The Oro-Helical Length Accurately Predicts Endotracheal Tube Insertion Depth in Neonates

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We evaluated the reliability of the oro-helical length in predicting the ideal endotracheal tube depth in neonates and found the oro-helical length was a consistently more reliable and better predictor of the ideal endotracheal tube depth on chest radiograph than the 7-8-9 rule, especially in infants weighing ≤1500 g. *(J Pediatr 2018;200:265-9).*

Endotracheal tube (ETT) malposition is common, especially in very low birth weight infants. Insufficient ventilation, pneumothorax, laryngeal trauma, atelectasis, or even death can result from ETT malposition.[1,2] To minimize these complications in neonates, the ideal position for the tip of an inserted ETT should be between the upper border of the first thoracic vertebra (T1) and the lower border of the second thoracic vertebra (T2).[3,4]

The 7-8-9 rule described by Tochen, which adds 6 cm to the infant's weight in kilograms, is the most commonly used method of ETT depth determination in neonates and was recommended by the sixth edition of the Neonatal Resuscitation Program (NRP).[5,6] Several methods have been used to determine the ideal location of the inserted ETT tip to overcome the inaccuracy of the 7-8-9 rule in neonates weighing <1500 g.[1,7-9] The seventh edition of the NRP[10] recommended 2 methods: the nasal tragus length (NTL) formula (distance in centimeters from nasal septum to ear tragus plus 1 cm)[11] or gestational age-based table.[7] Despite these recommendations, some clinicians still use the 7-8-9 rule. Wang et al found significant variation in the ideal ETT depth and NTL in the Asian population.[12] As a result, they recommended modifications to NTL in Asian infants based on weight: NTL + 1 cm for infants weighing ≤2500 g and NTL + 0.5 cm for infants weighing >2500 g.[12] Flinn et al, in a randomized study, did not note any significant difference in ETT malposition between the 7-8-9 rule and the gestational age-based guideline.[13] Recently, the 7-8-9 rule was found to correctly position the ETT by a slight margin when compared with the vocal cord guide in estimating the optimal ETT insertion depth (44% vs 40%).[14]

In this prospective study, we describe a novel technique that targets positioning of the ETT tip in the T1-T2 vertebral area on the chest radiograph called the oro-helical length (OHL). The OHL length is the distance in centimeters from the angles of the mouth to the ipsilateral helix tubercle of the ear on either side of the face (**Figure 1**, A; available at www.jpeds.com). By comparing the predicted insertion depths using the OHL method and the 7-8-9 rule with the ideal ETT location at T1-T2 vertebrae on a chest radiograph, we hypothesized that the OHL is a more reliable and better predictor of the ideal ETT depth in neonates, especially in those weighing ≤1500 g.

ETT	Endotracheal tube
NRP	Neonatal Resuscitation Program
NTL	Nasal tragus length
OHL	Oro-helical length

Methods

This was a prospective, observational study approved by the Institutional Review Board and conducted from April 2015 through August 2016 at Stony Brook Children's Hospital (Stony Brook, New York), a level IIIC Neonatal Intensive Care Unit. All the parents/guardians of eligible orally intubated patients gave written informed consent prior to enrollment in the study. Infants with craniofacial, vertebral anomalies or those whose parents declined consent were excluded from the study.

Infants were intubated at the discretion of the primary care team, and the standard intubation guidelines according to the NRP were followed. Chest radiographs were taken with the infant's head in a neutral position per standard unit practice, and the inserted ETT depths were adjusted to acceptable locations as per the reading by the pediatric radiologist who was unaware of the infants' involvement in the study. The ETTs were secured using a Neo-Bar (Neotech Products, Valencia, California) in midline position with identifiable insertion depth at the upper lip.

Using the postintubation chest radiograph, we compared 3 insertion depths with the ideal ETT depth: the 7-8-9 rule depth, the left OHL depth, and the right OHL depth. The ideal ETT depth was defined as the area between the first and second thoracic vertebrae as seen on a chest radiograph. The 7-8-9 rule estimated depth was calculated using the weight at intubation. The OHL depth was measured on the right and left side of each enrolled neonate using a measuring tape marked in centimeters by 2 independent medical providers who were blinded to the 7-8-9 rule position, ideal ETT depth, and each

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other. ETT depth malposition was defined as any predicted measurement (OHL or 7-8-9 rule) ≥0.5 cm above upper border of T1 or below lower border of T2 on the chest radiograph. Maternal and neonatal demographic data were extracted from the electronic medical records.

All enrolled patients were placed into 2 groups based on their weight at intubation: ≤1500 g and >1500 g. A subgroup analysis was performed for neonates weighing ≤1000 g because of the reported discrepancies using the 7-8-9 rule.

