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ORIGINAL ARTICLE

Accuracy of the 7-8-9 Rule for endotracheal tube placement in the neonate

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Objective: To determine accuracy of the 7-8-9 Rule in a cohort of neonates.

Study Design: This study was cross-sectional in design. Seventy-five consecutive neonates who required oral intubation from June 2004 to November 2004 for cardiopulmonary failure, respiratory distress, or surfactant administration were the subjects of this study. The initial endotracheal tube (ETT) depth of insertion was determined using either an estimated birth weight or actual weight in the 7-8-9 Rule calculation followed by auscultation and subsequent adjustment if necessary. Midtracheal position was identified as the point halfway between the inferior clavicle and carina on a chest radiograph. The initial depth was compared to the midtracheal depth to determine clinical accuracy of the 7-8-9 Rule. The depth predicted by the 7-8-9 Rule was also calculated using only actual weights. This predicted depth was compared to the midtracheal depth to determine true accuracy of the 7-8-9 Rule. Accuracy was determined using mean paired differences with 95% confidence intervals (CI) between initial or predicted depth and ideal, midtracheal ETT depth. Linear regression was used to adjust for confounding variables.

Results: Mean (range) gestational age was 32 weeks (23 to 44 weeks) and weight was 2001 g (490 to 4400 g). Eighteen (24%) infants weighed 1000 g or less, 20 (27%) weighed between 1001 and 2000 g, 21 (28%) weighed between 2001 and 3000 g, 15 (20%) weighed between 3001 and 4000 g, and one (1%) weighed more than 4000 g. Thirteen of the 18 extremely low birth weight infants weighed <750 g. The initial depth of insertion was 0.004 cm above midtracheal position (95% CI −0.13 to 0.14, $P = 0.96$). After controlling for head position, the initial depth did not significantly differ from the midtracheal position among weight groups. Predicted depth using the 7-8-9 Rule placed the ETT 0.12 cm above midtracheal position (95% CI −0.30 to 0.06, $P = 0.20$). However, after controlling for head position, the 7-8-9 Rule positioned the ETT significantly below midtracheal position in infants weighing <750 g (mean 0.62 cm; 95% CI 0.30 to 0.93, $P = 0.002$).

Conclusions: The 7-8-9 Rule appears to be an accurate clinical method for endotracheal tube placement in neonates weighing more than 750 g. When the 7-8-9 Rule is applied to infants weighing <750 g, caution is warranted. The current rule may lead to an overestimated depth of insertion and potentially result in clinically significant consequences. *Journal of Perinatology* (2006) **26,** 333–336. doi:10.1038/sj.jp.7211503; published online 27 April 2006

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Introduction

Indications for neonatal intubation include cardiopulmonary resuscitation, hypoxemia, hypercapnea, administration of surfactant or airway protection.[1] When correctly placed, the tip of the endotracheal tube (ETT) should be positioned in the midtracheal region, or halfway between the clavicles and the carina.[1,2] ETT position must be precise to reduce the incidence of complications including: atelectasis, hyperinflation of the right lung, pneumothorax, tracheal damage, unplanned extubation or postextubation stridor.[3,4]

In 1979, Tochen originally described a simple calculation for determining the depth of ETT insertion.[5] The prediction equation for the estimated depth of insertion was 1.17 multiplied by the infant's weight (in kg) plus 5.58. This translated into an infant weighing 1 kg being intubated to a depth of 7 cm, a 2 kg infant to a depth of 8 cm, and a 3 kg infant to a depth of 9 cm.[5] The popularized '7-8-9 Rule' was, and continues to be, endorsed by The American Academy of Pediatrics/American Heart Association Textbook of Neonatal Resuscitation. Simply, it adds 6 cm to the infant's weight (i.e. 1 kg + 6 = 7 cm) to estimate the depth of ETT insertion.[6]

