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ORIGINAL ARTICLE

A novel measurement point for determining the optimal endotracheal tube tip depth in neonates: The gum

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ABSTRACT

Objective: Improper placement of an endotracheal tube can result in numerous severe complications. Several techniques have been suggested to determine the correct positioning of orotracheal intubation in neonates. Our objective was to evaluate measurements obtained at both the lip and gingival levels, with the aim of identifying an alternative approach for determining the optimal depth of the endotracheal tube.

Material and Methods: This prospective observational study was conducted between December 2022 and September 2023. The depth of the endotracheal tube was evaluated by a single investigator, and a chest X-ray (CXR) was performed afterwards. Immediately before the CXR, the investigator marked the tube both at the levels of the anterior superior gingival margin and the upper lip margin on the midline. The position of the endotracheal tube tip, as assessed in the CXR, was compared to measurements taken from the anterior superior gingival and upper lip margin levels. Since the main problem with most formulas for appropriate endotracheal tube positioning is faced when the babies are very small, we divided the group into very low birth weight infants and the others.

Results: During the study period, 59 intubated patients had a scheduled CXR during working hours, resulting in a total of 94 measurements from 26 females (44%) and 33 males (56%). Endotracheal tube tip–lip, endotracheal tube tip–gingiva, and nasal tragus distances were classified according to whether the endotracheal tube was within the target range or positioned deep or high according to the CXR. It was determined that there was statistically high agreement among all measurements. Formulas were developed for the targeted lip and gum measurements for achieving the optimal endotracheal tube position, and the results were found to be statistically significant.

Conclusion: The formulas established in this study provide a swift and precise method for determining the insertion depths of the endotracheal tube tip at the gingival level in neonates.

Keywords: Chest-x-ray, endotracheal tube depth, gum, lip, neonates.

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INTRODUCTION

Endotracheal intubation, a life-saving yet challenging procedure, is often performed in neonates when they experience hypercapnia, hypoxia, or apnea, or require cardiopulmonary resuscitation or surfactant administration.[1–4] After intubation, maintaining the endotracheal tube (ETT) at an appropriate depth is crucial for ensuring effective ventilation and oxygenation, and for achieving equal distribution of surfactant in both lungs, particularly in premature infants.[3,5,6] It is essential to secure the ETT tip at the midpoint of the trachea and make a note of the depth at which the tube is fastened at the lip edge.[1,2]

When intubating patients who are monitored due to respiratory distress in the neonatal intensive care unit (NICU), the calculation of the tube depth is primarily done by taking into account the weight or week of gestation. The “7-8-9” rule, introduced by Tochen in 1979 and subsequently endorsed by both the American Academy of Pediatrics and the American Heart Association, has been the most widely utilized method for determining ETT depth.[1,2,5,7] However, data regarding the accuracy of this rule are limited, especially in extremely low birth weight and macrosomic infants. An alternative method was developed by Shukla et al.,[8] which involves adding 1 cm to the nasal-tragus distance. This method was highlighted as a viable option in the 2017 Neonatal Resuscitation Program (NRP) as it demonstrated an accuracy rate of 98%. In addition to auscultation, CXR remains regarded as the “gold standard” technique for verifying the correct placement of the ETT.[1,4,6,9]

For ETT length calculation, studies primarily consider lip level for practicality; however, various reference points have been explored due to the potential impact of skin edema or certain deformities on the results. In the study conducted by Zaytseva et al.,[1] it was suggested that the more stable structure of the gum, as compared to the lip, may be more reliable for determining ETT depth.

In our study, we aimed to compare measurements made at the lip edge and gum level to evaluate an alternative method for predicting the optimal depth of the ETT in the NICU.

MATERIAL AND METHODS

This prospective observational study was undertaken in a level IV NICU, accommodating up to 61 beds, between December 2022 and September 2023. Ethical approval was obtained from the hospital’s ethics committee on November 24, 2022, under reference number B.10.1.TKH.4.34.H.GP.0.01/367. Written informed consent from the parents of all participants was secured prior to their inclusion in the study.

