistical significance. This could result from the large sample size or a non-random data distribution, suggesting that statistically significant results may not accurately represent a true causal relationship. Furthermore, the observed 0.4 cm depth difference in ETT depth between the Tochen formula and modified formula in neonates with gestational age of 28–30 weeks highlights the risk of clinically relevant misplacement. These findings suggest the need for future longitudinal studies to validate and refine the modified formula for boarder clinical application.

5. CONCLUSION

The results of this study demonstrate that gestational age and birth weight significantly influence the accuracy of the conventional Tochen formula in determining the appropriate depth for ETT placement in neonates. The formula proves inadequate for infants weighing less than 1500 grams or born before 32 weeks of gestation, resulting in a high rate of tube misplacement. Therefore, modification of the Tochen formula is necessary to enhance precision and ensure optimal ETT positioning in this vulnerable population. By incorporating these factors, the modified formula markedly improves the accuracy of ETT placement, thereby reducing the risks of complications and enhancing neonatal care outcomes. Implementing modified formula is essential for achieving more reliable and effective clinical practice in neonatal intensive care settings.

REFERENCES

[1] Schaefer-Randolph JL, Shumway SG, Fuller CW, Ramjee VG, Vasan NR. Neonatal Tracheal Intubation in the NICU: A Literature Review. Healthcare. 2025 May 24;13(11):1242.

[2] Kresnawati W, Pandie PJ, Rohsiswatmo R. Very low birth weight infant outcomes in a resource-limited setting: a five-year follow-up study. Front Pediatr. 2025;13:1581033.

[3] Jańczewska I, Wierzba J, Jańczewska A, Szczurek-Gierczak M, Domżalska-Popadiuk I. Prematurity and Low Birth Weight and Their Impact on Childhood Growth Patterns and the Risk of Long-Term Cardiovascular Sequelae. Children (Basel). 2023 Sep 25;10(10):1599.

[4] Volsko TA, McNinch NL, Page-Goertz C. Development and internal validation of an equation using anthropometric measures to predict correct endotracheal tube insertion depth. Can J Respir Ther. 2022;58:9–14.

[5] Naseh N, Wallström L, Sindelar R, Ågren J. Standardized endotracheal tube and intravascular access placement in infants born at 22-23 weeks gestation. Pediatr Res [Internet]. 2025 Jun 18 [cited 2025 Jun 25]; Available from: https://www.nature.com/articles/s41390-025-04186-8

[6] Miller KA, Kimia A, Monuteaux MC, Nagler J. Factors Associated with Misplaced Endotracheal Tubes During Intubation in Pediatric Patients. The Journal of Emergency Medicine. 2016 Jul;51(1):9–18.

[7] Amarilyo G, Mimouni FB, Oren A, Tsyrkin S, Mandel D. Orotracheal tube insertion in extremely low birth weight infants. J Pediatr. 2009 May;154(5):764–5.

[8] Chung HW, Lee WT, Chen HL. Reexamining the ideal depth of endotracheal tube in neonates. Pediatr Neonatol. 2018 Jun;59(3):258–62.

[9] Avva U, Lata JM, Hendrix JM, Kiel J. Airway Management. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 [cited 2025 Jun 25]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK470403/

[10] Cook TM, MacDougall-Davis SR. Complications and failure of airway management. British Journal of Anaesthesia. 2012 Dec;109:i68–85.

[11] Takeuchi S, Arai J, Nagafuji M, Hinata A, Kamakura T, Hoshino Y, et al. Ideal endotracheal tube insertion depth in neonates with a birthweight less than 750 g. Pediatr Int. 2020 Aug;62(8):932–6.

[12] Kempley ST, Moreiras JW, Petrone FL. Endotracheal tube length for neonatal intubation. Resuscitation. 2008 Jun;77(3):369–73.

[13] Sakhuja P, Finelli M, Hawes J, Whyte H. Is It Time to Review Guidelines for ETT Positioning in the NICU? SCEPTIC-Survey of Challenges Encountered in Placement of Endotracheal Tubes in Canadian NICUs. Int J Pediatr. 2016;2016:7283179.