Study Outcomes

The primary outcome measure was the difference between the predicted ETT insertion depth (right OHL, left OHL, and the 7-8-9 rule depth) and the ideal ETT depth. We evaluated the following secondary outcomes: the proportion of ETTs in abnormal position for each of the 3 insertion depth prediction methods, as well as the correlations to the gestational age and weight by the predicted ETT lengths and ideal ETT depth.

Statistical Analyses

We estimated that 75 infants were needed for the study to detect a difference of ≥0.4 cm between the ideal ETT depth and the OHL predicted depths with a confidence level of 95%, and power of 90%. Data were analyzed with SAS v9.4 (SAS Institute, Cary, North Carolina), and the significance level was set at $P < .05$. The mean and standard deviations were calculated for the 3 ETT depths relative to the ideal ETT depth. The relationship between the estimated insertion depths and ideal ETT depth were evaluated using a linear mixed model with post hoc pairwise *t* test. *P* values were adjusted by Bonferroni method.

Results

During the study period, 97 intubated neonates were assessed for eligibility, and 75 were enrolled (**Figure 1**, B). The demographic data of the groups are summarized in **Table I**. After the evaluation of baseline characteristics, no significant effect of sex, mode of delivery, or race was seen on any of the methods of ETT depth prediction (**Table I**).

All Infants

We found no differences between the ideal ETT depth and the right and left OHL depths or the 7-8-9 rule depth when we analyzed all 75 babies in the study together. Compared to the ideal ETT depth, there was an overall mean difference of 0.4 cm using the 7-8-9 rule method, but 0.01 cm and 0.04 cm for the right and left OHL, respectively ($P > .05$; 95% CI, –0.99 to 0.19; $P > .05$; 95% CI, –0.6 to 0.6; $P > .05$; 95% CI, –0.6 to 0.6; **Figure 2**, A; available at www.jpeds.com). Nevertheless, the proportion of ETT depth malposition was 41% (31 of 75) when predicted using the 7-8-9 rule and 11% (8 of 75) when predicted using either the right or the left OHL (**Table II**; available at www.jpeds.com).

Infants ≤1500 Grams

We found no difference between the ideal ETT depth and the OHL depths: 0.03 cm and 0.01 cm on the right and left side respectively ($P > .05$ [95% CI, –0.51 to 0.45]; $P > .05$ [95% CI, –0.49 to 0.47]; **Figure 2**, B). There was no difference between the right and left OHL measurements ($P > .60$). However, the 7-8-9 rule estimated ETT insertion depth was significantly different from the ideal ETT depth. The mean difference was 0.76 cm deeper than the lower border of T2 ($P < .001$; 95% CI, –1.2 to –0.28). The proportion of ETT depth malposition was 65% (20 of 31) for the 7-8-9 rule vs 13% (4 of 31) and 10% (3 of 31) for the right and left OHL, respectively (**Table II**). With subgroup analysis of the infants ≤1000 g birth weight, the differences were magnified. There were no significant differences between the ideal ETT depth and the OHL depths. The mean insertion depth differences were 0.0 cm and 0.07 cm on the right and left, respectively ($P > .05$ [95% CI, –0.57 to 0.57], $P > .05$ [95% CI, –0.50 to 0.64]; **Figure 2**, B). Also, the right and the left measured OHL were not different ($P > .60$). Moreover, the mean ETT insertion depth difference predicted by the 7-8-9 rule was 0.97 cm below the lower border of T2 and was statistically significant ($P < .001$; 95%

Table I. Characteristics of the enrolled infants

Variables	Weight ≤1000 g (n = 16)	Weight ≤1500 g (n = 31)	Weight >1500 g (n = 44)	Total (n = 75)	Right OHL *P* value*	Left OHL *P* value*	7-8-9 *P* value*
Weight, kg	0.75 (0.47-1)	1.0 (0.47-1.44)	2.82 (1.58-4.32)	2.07 (0.47-4.32)	.79	.47	<.001
Gestation, wk	28 (23.4-33.4)	31 (23.4-35.7)	37.1 (31.3-42)	35.4 (23.2-42)			
Weight classification, %	56 AGA	68 AGA	68 AGA	68 AGA			
	44 SGA	29 SGA	23 SGA	25 SGA			
	0 LGA	3 LGA	9 LGA	7 LGA			
Male sex, %	56	42	57	51	.25	.58	.95
Delivery, cesarean, %	81	81	59	68	.70	.73	.83
Race, %					.40	.73	.43
White	50	61	45	52			
Black	31	23	14	16			
Hispanic	19	10	23	16			
Asian	0	0	7	4			
Other	0	6	11	12			

AGA, Appropriate for gestational age; *LGA*, large for gestational age; *SGA*, small for gestational age.
Data were medians (IQR) or (%).
Weight was significant different when the ETT insertion depth predicted by the 7-8-9 method was compared with the OHL method ($P < .001$).
**P* values were from linear mixed models comparing insertion depths of right OHL, left OHL and 7-8-9 method with weight, sex, mode of delivery, and race.