Inclusion Criteria

Throughout the study period, neonates who had been previously intubated and were receiving invasive ventilation were enrolled in the research when a CXR was scheduled during regular working hours. In our NICU, endotracheal intubations are performed by either a pediatric resident or a neonatologist, and the depth of the ETTs is adjusted according to the nasal tragus distance formula initially and confirmed with auscultation and CXR afterwards. Single-lumen, uncuffed, sterile, latex-free ETTs marked with centimeter graduations (TUORen®, Germany) were utilized in the study.

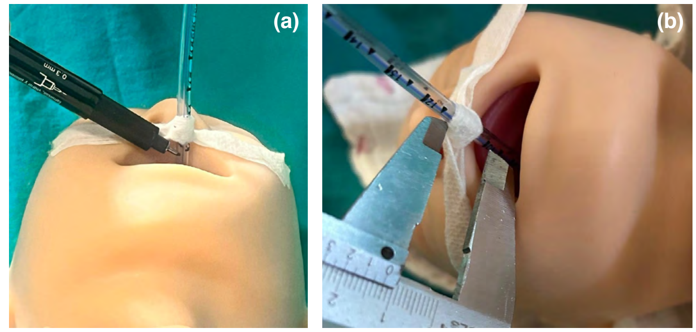

Figure 1: (a) Marking the intubation tube on the anterior upper gum and the upper lip edge. **(b)** Measurement using a Vernier Caliper.

Exclusion Criteria

Infants for whom parental consent was not obtained, or who had congenital anomalies and upper airway abnormalities, were excluded from the study.

Data Collection

The demographic characteristics of the patients were documented. The depth of the ETT was assessed by a single investigator, followed by CXR. During both procedures, the newborn was maintained in a neutral head position within the baby nest, with head support provided. Corrective adjustments to the ETT depth were made if malposition was identified on CXR, the gold standard method.

Measurements

To minimize measurement variability, the study was conducted by a single investigator, an experienced neonatologist. Immediately before the CXR, the investigator marked the tube with a fine-tip permanent pen both at the levels of the anterior superior gingival margin and the upper lip margin on the midline (Fig. 1a).[1] To calculate the actual lip-to-tip and gum-to-tip distances, we used a similar method described by Priyadarshi et al.[9] Using a Vernier caliper, the distance between the initial tube marking (visible adjacent to the adhesive tape) and both markings was subtracted (Fig. 1b). The procedure was discontinued immediately if desaturation or bradycardia occurred during its execution. The location of the ETT tip, as assessed in the CXR, was compared to measurements taken from the anterior superior gingival and upper lip margin levels.

CXR Evaluation

A portable X-ray device (Siemens, Mobilet Miramax, 3638, 1015544537) was utilized for CXR, which was performed in the NICU by a radiology technician in an anteroposterior position. The CXR taken immediately after the measurement served as a reference, with the optimal ETT tip position defined as being located between the lower border of the first and upper border of the third thoracic vertebral bodies. The position was subsequently categorized into three groups: correct (located between the lower border of the first and upper border of the third thoracic vertebral bodies), high (positioned above the T1 vertebra), and deep (positioned below the T3 vertebra).[10]

Table 1: Demographic characteristics of the patient and control groups Distribution of demographic and clinical characteristics

Characteristics (n=59)	n (%)	Median (Min–Max)
Sex		
Female	26 (44.1)	
Male	33 (55.9)	
Gestational week (w)		32.3 (22.5–39.4)
Birth weight (g)		1790 (465–3625)
Head circumference (cm)		29 (19–36)
Length (cm)		42 (28–52)
Mode of delivery		
C/S	45 (76.2)	
NSVD	14 (23.7)	

NSVD: Normal spontaneous vaginal delivery.

Calculation of the Formulas

As the main problem for most of the formulas for appropriate ETT positioning is with the tiniest infants, we aimed to calculate a potential formula for newborns with very low birth weight (VLBW). Therefore, we divided the group into two as VLBW and the others.

Statistical Analysis

The patient data gathered during the study were analyzed using IBM Statistical Package for the Social Sciences (SPSS) for Windows, version 23.0 (IBM Corp., Armonk, NY). Categorical variables were represented through frequency and percentage distributions, while continuous variables were described using the mean, standard deviation, median, as well as minimum and maximum values. Intraclass correlation analysis was performed to assess the agreement among measurements. Linear regression analysis was employed to predict lip and gum measurements based on the infants' weights at the time of measurement. Results were considered significant when $p<0.05$.

