Endotracheal Tube Size Adjustments Within Seven Days of Neonatal Intubation

Patrick J. Peebles, MD,[a,b] Erik A. Jensen, MD, MSCE,[a] Heidi M. Herrick, MD, MSCE,[a] Paul J. Wildenhain, BA,[a] Jennifer Rumpel, MD,[c] Ahmed Moussa, MD, MMEd,[d] Neetu Singh, MD, MPH,[e] Ayman Abou Mehrem, MD, MSc,[f] Bin Huey Quek, MRCP,[g] Michael Wagner, MD, PhD,[h] Nicole R. Pouppirt, MD,[i] Kristen M. Glass, MD,[j] David G. Tingay, MD, FRACP, PhD,[k] Kate A. Hodgson, MB, BS,[l] Joyce E. O'Shea, MD, MBBChBAO,[m] Taylor Sawyer, DO, MBA, MEd,[n] Brianna K. Brei, MD,[o] Philipp Jung, MD,[p] Jennifer Unrau, MD,[q] Jae H. Kim, MD, PhD,[r] James Barry, MD,[s] Stephen DeMeo, DO, MEd,[t] Lindsay C. Johnston, MD, MEd,[u] Akira Nishisaki, MD, MSCE,[a] Elizabeth E. Foglia, MD, MSCE[a]

abstract

BACKGROUND AND OBJECTIVES: Neonatal endotracheal tube (ETT) size recommendations are based on limited evidence. We sought to determine data-driven weight-based ETT sizes for infants undergoing tracheal intubation and to compare these with Neonatal Resuscitation Program (NRP) recommendations.

METHODS: Retrospective multicenter cohort study from an international airway registry. We evaluated ETT size changes (downsizing to a smaller ETT during the procedure or upsizing to a larger ETT within 7 days) and risk of procedural adverse outcomes associated with first-attempt ETT size selection when stratifying the cohort into 200 g subgroups.

RESULTS: Of 7293 intubations assessed, the initial ETT was downsized in 5.0% of encounters and upsized within 7 days in 1.5%. ETT downsizing was most common when NRP-recommended sizes were attempted in the following weight subgroups: 1000 to 1199 g with a 3.0 mm (12.6%) and 2000 to 2199 g with a 3.5 mm (17.1%). For infants in these 2 weight subgroups, selection of ETTs 0.5 mm smaller than NRP recommendations was independently associated with lower odds of adverse outcomes compared with NRP-recommended sizes. Among infants weighing 1000 to 1199 g: any tracheal intubation associated event, 20.8% with 2.5 mm versus 21.9% with 3.0 mm (adjusted OR [aOR] 0.62, 95% confidence interval [CI] 0.41–0.94); severe oxygen desaturation, 35.2% with 2.5 mm vs 52.9% with 3.0 mm (aOR 0.53, 95% CI 0.38–0.75). Among infants weighing 2000 to 2199 g: severe oxygen desaturation, 41% with 3.0 mm versus 56% with 3.5mm (aOR 0.55, 95% CI 0.34–0.89).

CONCLUSIONS: For infants weighing 1000 to 1199 g and 2000 to 2199 g, the recommended ETT size was frequently downsized during the procedure, whereas 0.5 mm smaller ETT sizes were associated with fewer adverse events and were rarely upsized.

[a]*Children's Hospital of Philadelphia, Philadelphia, Pennsylvania;* [b]*University of Wisconsin School of Medicine and Public Health, Madison, Wisconsin;* [c]*Univeristy of Arkansas for Medical Sciences, Little Rock, Arkansas;* [d]*Centre Hospitalier Universitaire Sainte-Justine, Université de Montréal, Montréal, Canada;* [e]*Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire;* [f]*Foothills Medical Centre, Alberta, Canada;* [g]*KK Women's and Children's Hospital, Singapore;* [h]*Medical University of Vienna, Vienna, Austria;* [i]*Lurie Children's Hospital, Chicago, Illinois;* [j]*Penn State Health Children's Hospital, Hershey, Pennsylvania;* [k]*Neonatal Research, Murdoch Children's Research Institute, Melbourne, Australia; Royal Children's, Melbourne, Australia; Department of Paediatrics, University of Melbourne, Australia;* [l]*Royal Women's Hospital, Melbourne, Australia;* [m]*Royal Hospital for Children, Glasgow, United Kingdom;* [n]*Seattle Children's Hospital, Seattle, Washington;* [o]*University of Nebraska Medical Center, Omaha, Nebraska;* [p]*University Hospital Schleswig Holstein, Campus Lübeck, Lübeck, Germany;* [q]*Alberta Children's Hospital, University of Calgary, Alberta, Canada;* [r]*Perinatal Institute, Department of Pediatrics, Cincinnati Children's Hospital Medical Center, University of Cincinnati College of Medicine, Cincinnati, Ohio;* [s]*University of Colorado School of Medicine, Aurora, Colorado;* [t]*WakeMed Health, Raleigh, North Carolina; and* [u]*Yale University School of Medicine, New Haven, Connecticut*

WHAT'S KNOWN ON THIS SUBJECT: The Neonatal Resuscitation Program recommends endotracheal tube size (ETT) selection for neonatal intubation using the following weight-based ranges: <1 kg, 2.5 mm ETT; 1 to 2 kg, 3.0 mm ETT; >2 kg, 3.5 mm ETT. Whether these ranges result in optimal patient outcomes is uncertain.