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Although this rule is widely used in neonatal resuscitation, data regarding its accuracy are lacking in the literature. Since the 1970s, more extremely low birth weight infants are being resuscitated and admitted to neonatal intensive care units (NICU).[7] As a result, smaller infants are requiring intubation for mechanical ventilation. Tochen's original regression model included infants admitted to a single NICU from 1975 to 1976 with birth weights ranging from 700 to 4100 g. Ten of the 40 patients (25%) had a birth weight of 1 kg or less, but none weighed <700 g. Predictions based on linear regression are most stable when observations near the middle of the distribution are used; hence it is risky to extrapolate beyond the range of actual data.[8]

Additionally, situations frequently arise in the delivery room or NICU where intubations are necessary but the weight of the infant must be estimated. Since the 7-8-9 Rule requires knowledge of an infant's weight prior to intubation, accuracy of this rule in the clinical setting is unknown. Therefore, the objective of this study was to determine the accuracy of the 7-8-9 Rule using a cohort of neonates including those with extremely low birth weight.

Material and methods

Institutional Review Board approval was obtained prior to this study. Informed consent was not required since the protocol did not involve greater than minimal risk to the patient. This study was cross-sectional in design. Seventy-five consecutive neonates who required oral intubation following resuscitation in the delivery room or a tertiary level NICU from June 2004 to November 2004 were the subjects in this study. All infants were intubated for cardiopulmonary failure, respiratory distress or surfactant administration. Any infant who was previously intubated or had a congenital anomaly was excluded. The intubation was performed by a supervised pediatric resident, neonatal fellow, or neonatal nurse practitioner and was in accordance with the guidelines established by the Neonatal Resuscitation Program.[1] Only fellows and nurse practitioners intubated infants <1000 g. Initial depth of ETT insertion was clinically determined using the 7-8-9 Rule and auscultation. The weight used in this depth was either an estimated birth weight for infants intubated emergently in the delivery room or an actual infant weight obtained within the last 24 h for infants that required intubation once admitted to the NICU. One of two experienced respiratory therapists auscultated and secured the ETT. The ETT depth, using the upper lip as the reference point, was recorded using the whole centimeter markings on the ETT.

A portable chest radiograph with digitalized measurements was obtained to document ETT position. Head position at the time of the radiograph was recorded as neutral, to the right, or to the left. A respiratory therapist measured two distances on the radiograph: the distance from the ETT tip to the inferior portion of the clavicle (Figure 1A); and the distance from the ETT tip to the carina (Figure 1B). Ideal placement of the ETT was defined as the tip of the ETT lying at the midtrachea. This position was defined *a priori* as the point halfway between the inferior portion of the clavicle and carina (Figure 1C and D). Ideal, midtracheal ETT depth was calculated as the difference between the initial ETT depth and the midtracheal position (Figure 1E). Predicted, 7-8-9 Rule ETT depth was calculated by taking the infant's actual weight on either admission or within the last 24 h and adding 6 cm.