RESULTS

During the study period, 59 intubated patients had a scheduled CXR during working hours, resulting in a total of 94 measurements from 26 females (44%) and 33 males (56%). The distribution of demographic and clinical characteristics of the patients included in the study is presented in Table 1.

The postmenstrual age, chronological age, and body weights of the patients at the time of measurement, as well as the distances from the ETT tip to lip, ETT tip to gum, nasal tragus distance, MV mode, and X-ray ETT tip, are shown in Table 2.

The results of the intraclass correlation analysis, which assessed the agreement between the measurements of lip and gum distances in the evaluated patients, are presented in Table 3. Upon examining the table, it was determined that there was statistically high agreement among all measurements ($p<0.001$).

Table 2: Distribution of measurements and clinical findings

Characteristics (n=94)	n (%)	Median (Min–Max)
Time of measurement (day)		6 (1–63)
Body weight (g)		1410 (515–4090)
<1500 g		
>1500 g		
Postmenstrual week (w)		33.6 (22.5–42.6)
ETT size (Fr)		3.0 (2.5–5.0)
Nasal tragus distance (cm)		6.5 (3.8–9.5)
ETT tip - lip distance (cm)		7.6 (6.0–11.0)
ETT tip - gum distance (cm)		7.3 (5.5–10.5)
MV mode		
Conventional	75 (79.8)	
HFO	19 (20.2)	
X-ray ETT tip		
In place	73 (77.7)	
High	12 (12.8)	
Deep	9 (9.6)	

ETT: Endotracheal tube; MV: Mechanical ventilation; HFO: High-frequency oscillation.

Table 3: Agreement between measurements

Measurements	Intraclass correlation coefficient (95% CI)	p
ETT tip - lip ETT tip - gum	**0.988 (0.982–0.992)**	**<0.001**
ETT tip - lip Nasal Tragus	**0.909**	**<0.001**
ETT tip- gum Nasal Tragus	**0.885**	**<0.001**

ETT: Endotracheal tube.

The measurements of lip and gum distances were evaluated in cases where the optimal ETT position was predetermined on the CXR. Two groups were created based on body weights at the time of measurement: <1500 g (49, 52.1%) and ≥1500 g (45, 47.9%). Based on measurement locations, the distribution of tube placement accuracy as determined by the CXR showed that optimal placement was observed in 73 cases (77.7%), high placement in 12 cases (12.8%), and deep placement in 9 cases (9.6%). Formulas were developed for the targeted lip and gum measurements for achieving the optimal ETT position, and the results were found to be statistically significant. Among these models, the gingival measurements demonstrated a stronger predictive power for optimal ETT placement,

Table 4: Distribution of estimated lip and gingival measurements according to patient weights

Variable	Model	Sum of squares	Degrees of freedom	Mean square	F	p	
Gum (R^2=66.0)	Regression	77.515	1	77.515	178.392	<0.001	
	Remains	39.976	92	0.435			
	Total	117.492	93				
		β	Standard error		t	p	95% CI
	Constant	**5.806**	**0.139**		**41.865**	**<0.001**	**5.530–6.081**
	Patient weight	**0.001**	**0.000**		**13.356**	**<0.001**	**0.001–0.001**
Variable	**Model**	**Sum of squares**	**Degrees of freedom**	**Mean square**	**F**	**p**	
Lip (R^2=74.5)	Regression	98.935	1	98.935	269.350	<0.001	
	Remains	33.793	92	0.367			
	Total	132.728	93				
		β	Standard error		t	p	95% CI
	Constant	**6.109**	**0.128**		**47.914**	**<0.001**	**5.856–6.362**
	Patient weight	**0.001**	**0.000**		**16.412**	**<0.001**	**0.001–0.001**

CI: Confidence interval.