WHAT THIS STUDY ADDS: In specific subgroups, Neonatal Resuscitation Program-recommended ETT sizes were commonly downsized during intubation, whereas smaller ETTs were associated with improved procedural safety and were rarely upsized after intubation. Study results may inform ETT size recommendations for neonatal intubation.

To cite: Peebles PJ, Jensen EA, Herrick HM, et al. Endotracheal Tube Size Adjustments Within Seven Days of Neonatal Intubation. *Pediatrics.* 2024;153(4):e2023062925

Downloaded from http://publications.aap.org/pediatrics/article-pdf/153/4/e2023062925/1615195/peds.2023-062925.pdf
by Children's Hospital of Philadelphia, Elizabeth Foglia

Tracheal intubation (TI) is an essential procedure for critically ill infants that is frequently performed to treat infants with respiratory failure, to administer surfactant, and to support patient safety and comfort during invasive procedures. TI is especially common among premature infants.[1]

Choice of endotracheal tube (ETT) size in infants must balance the need to facilitate adequate oxygenation and ventilation during mechanical ventilation but minimize the risk of trauma to the airway. ETTs that are sized too small may predispose to airway leak around the ETT, incorrect ventilator measurements, ventilator autotriggering, and higher ETT resistance.[2–5] ETTs that are sized too large increase the risk for direct airway injury, intubation procedural failure, and potential for long-term damage to the airway such as subglottic stenosis.[6,7] Despite the importance of appropriate ETT size selection, there are limited data available to inform best practice in infants.[8–10]

The Neonatal Resuscitation Program (NRP) provides the following recommendations for endotracheal tube sizes based on patient weight: 2.5 mm (internal diameter) for infants weighing <1000 g, 3.0 mm for infants weighing 1000 to 2000 g, and 3.5 mm for infants weighing >2000 g.[11] However, these guidelines are based upon expert consensus, and other guidelines recommend different weight cutpoints for ETT size selection.[7,12–14] Our study objectives were to determine data-driven weight-based ETT size thresholds for infants undergoing TI and to compare these thresholds with NRP recommendations.

METHODS

Setting

This study used registry-based data collected in 21 academic neonatal centers in the United States, Canada, Germany, the United Kingdom, Austria, Singapore, and Australia.

Design

This was a retrospective multicenter cohort study using prospectively collected TI practice and outcome data in the National Emergency Airway Registry for Neonates (NEAR4NEOS).[1] TI data were collected using standardized operational definitions at each participating site and were entered into a centralized online secure database hosted at the Children's Hospital of Philadelphia.[15,16] The institutional review boards at each site approved NEAR4NEOS data collection or deemed data collection exempt as a quality improvement initiative.

Inclusions and Exclusions

The NEAR4NEOS registry organizes TI events into discrete TI encounters. Each TI encounter may include multiple TI attempts if the first attempt is unsuccessful, and the size of ETT for each attempt is recorded. We included infants who had their first TI encounter recorded in the NEAR4NEOS registry between August 2016 and September 2022. Only infants with a first TI encounter performed via the oral or nasal route using exclusively uncuffed ETTs were evaluated. We excluded infants with a first TI encounter performed by a non-neonatology provider (otolaryngology, anesthesia, surgery), infants with a first TI encounter that had an ETT larger than 4.0 mm or missing ETT size data for the first or final attempt, infants with airway or cranial anomalies, and infants with a first TI encounter that did not lead to the successful placement of an ETT by the final attempt. The successful placement of an ETT during the first encounter was necessary to determine the outcome measures of downsizing and upsizing.

Exposure and Outcome Measures

The ETT size used for the first attempt of the first TI encounter was categorized according to the patient's weight at the time of TI recorded in the NEAR4NEOS registry. Downsizing of the ETT was defined as a TI encounter in which the final successful TI attempt was completed using a smaller ETT than was selected for the first attempt. Upsizing was defined as a subsequent TI encounter that occurred within 7 days and concluded with the placement of a larger ETT than was placed at the end of the first TI encounter captured in the NEAR4NEOS registry. A frequency of upsizing or downsizing >10% for a particular ETT size within individual 200 g weight subgroups was a priori defined as suboptimal based on investigator consensus.