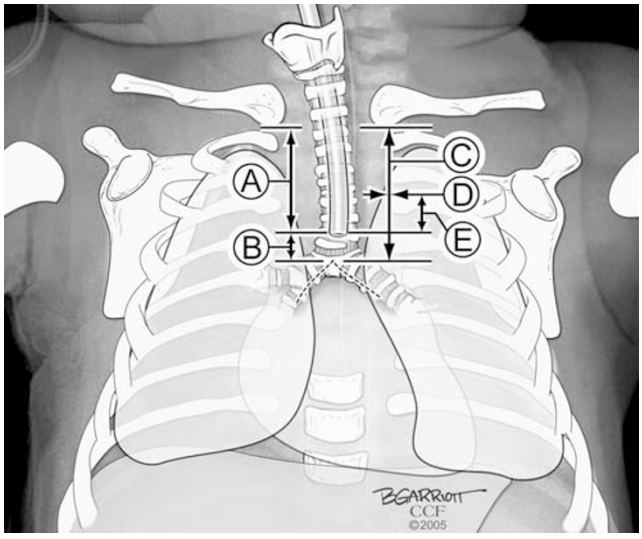

Figure 1 Measured and calculated distances obtained from a sample chest radiograph following endotracheal intubation. Measured distances included: the tip of the endotracheal tube (ETT) to the inferior portion of the clavicle (**A**) and the tip of the ETT to the carina (**B**). Calculated distances included: the inferior portion of the clavicle to the carina (**C**), the midtracheal position (**D**), and error between initial vs ideal ETT positions (**E**).

The initial ETT depth and the predicted ETT depth were compared to the ideal ETT depth. This allowed us to determine the accuracy of the 7-8-9 Rule in a more practical clinical setting (i.e. where an infant's weight may or may not be available and the ETT may be adjusted after auscultation) versus using the 7-8-9 Rule prediction equation alone (i.e. where the infant's actual weight was known prior to intubation). Measurements were recorded in centimeters. All radiographs were interpreted by the respiratory therapists. Since the respiratory therapists assisted with the intubation, they were not blinded to ETT insertion depth.

Infants were placed into weight groups of <1000, 1001 to 2000, 2001 to 3000, 3001 to 4000 and >4000 g. These categories were chosen based on the weight categories used for appropriate selection of ETT size.[1] We also divided the <1000 g weight group into a subgroup of <750 g to specifically evaluate the most extremely low birth weight neonates. This was of particular interest since Tochen's original cohort did not include patients with weights <700 g.

Accuracy was determined using mean paired differences with 95% confidence intervals (CI) between initial or predicted ETT

depths and ideal ETT depth. Linear regression was used to adjust for confounding variables. All tests were two-tailed and $P<0.05$ was considered statistically significant. Statistics were performed using JMP 5.1 (SAS Corp., Cary, NC).

Results

Mean (range) gestational age for the 75 infants was 32 weeks (23 to 44 weeks) and weight was 2001 g (490 to 4400 g). Eighteen (24%) infants weighed 1000 g or less, 20 (27%) weighed between 1001 and 2000 g, 21 (28%) weighed between 2001 and 3000 g, 15 (20%) weighed between 3001 and 4000 g and one (1%) weighed more than 4000 g. Thirteen of the 18 extremely low birth weight infants weighed <750 g. Infants weighing <750 grams were significantly more likely to have their head positioned to the left at the time of the chest radiograph compared to infants weighing more than 750 g (30 vs 3%, $P=0.004$).

The overall accuracy of the 7-8-9 Rule in a clinical setting with auscultation and ETT adjustment gave an initial ETT depth 0.004 cm above midtracheal position (95% CI −0.13 to 0.14, $P=0.96$). After controlling for head position, the initial ETT depth did not significantly differ from the midtracheal position among the weight groups.

Using the 7-8-9 Rule with the infant's actual weight placed the predicted ETT depth 0.12 cm above midtracheal position (95% CI −0.30 to 0.06, $P=0.20$). After controlling for head position, the 7-8-9 Rule positioned the ETT significantly below the midtracheal position in infants weighing <750 g (mean 0.62 cm; 95% CI 0.30 to 0.93, $P=0.002$). We were unable to show a difference between predicted ETT depth and midtracheal position for infants in the remaining weight groups (Table 1).

Table 1 Distance between predicted endotracheal tube depth using the 7-8-9 Rule and ideal endotracheal tube depth based on midtracheal position by weight group

Weight (g)	*Number of infants (%)*	*Distance (cm) (95% CI) from midtrachea*[a]	P-*value*
<750	13 (17)	0.62 (0.30−0.93)	0.002
750−1000	5 (7)	−0.47 (−1.2 to 0.24)	0.61
1001−2000	20 (27)	−0.18 (−0.46 to 0.10)	0.74
2001−3000	21 (28)	−0.41 (−0.70 to 0.11)	0.39
3001−4000	15 (20)	−0.12 (−0.73 to 0.48)	0.63
>4000	1 (1)	−0.85	—

[a]Values were determined using mean paired differences after controlling for head position. A positive value is below and a negative value is above the midtracheal position.