Table 5: Distribution of estimated lip and gingival measurements of patients with chest X-ray results and <1500 gr measurement weight according to patient weight

Variable	Model	Sum of squares	Degrees of freedom	Mean square	F	p	
Gum (R^2=44.5)	Regression	**6.968**	**1**	**6.968**	**29.716**	**<0.001**	
	Remains	**8.676**	**37**	**0.234**			
	Total	**15.644**	**38**				
		β	Standard error		t	p	95% CI
	Constant	**4.925**	**0.313**		**15.717**	**<0.001**	**4.290–5.559**
	Patient weight	**0.002**	**0.000**		**5.451**	**<0.001**	**0.001–0.002**
Variable	**Model**	**Sum of squares**	**Degrees of freedom**	**Mean square**	**F**	**p**	
Lip (R^2=53.5)	Regression	**8.007**	**1**	**8.007**	**42.619**	**<0.001**	
	Remains	**6.951**	**37**	**0.188**			
	Total	**14.957**	**38**				
		β	Standard error		t	p	95% CI
	Constant	**5.244**	**0.280**		**18.698**	**<0.001**	**4.676–5.812**
	Patient weight	**0.002**	**0.000**		**6.528**	**<0.001**	**0.001–0.003**

CI: Confidence interval.

as indicated by higher R^2 values and a greater effect size (e.g., t=6.528, p<0.001), particularly highlighting the influence of patient weight on gingival positioning compared to lip-based measurements. The models obtained for gum and lip measurements based on body weight are presented in Tables 4, 5, and 6, and potential formulas can be summarized as follows:

- For all weight groups:

  ETT tip–Gum distance (cm)=5.8+0.001 (body weight)

  ETT tip–Lip distance (cm)=6.1+0.001 (body weight)

- For <1500 g:

  ETT tip–Gum distance (cm)=4.93+0.002 (body weight)

Table 6: Distribution of estimated lip and gingival measurements of patients with chest X-ray results and measurement weights of ≥1500 g according to patient weights

Variable	Model	Sum of squares	Degrees of freedom	Mean square	F	p	
Gum (R^2=49.7)	Regression	12.892	1	12.892	31.659	<0.001	
	Remains	13.031	32	0.407			
	Total	25.922	33				
		β	Standard error		t	p	95% CI
	Constant	6.318	0.393		16.085	<0.001	5.518–7.119
	Patient weight	0.001	0.000		5.627	<0.001	0.001–0.001
Variable	**Model**	**Sum of squares**	**Degrees of freedom**	**Mean square**	**F**	**p**	
Lip (R^2=58.3)	Regression	17.232	1	17.232	44.658	<0.001	
	Remains	12.347	32	0.386			
	Total	29.579	33				
		β	Standard error		t	p	95% CI
	Constant	6.540	0.382		17.103	<0.001	5.761–7.319
	Patient weight	0.001	0.000		6.683	<0.001	0.001–0.001

CI: Confidence interval.

ETT tip–Lip distance (cm)=5.24+0.002 (body weight)

- For ≥1500 g:

ETT tip–Gum distance (cm)=6.32+0.001 (body weight)

ETT tip–Lip distance (cm)=6.54+0.001 (body weight)

DISCUSSION

With this study, we demonstrated that in predicting the appropriate placement depth of the ETT, the gum measurement can be considered as an alternative reference point to the most commonly used ETT–lip edge measurement in neonatal units. After the intubation procedure, securing the ETT to the lip edge with adhesive tape makes it challenging to assess the tube level numerically. Relying on a more stable structure, such as the gum as a reference point, enhances the accuracy of ETT depth tracking. In our study, we found a statistically significant agreement between the measurements of lip, nasal tragus, and gum distances in patients.

While various methods have been studied to estimate ETT depth in neonates, the lip edge has generally been employed as a reference point.[1–3,5,6,9,11] The “7-8-9” rule (Tochen’s formula), developed by Tochen in 1979, which is also the starting point of these studies, was frequently used in routine practice. However, in this study involving 40 cases within the 26–44 weeks gestational age range, only 10 had a body weight between 700–1000 g. This led researchers to explore different methods for more reliable results in this high-risk group of infants. Studies have demonstrated that in Tochen’s formula, the prediction value for optimal placement depth is significantly higher for infants weighing <750 g, indicating that the tube may go further than intended.[2] Bartle et al.[12] hypothesized that the weight-based Duke formula (5.5 cm+1 cm/kg for 500–999 g; 5.0+1 cm/kg for <500 g) used in their clinic would accurately predict appropriate ETT placement in infants weighing <1 kg. However, because their weight-based formula had low sensitivity in predicting appropriate ETT depth, they concluded that rapid radiographic confirmation of ETT placement is necessary in infants weighing <1 kg.[12]