Our primary outcome was any TI associated event (TIAE), and the secondary outcome was severe oxygen desaturation, following NEAR4NEOS operational definitions.[1] TIAEs occurred during the intubation or up to 20 minutes afterward; TIAEs were not the indication for the intubation. Multiple TIAEs could occur during an intubation; however, this would only be counted once for the composite outcome of "any TIAE." TIAEs were further classified as severe and nonsevere per NEAR4NEOS; we examined severe TIAEs and nonsevere TIAEs as exploratory outcomes. Severe TIAEs were defined as any of the following: cardiac arrest, esophageal intubation with delayed recognition, hypotension requiring therapy, cardiac compressions <1 minute, laryngospasm, vomit with aspiration, gum or dental trauma, pneumothorax and/or pneumomediastinum, and direct airway injury. Nonsevere TIAEs were defined as any of the following: esophageal intubation with immediate recognition, dysrhythmia (including any duration of bradycardia <60 beats per minute without chest compressions performed), medication error, mainstem bronchial intubation, vomit without aspiration, hypertension requiring therapy, pain and/or agitation requiring additional medications causing a delay in intubation, epistaxis, and lip trauma. Severe oxygen desaturation was defined as ≥20% decrease in the oxygen saturation from the highest oxygen saturation

Downloaded from http://publications.aap.org/pediatrics/article-pdf/153/4/e2023062925/1615195/peds.2023-062925.pdf
by Children's Hospital of Philadelphia, Elizabeth Foglia

immediately before the first TI attempt to the lowest saturation during the procedure.

STATISTICAL ANALYSIS

Patient characteristics and intubation practice measures were summarized using standard descriptive statistics. We used Wilcoxon Rank Sum tests and χ-square tests to compare patient characteristics, intubation characteristics, and procedural adverse outcomes between TI encounters where the ETT size selected did or did not adhere to NRP recommendations. To examine the relationship between ETT size and the study outcomes, we stratified the cohort into 200 g weight subgroups. The frequency of ETT downsizing and upsizing were reported for the 2 most frequently selected ETT sizes in each weight subgroup. We analyzed the association between downsizing and procedural adverse outcomes for the entire cohort using χ-squared tests.

Within patient weight subgroups, we compared procedural adverse outcome rates between the 2 most common ETT sizes selected for the first attempt. We used logistic regression to evaluate the independent association between ETT size and any TIAE, and severe oxygen desaturation, nonsevere TIAEs, and severe TIAEs, controlling for variables that have previously been shown to be associated with decreased risk of adverse events during intubation (use of a paralytic medication, video laryngoscope, and first airway provider).[1,17–19] Location of intubation (delivery room versus NICU) was not included in the model, as this is not associated with differences in procedural outcomes.[20] A sensitivity analysis was performed to evaluate whether the TI route (oral versus nasal) impacted the results of the logistic regression model. A robust sandwich variance estimator was used to calculate standard errors in all regression models to account for clustering by site. A P value $< .05$ was considered statistically significant. Statistical analyses were performed using Stata 17.0 (Stata Corp, College Station, TX).

RESULTS

A total of 8653 unique patients representing 21 centers that participate in the NEAR4NEOS registry were intubated during the study period, and 7293 patients were eligible for inclusion in the study cohort (Supplemental Fig 3). The ETT size for the first TI attempt was consistent with NRP recommendations in 5752 (78.9%) of these. Site level adherence with NRP recommendations for the first ETT size ranged from 46% to 100% (Supplemental Fig 4). Many patient and practice characteristics varied between TIs based on adherence with NRP recommendations for the first ETT size as shown in Table 1, but procedural outcomes did not differ between these groups in aggregate (Table 2).

For many 200 g weight subgroups examined, the first ETT size selected varied substantially (Fig 1). This variability was most pronounced in the weight subgroups of 1000 to 1199 g and 2000 to 2199 g, both of which are immediately above the NRP recommended threshold cutpoints of 1000 g and 2000 g. Clinicians selected an initial ETT size of 2.5 mm (NRP recommends a 3.0 mm) in 260 of 686 (37.9%) infants weighing 1000 to 1199 g and 3.0 mm (NRP recommends a 3.5 mm ETT) in 206 of 329 (62.6%) infants weighing 2000 to 2199 g.

When assessed in the full study cohort, the ETT was downsized from the first selected size in 5.0% of TI encounters and was upsized within 7 days in 1.5% TI encounters. Figure 2 demonstrates the frequency of downsizing and upsizing for the weight subgroups that surround the NRP recommended weight thresholds used to transition between ETT sizes. The rate of ETT downsizing was highest when NRP-recommended ETT sizes were used in weight subgroups that were immediately above NRP-based weight thresholds. The ETT was downsized from a 3.0 mm to a smaller ETT in 53 of 420 (12.6%) infants weighing 1000 to 1190 g and from a 3.5 mm to smaller ETT in 20 of 117 (17.1%) of infants weighing 2000 to 2199 g (Fig 2). Across the cohort, procedural adverse outcomes were more common in TI procedures where downsizing occurred compared with procedures without downsizing: any TIAE (32.9% vs 16.8%, $P < .001$) and severe oxygen desaturation (60.3% vs 40.1%, $P < .001$).

Among infants weighing 1000 to 1199 g, initial use of a 2.5 mm ETT versus the NRP-recommended 3.0 mm ETT was associated with lower adjusted odds of any TIAE (adjusted odds ratio [aOR] 0.62, 95% confidence interval [CI] 0.41–0.94) and severe oxygen desaturation (aOR 0.53, 95% CI 0.38–0.75) (Table 3). In the weight subgroup of 2000 to 2199 g, use of a 3.0 mm ETT versus the NRP-recommended 3.5 mm ETT was associated with lower adjusted odds of severe oxygen desaturation (aOR 0.55, 95% CI 0.34–0.89). Nonsevere TIAEs and severe TIAEs stratified by weight subgroup and initial endotracheal tube size are shown in the Supplemental Table 4. Results were similar in sensitivity analyses including route of intubation (oral versus nasal) in the model (Supplemental Tables 5 and 6).