Discussion

Various studies have proposed different techniques for determining the appropriate depth of ETT insertion. Lee *et al*.[9] found that flexible fiberoptic bronchoscopy correlated well with the chest radiograph and required less time to confirm ETT position in pediatric and neonatal patients. A mathematical algorithm, developed by Lange *et al*.,[10] used head position in 24 preterm neonates to verify ETT position without chest radiography confirmation. Most recently, Jain *et al*.[11] reported that digital palpation on the ETT tip in the suprasternal notch was a safe and teachable method of confirming ETT position in neonates.

Despite these alternative methods, the neonatal resuscitation program continues to use the 7-8-9 Rule to determine ETT depth of insertion. The rule is easy to use, safe, inexpensive and effective. This study provides additional evidence that the 7-8-9 Rule is an accurate method for endotracheal tube placement in most neonates. This accuracy appears to improve following auscultation and adjustment, when necessary.

However, the 7-8-9 Rule appears to inaccurately position the ETT between 0.30 and 0.93 cm too deep in infants weighing <750 g. This inaccuracy is concerning and may have several consequences. Inaccurate ETT placement may increase the infant's risk for pneumothorax and subsequent intraventricular hemorrhage.[12,13] Secondly, surfactant is often given prophylactically in the delivery room prior to radiographic confirmation of the ETT position. If the ETT is positioned too deep, right mainstem bronchus intubation may occur and surfactant may be preferentially given to the right lung.

A revision of the 7-8-9 Rule for the extremely low birth weight neonate may be justified. We recommend placing the ETT in these patients at a depth at least 0.5 cm higher than the depth currently recommended by the 7-8-9 Rule. This technique adjustment is also supported in the Neonatal Resuscitation Textbook which states, 'Babies weighing <750 g may require only 6 cm insertion.'[1] A prospective study examining the accuracy of this revised equation for ETT insertion depth in infants weighing <750 g is warranted. Furthermore, current manufactured tubes have only whole centimeter markings that make adjustments of <1 cm challenging. Manufacturing a neonatal ETT with $\frac{1}{2}$ cm markings may aid in more accurate placement.

The strengths of this study include a larger sample size and a group of infants weighing <700 g. We chose to estimate our error of intubation by using a fixed midtracheal position rather than a range. Tochen defined midtracheal depth at the level of the first or second thoracic vertebral body. Using a fixed point rather than a range of distances to define midtracheal position allowed us to obtain a more accurate estimate of placement. Although this may be statistically significant, it may not be clinically meaningful. Finally, our study examined the use of the 7-8-9 Rule as it is most often applied in clinical practice. This allows for a more generalizable estimate of accuracy of the rule.

Weaknesses are that the ETT depth was not reconfirmed prior to the chest radiograph. The ETT was secured and the depth was

recorded following intubation. It is possible that the ETT position may have changed if a significant delay occurred between the recording of ETT depth and the time of the radiograph. Additionally, we did not record whether the chin position was up or down. Endotracheal tube depths may be deeper or higher if the chin was up or down, respectively. Although our respiratory therapists were qualified, a radiologist did not verify the therapists' measurements. This may have been a useful way to assess interobserver reliability in midtracheal placement. Finally, the qualities of the films were not standardized and a chest radiograph that was poor in quality may have resulted in inaccurate measurements.

The 7-8-9 Rule appears to be an accurate clinical method for endotracheal tube placement in neonates weighing more than 750 g. When the 7-8-9 Rule is applied to infants weighing <750 g, caution is warranted. The current rule may lead to an overestimated depth of insertion and potentially result in clinically significant consequences.

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