As an alternative to Tochen’s formula, Kempley et al.[5] demonstrated that optimal ETT depth correlates with the infant’s gestational age. Flinn et al.,[13] when evaluating gestational age versus body weight for predicting ETT depth, did not find a significant difference between the two. To better assess the relationship between optimal tube placement and body weight, infants weighing between 440 g and 4.5 kg were included. Among these, 100 had a weight below 1000 g. In this study, it was reported that the measured depth of the tube, which should have been 6.5 cm for a baby weighing 500 g according to the “7-8-9” rule, was found to be 5.4 cm. Despite the seemingly small difference, it was noted to pose a risk for complications due to improper tube placement.[5]

Razak et al.[6] evaluated studies on the prediction of ETT depth and found significant heterogeneity ranging from 8.8% to 93% in defining the optimal position across all methods. Using a weight-based approach, it was observed that the probability of achieving optimal tube placement was greater in neonates with a mean gestational age >30 weeks, compared to those with a mean gestational age <30 weeks. None of the existing methods have been shown to provide definitive results, with more than half of the routinely used methods leading to incorrect placement of the ETT, especially in premature infants.[6]

Hunyady et al.,[14] in their study using the Morgan formula (ETT position at upper front teeth (cm): 0.1×height(cm)+5), showed that the distance between the front teeth and the carina is related to the child's height. However, it was stated that although the Morgan formula provides good guidance for intubation in children, it may cause distal placement of the endotracheal tube in young infants.[14] In our study, when we took into account the body weight as a result of the different measurements we made, the formula for gum alignment under 1500 g body weight was found to be 4.93+0.002 (body weight).

Tatwavedi et al.,[11] in their study evaluating infants with a mean gestational age and weight of 31 weeks and 1300 g, respectively, demonstrated that weight remains the best determinant of ETT length. However, in subgroup analyses, it was observed that in low birth weight infants, weight tends to overestimate the length. In the subgroup analysis of the cases in our study, we demonstrated that the tube should be positioned further back in <1500 g infants, as we identified values of 4.93+0.002 (body weight) for those <1500 g and 6.32+0.001(body weight) for ≥1500 g for the ETT tip–gum measurement. In our study, due to the insufficient number of patients weighing <750 g, subgroup analysis could only be conducted for those weighing <1500 g. Although the results were not identical, similar findings were obtained for the ETT–lip distance.

The lip is a mobile structure, and it can lead to incorrect assessments due to edema or anomalies. In pediatric and adult patients, teeth are often used to assess the position of the ETT.[14] Considering this approach, Zaytseva and her colleagues used the gum as a stable marker in newborns in their study[1] to reduce complications caused by incorrect ETT placement. When they conducted ETT–gum measurements, they identified the formulas "5+weight (kg)" or "5.5+weight (kg)" for ETT depth. They demonstrated that in achieving the optimal tube position, the gum was a superior reference point to the "6+weight (kg)" value, which is based on the ETT–lip distance. They concluded that the gum, being a stable structure, may be more reliable than the lip.[1] The reason for using the gum as a reference point in our study was that in very small premature infants who require precise adjustments, the gum is a more stable structure compared to the lips when determining the target ETT depth.

CONCLUSION

Malposition of the ETT remains a common occurrence in newborns after intubation. In the neonatal intensive care unit, the primary goal should be to ensure the stability of the ETT rather than frequently relying on CXR to determine tube position in monitored patients. Moreover, while various formulas have been suggested for estimating the optimal ETT depth, it is essential to consider that the accuracy of these formulas tends to decrease as the degree of prematurity increases. Hence, there is a need for customized formulas to determine the optimal tube depth in very small premature infants. In this study, we identified formulas that can be used for infants born weighing <1500g, demonstrating that the gum, being a stable structure, is a reliable reference point for predicting ETT depth.

Statement

Ethics Committee Approval: The Istanbul Health Sciences University Umraniye Training and Research Hospital Clinical Research Ethics Committee granted approval for this study (date: 24.11.2022, number: B.10.1.TKH.4.34.H.GP.0.01/367).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Conflict of Interest: The authors have no conflict of interest to declare.

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