DISCUSSION

We used a large contemporary multicenter quality improvement research database to identify data-supported weight-based thresholds for ETT size selection in infants undergoing TI. There are several important findings for infants weighing up to 200 g above the current NRP-based thresholds of 1000 g and 2000 g. First, within these weight subgroups, clinicians frequently chose ETTs sized 0.5 mm below NRP recommendations or downsized the ETT below NRP recommendations during the TI encounter. Second, upsizing the ETT within 7 days was uncommon when smaller than NRP-recommended ETT sizes were placed

Downloaded from http://publications.aap.org/pediatrics/article-pdf/153/4/e2023062925/1615195/peds.2023-062925.pdf
by Children's Hospital of Philadelphia, Elizabeth Foglia

TABLE 1 Patient and Intubation Characteristics for the Entire Cohort and According to Adherence With NRP Recommendations for First ETT Size Selected

Characteristic	All, Median [IQR] or *n* (%), (*N* = 7293)	Followed NRP, Median [IQR] or *n* (%), (*N*= 5752)	Did Not Follow NRP, Median [IQR] or *n* (%), (*N* = 1541)	*P*
Birth gestational age (weeks)	30 [26–36]	30 [26–36]	31 [27–35]	.01
Postnatal age (days)	0 [0–2]	0 [0–2]	0 [0–8]	<.001
Birth wt (g)	1378 [810–2548]	1340 [780–2644]	1648 [1000–2405]	<.001
Patient wt (g)	1515 [900–2710]	1460 [840–2800]	2010 [1045–2520]	<.001
Indication for intubation[a]				
Oxygen failure	2049 (28.1)	1606 (27.9)	443 (28.8)	.52
Procedure	459 (6.3)	340 (5.9)	119 (7.7)	.009
Ventilation failure	1520 (20.8)	1163 (20.2)	357 (23.2)	.01
Frequent apnea and bradycardia	908 (12.5)	726 (12.6)	182 (11.8)	.39
Unstable hemodynamics	215 (2.9)	164 (2.9)	51 (3.3)	.35
Surfactant administration	2592 (35.5)	2120 (36.9)	472 (30.6)	<.001
Delivery room – routine practice for diagnosis	263 (3.6)	225 (3.9)	38 (2.5)	.007
Delivery room – clinical indication	2136 (29.3)	1725 (30.0)	411 (26.7)	.01
Reintubation after unplanned extubation	182 (2.5)	140 (2.4)	42 (2.7)	.52
ETT exchange	233 (3.2)	147 (2.6)	86 (5.6)	<.001
Other	324 (4.4)	265 (4.6)	59 (3.8)	.19
Number of tracheal intubation attempts	1 [1–2]	1 [1–2]	1 [1–2]	.31
Airway provider for initial attempt[b]				<.001
Attending neonatologist	533 (7.3)	383 (6.7)	150 (9.7)	
Fellow	2681 (36.8)	2153 (37.5)	528 (34.3)	
NP, PA, or hospitalist	2198 (30.2)	1685 (29.3)	513 (33.3)	
Resident	1236 (17.0)	980 (17.0)	256 (16.6)	
Respiratory therapist	491 (6.7)	422 (7.3)	69 (4.5)	
Other	150 (2.1)	125 (2.2)	25 (1.6)	
Delivery room	2590 (35.5)	2095 (36.4)	495 (32.1)	.002
Oral route of tracheal intubation[c]	6955 (95.4)	5555 (96.6)	1400 (90.9)	<.001
Endotracheal size selected for first attempt				<.001
2.0	56 (0.8)	0	56 (3.6)	
2.5	2313 (31.7)	1914 (33.3)	399 (25.9)	
3.0	2711 (37.2)	1777 (30.9)	934 (60.6)	
3.5	2118 (29.0)	2061 (35.8)	57 (3.7)	
4.0	95 (1.3)	0	95 (6.2)	

The *P* value reflects comparison of the followed NRP versus did not follow NPR groups. IQR, interquartile range; NP, nurse practitioner; PA, physician assistant.
[a] More than 1 indication can be selected. Only indications present in >1% of the population are shown.
[b] Airway provider type not available in 4 intubations.
[c] Route not available in 6 intubations.

in these subgroups. Finally, using an ETT 0.5 mm smaller than the recommended size was independently associated with a reduction in the odds of important procedural adverse outcomes. These findings suggest that for infants weighing up to 200 g above the NRP-based thresholds, use of an ETT that is 0.5 mm smaller than presently recommended may be appropriate.

At present, there is no gold standard to determine the most appropriate ETT size for a given infant. In this study, we used both the frequency of ETT size change (downsizing and upsizing) and procedural adverse outcomes to identify optimal ETT sizes for individual weight subgroups. Downsizing was used as a clinical signal that the airway provider believed a smaller ETT was more appropriate after attempting to place a larger sized tube, presumably because of difficulty passing the ETT into the airway or concern for possible airway injury owing to perceived anatomic size mismatch. Upsizing served as a balancing measure indicating that a smaller ETT was not clinically satisfactory within 7 days after placement. We chose a 7-day interval by investigator consensus, as upsizing within this timeframe was deemed to be most likely attributable to a suboptimal ETT size rather than interval patient growth.

Based on the data collected through NEAR4NEOS, we are unable to ascertain the indication for downsizing or upsizing. However, the fact that the ETT was downsized or upsized, irrespective of the medical reason, serves as a clinically relevant indicator given that current tube size

Downloaded from http://publications.aap.org/pediatrics/article-pdf/153/4/e2023062925/1615195/peds.2023-062925.pdf
by Children's Hospital of Philadelphia, Elizabeth Foglia

TABLE 2 Procedural Adverse Outcomes for the Entire Cohort and According to Adherence With NRP Recommendations for First ETT Size Selected				
Outcome	All, *n* (%), (*N* = 7293)	Followed NRP, *n* (%), (*N* = 5752)	Did Not Follow NRP, *n* (%), (*N* = 1541)	*P*
Any TIAE[a]	1287 (17.6)	1032 (17.9)	255 (16.6)	.20
Severe oxygen desaturation[b]	2627 (41.1)	2099 (41.5)	528 (39.7)	.24
Severe TIAE	268 (3.7)	202 (3.5)	66 (4.3)	.15
Nonsevere TIAE	1124 (15.4)	909 (15.8)	215 (14.0)	.07

The *P* value reflects comparison of the followed NRP versus did not follow NPR groups. TIAE, tracheal intubation associated event.
[a] More than 1 TIAE could occur during a given intubation.
[b] Oxygen saturation data not available for 907 intubations.

guidelines are not evidence-based. Additionally, given the medical implications of ETT size changes (association with procedural adverse outcomes or subjecting the patient to another TI procedure), identifying an ETT size that avoids a size change is important.

The observed association between downsizing and TIAEs is likely multifactorial. In some cases, the larger ETT can directly lead to trauma, an esophageal intubation, or epistaxis (during nasal intubation). In other cases, an initial failed attempt because of the use of an ETT that is too large can result in adverse events owing to prolongation of the TI encounter, predisposing the patient to physiologic deterioration, and the need for additional TI attempts.

Many intubation procedures in our cohort did not conform with NRP recommendations for ETT size. This phenomenon occurred most frequently among infants weighing just above 1000 g and 2000 g. We observed site-level variation in the proportion of intubations that followed NRP recommendations, but we were unable to determine why providers selected ETT sizes for individual intubations.

To our knowledge, this is the first large scale study to evaluate the optimal ETT size for infants undergoing TI. Previous published literature referenced guidelines as expert opinion or usual practice. Compared with previously published guidelines, NRP generally recommends larger ETTs based on weight. Previous guidelines had the upper weight limit for a 2.5 mm ETT ranging from 1000 to 2500 g and the upper weight limit for a 3.0 mm ETT ranging from 2500 to 4000 g.[7,12–14] Our data reinforce that selecting an ETT

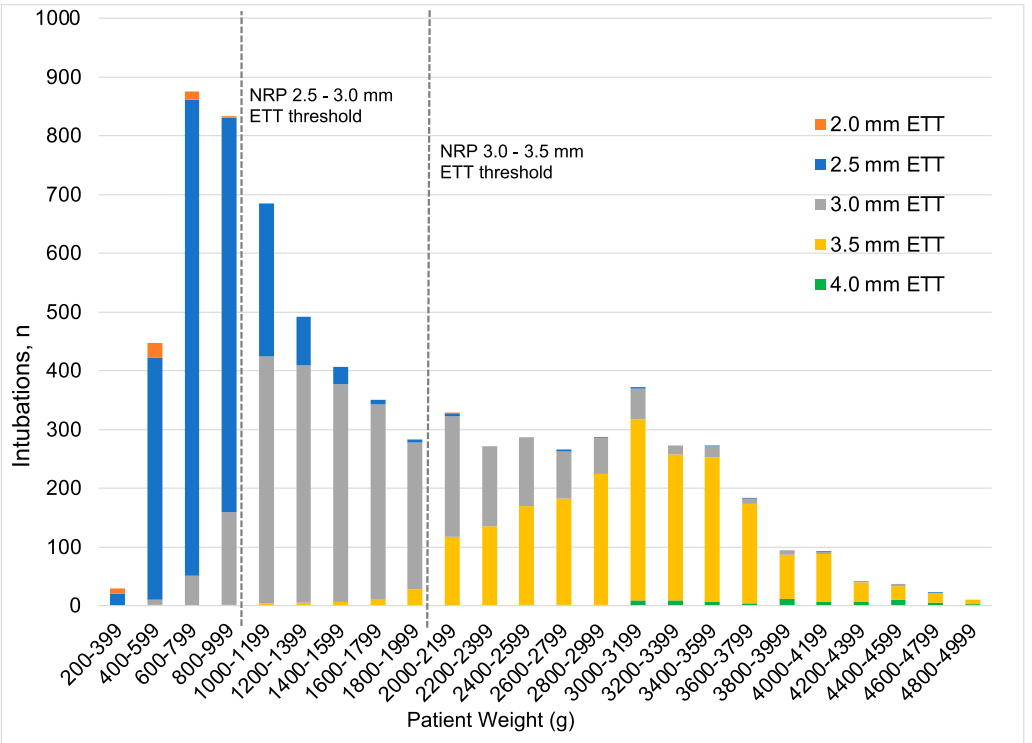

FIGURE 1
Distribution of ETT size selection for the first TI attempt by weight subgroups. The NRP-recommended thresholds are shown in vertical reference lines. Not shown are 49 infants with a weight of ≥5000 g.

Downloaded from http://publications.aap.org/pediatrics/article-pdf/153/4/e2023062925/1615195/peds.2023-062925.pdf
by Children's Hospital of Philadelphia, Elizabeth Foglia

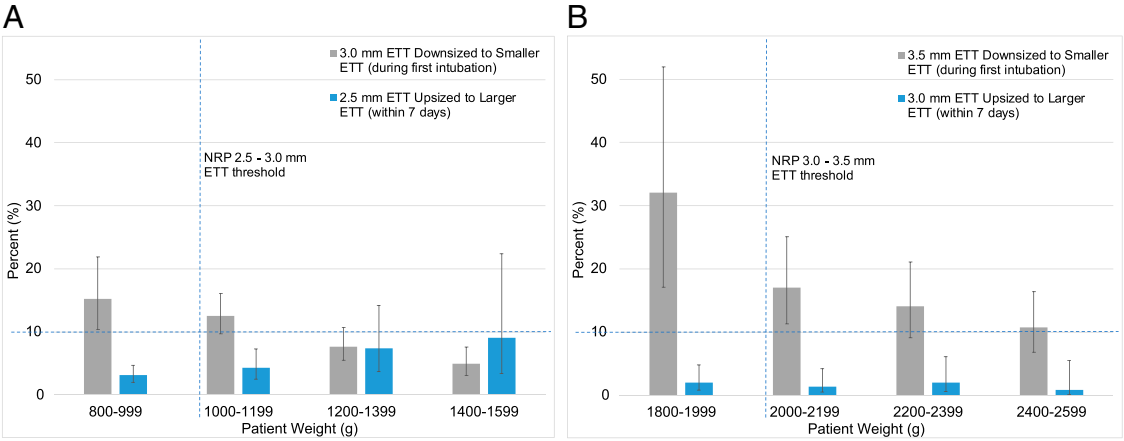

FIGURE 2

TI encounters with the ETT downsized during the procedure or upsized within 7 days, by weight subgroups. A: 2.5 to 3.0 mm ETT threshold. B: 3.0 to 3.5 mm ETT threshold. NRP-recommended thresholds are shown in vertical lines. Downsizing or upsizing >10% was considered suboptimal, indicated by the horizontal line. Error bars represent 95% confidence intervals.

larger than current NRP recommendations should be avoided given the suboptimal downsizing rates and associations with procedural adverse outcomes. Despite this, we found that larger than NRP-recommended ETTs are occasionally selected, especially near the current NRP weight thresholds. Autopsy airway measurements in premature infants have been shown to underestimate the size of endotracheal tube that can pass through the vocal cords, likely because of airway elasticity.[10] This highlights the importance of the clinical data in this study to inform decisions around ETT sizing for TIs.

We chose to focus on infant weight as a basis for determining data-driven thresholds. In autopsy measurements, both gestational age and patient weight correlate strongly with airway size.[10] However, given potential imprecision in gestational age estimates depending on when dating is performed during pregnancy, we chose to use patient weight to define patient subgroups. We acknowledge that patient weight is sometimes estimated in the delivery room; however, most TIs in our study were performed in the NICU, where patient weight has been measured.

This study has limitations. Data collected in NEAR4NEOS are self-reported and could be subject to reporting bias. We attempted to focus on the noninstrumented airway to best understand the ETT size thresholds. Therefore, we limited our study to the first TI for each patient in the NEAR4NEOS database to reduce the possibility of airway swelling or trauma from a previously placed ETT. Some infants were previously intubated at another institution that did not participate in NEAR4NEOS and therefore the first TI captured by NEAR4NEOS was not their first TI. ETTs are measured by the internal diameter, and the outer diameter may vary by manufacturer.[21] We did not document the manufacturer of ETTs used for this study. For the minority of ETTs placed nasally, the size of the nares could have impacted ETT size selection; including nasal route, but in our models, it did not substantially change the observed results. The NEAR4NEOS database does not

TABLE 3 Independent Association Between Procedural Adverse Outcomes and First ETT Size Selected Within Infant Weight Subgroups

Wt Subgroup	Any TIAE				Severe Oxygen Desaturation			
	2.5 mm, *n*/*N* (%)	3.0 mm, *n*/*N* (%)	aOR (95% CI)	*P*	2.5 mm, *n*/*N* (%)	3.0 mm, *n*/*N* (%)	aOR (95% CI)	*P*
800–999 g	151/672 (22.5)	36/157 (23)	0.78 (0.57–1.07)	.13	270/608 (44.4)	69/133 (52)	0.84 (0.58–1.20)	.34
1000–1199 g	54/260 (20.8)	92/420 (21.9)	0.62 (0.41–0.94)	.03	82/233 (35.2)	201/380 (52.9)	0.53 (0.38–0.75)	<.001
1200–1399 g	12/83 (15)	69/404 (17.1)	0.76 (0.37–1.52)	.43	23/71 (32)	162/369 (43.9)	0.69 (0.39–1.22)	.20
1400–1599 g	4/29 (14)	63/371 (17.0)	0.60 (0.14–2.62)	.50	3/21 (14)	146/337 (43.3)	0.26 (0.07–0.99)	.05
Wt subgroup	**Any TIAE**				**Severe oxygen desaturation**			
	3.0 mm	**3.5 mm**	**aOR (95% CI)**	***P***	**3.0 mm**	**3.5 mm**	**aOR (95% CI)**	***P***
1800–1999 g	44/250 (17.6)	4/28 (14)	1.22 (0.45–3.26)	.70	93/230 (40.4)	20/27 (74)	0.26 (0.11–0.59)	.001
2000–2199 g	28/206 (13.6)	16/117 (14)	0.92 (0.46–1.83)	.80	74/181 (41)	57/102 (56)	0.55 (0.34–0.89)	.02
2200–2399 g	23/136 (17)	18/135 (13)	1.24 (0.70–2.20)	.47	50/120 (42)	49/111 (44)	0.93 (0.60–1.44)	.74
2400–2599 g	14/117 (12)	27/169 (16)	0.70 (0.36–1.37)	.30	31/101 (31)	54/150 (36)	0.84 (0.49–1.42	.50

Adjusted odds ratios for adverse outcomes presented for smaller tube size, with larger tube size as reference. Multivariable models adjusted for paralysis premedication, video laryngoscope, first airway provider and clustering by site.

Downloaded from http://publications.aap.org/pediatrics/article-pdf/153/4/e2023062925/1615195/peds.2023-062925.pdf
by Children's Hospital of Philadelphia, Elizabeth Foglia

document the ETT leak post intubation, and postextubation airway outcomes that may be relevant, such as stridor or subglottic stenosis, were not consistently available for this cohort. Some infants with a large ETT leak may not have undergone ETT upsizing as the clinical team may have chosen to tolerate the degree of leak or to extubate to noninvasive respiratory support. Finally, it is possible that infants experienced other adverse outcomes related to ETT sizing that were not captured in this study.

Strengths of the study include the use of clinical data from a large international cohort. This is the first study to our knowledge to use clinical data to guide ETT size selection for neonatal TI. The observed variation in the initial ETT size selection within weight subgroups facilitated a robust analysis of outcomes for different ETT sizes within the same weight groups. Finally, the NEAR4NEOS data are well suited for this study. ETT size is collected for each TI attempt, which allowed us to determine instances of downsizing, and multiple TI encounters for the same patient are linked with a unique identifier in NEAR4NEOS, which allowed us to determine instances of upsizing within 7 days as a balancing measure.

CONCLUSIONS

For infants weighing 1000 to 1199 g and 2000 to 2199 g, the recommended ETT sizes of 3.0 mm and 3.5 mm, respectively, were commonly downsized during the procedure, and 0.5 mm smaller ETT sizes were commonly selected, rarely upsized within 7 days, and independently associated with reduced odds of procedural adverse outcomes. These results may inform evidence-based recommendations for ETT size selection during neonatal intubation.

ABBREVIATIONS

aOR: adjusted odds ratio
CI: confidence interval
ETT: endotracheal tube
NEAR4NEOS: National Emergency Airway Registry for Neonates
NRP: Neonatal Resuscitation Program
TI: tracheal intubation
TIAE: tracheal intubation associated event

Dr Peebles conceptualized and designed the study, conducted the data analyses, and drafted the initial manuscript; Drs Foglia, Jensen, Herrick, and Nishisaki conceptualized and designed the study, participated in the data analysis and interpretation of data, and critically reviewed and revised the manuscript; Mr Wildenhain contributed to the design of the project and critically reviewed and revised the manuscript; and Drs Rumpel, Moussa, Singh, Mehrem, Quek, Wagner, Pouppirt, Glass, Tingay, Hodgson, O'Shea, Sawyer, Brei, Jung, JUnrau, Kim, Barry, DeMeo, and Johnston coordinated and supervised data collection, and critically reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

DOI: https://doi.org/10.1542/peds.2023-062925

Accepted for publication Dec 8, 2023

Address correspondence to Elizabeth E. Foglia, MD, MSCE, Children's Hospital of Philadelphia, 3401 Civic Center Blvd, NW53, Philadelphia, PA 19104-4319. E-mail: foglia@chop.edu

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

Copyright © 2024 by the American Academy of Pediatrics

FUNDING: Dr Nishisaki's research has been funded by NICHD R21HD089151, R21HD103927, R01HD106996, and Chiesi, Inc, USA; Dr Tingay is supported by a National Health and Medical Research Council (Australia) Investigator grant (GNT2008212) and the Victorian Government Operational Infrastructure Support Program (Melbourne, Australia); Dr Foglia's research has been funded by NICHD R01HD106996-01A1; Dr Herrick's research has been funded by AHRQ K08HS029029; and Dr Jensen's research has been funded by NHLBI K23HL136843; and the other authors received no additional funding.

CONFLICT OF INTEREST DISCLOSURES: Dr Kim is on the Advisory Board of Medela and owns shares in Nicolette and Astarte Medical; and the other authors have no relevant conflicts to disclose.

COMPANION PAPER: A companion to this article can be found online at www.pediatrics.org/cgi/doi/10.1542/peds.2023-064843.

REFERENCES

1. Foglia EE, Ades A, Sawyer T, et al; NEAR4NEOS Investigators. Neonatal intubation practice and outcomes: an international registry study. *Pediatrics*. 2019;143(1):e20180902
2. Mahmoud RA, Proquitté H, Hadhood SE, Schmalisch G. Effect of endotracheal tube leakage on respiratory function monitoring: comparison of three neonatal ventilators. *J Pediatr Intensive Care*. 2012;1(2):61–69
3. Bernstein G, Knodel E, Heldt GP. Airway leak size in neonates and autocycling of three flow-triggered ventilators. *Crit Care Med*. 1995;23(10):1739–1744
4. Oca MJ, Becker MA, Dechert RE, Donn SM. Relationship of neonatal endotracheal tube size and airway resistance. *Respir Care*. 2002;47(9):994–997
5. Manczur T, Greenough A, Nicholson GP, Rafferty GF. Resistance of pediatric and neonatal endotracheal tubes: influence of flow rate, size, and shape. *Crit Care Med*. 2000;28(5):1595–1598

Downloaded from http://publications.aap.org/pediatrics/article-pdf/153/4/e2023062925/1615195/peds.2023-062925.pdf
by Children's Hospital of Philadelphia, Elizabeth Foglia

6. Sherman JM, Lowitt S, Stephenson C, Ironson G. Factors influencing acquired subgottic stenosis in infants. *J Pediatr.* 1986;109(2):322–327

7. Contencin P, Narcy P; Study Group for Neonatology and Pediatric Emergencies in the Parisian Area. Size of endotracheal tube and neonatal acquired subglottic stenosis. *Arch Otolaryngol Head Neck Surg.* 1993;119(8):815–819

8. Fishman RA, Pashley NR. A study of the premature neonatal airway. *Otolaryngol Head Neck Surg.* 1981;89(4):604–607

9. Schild JA. Relationship of laryngeal dimensions to body size and gestational age in premature neonates and small infants. *Laryngoscope.* 1984;94(10):1284–1292

10. Fayoux P, Devisme L, Merrot O, Marciniak B. Determination of endotracheal tube size in a perinatal population: an anatomical and experimental study. *Anesthesiology.* 2006;104(5):954–960

11. Weiner GM, Zaichkin J, Kattwinkel J. *Textbook of Neonatal Resuscitation*, 8th ed. American Academy of Pediatrics; 2021

12. Laing IA, Cowan DL, Ballantine GM, Hume R. Prevention of subglottic stenosis in neonatal ventilation. *Int J Pediatr Otorhinolaryngol.* 1986;11(1):61–66

13. McMillan DD, Rademaker AW, Buchan KA, Reid A, Machin G, Sauve RS. Benefits of orotracheal and nasotracheal intubation in neonates requiring ventilatory assistance. *Pediatrics.* 1986;77(1):39–44

14. Park RS, Peyton JM, Kovatsis PG. Neonatal airway management. *Clin Perinatol.* 2019;46(4):745–763

15. Harris PA, Taylor R, Minor BL, et al; REDCap Consortium. The REDCap consortium: building an international community of software platform partners. *J Biomed Inform.* 2019;95:103208

16. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* 2009;42(2):377–381

17. Moussa A, Sawyer T, Puia-Dumitrescu M, et al; National Emergency Airway Registry for Neonates (NEARNEOS) investigators. Does videolaryngoscopy improve tracheal intubation first attempt success in the NICUs? A report from the NEAR4NEOS. *J Perinatol.* 2022;42(9):1210–1215

18. Johnston L, Sawyer T, Ades A, et al; NEAR4NEOS Investigators. Impact of physician training level on neonatal tracheal intubation success rates and adverse events: a report from national emergency airway registry for neonates (NEAR4NEOS). *Neonatology.* 2021;118(4):434–442

19. Ozawa Y, Ades A, Foglia EE, et al; National Emergency Airway Registry for Neonates (NEAR4NEOS) Investigators. Premedication with neuromuscular blockade and sedation during neonatal intubation is associated with fewer adverse events. *J Perinatol.* 2019;39(6):848–856

20. Herrick HM, Glass KM, Johnston LC, et al; for the NEAR4NEOS Investigators. Comparison of neonatal intubation practice and outcomes between the neonatal intensive care unit and delivery room. *Neonatology.* 2020;117(1):65–72

21. Haase B, Badinska AM, Maiwald CA, Poets CF, Springer L. Comparison of nostril sizes of newborn infants with outer diameter of endotracheal tubes. *BMC Pediatr.* 2021;21(1):417

Downloaded from http://publications.aap.org/pediatrics/article-pdf/153/4/e2023062925/1615195/peds.2023-062925.pdf
by Children's Hospital of Philadelphia, Elizabeth Foglia