Association Between Video Laryngoscopy and Adverse Tracheal Intubation-Associated Events in the Neonatal Intensive Care Unit

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The effect of video laryngoscopy on adverse events during neonatal tracheal intubation is unknown. In this single site retrospective cohort study, video laryngoscopy was independently associated with decreased risk for adverse events during neonatal intubation. *(J Pediatr 2018;■■:■■-■■).*

Neonatal tracheal intubation is a challenging yet life-saving procedure that is associated with adverse events.[1-5] Video laryngoscopy, which improves the view of the glottis during intubation, may lower the risk of such events.[5,6] Studies that investigated the impact of video laryngoscopy on adverse events in the pediatric and adult populations report conflicting results.[6,7] Evidence regarding the effect of video laryngoscopy on adverse events during neonatal intubation is insufficient.[8-11] Randomized controlled trials demonstrated improved neonatal intubation success rates for trainees using video laryngoscopy compared with conventional laryngoscopy, but these trials only examined a limited number of adverse events.[12,13] We hypothesized that video laryngoscopy is associated with a decrease in adverse events during neonatal tracheal intubation.

Methods

We conducted a retrospective cohort study of neonatal intubations performed at our institution between July 1, 2013 and June 30, 2016. We retrospectively queried the National Emergency Airway Registry for Neonates (NEAR4NEOS), a prospectively developed database, for all intubation encounters in our neonatal intensive care unit (NICU). NEAR4NEOS is a multicenter neonatal airway registry that developed from the pediatric airway registry, National Emergency Airway Registry for Children.[14] Data on patient, provider and practice characteristics, and proximal outcomes are recorded at the time of intubation by the clinical team. The NEAR4NEOS registry is deemed an ongoing Quality Improvement Initiative by the Children's Hospital of Philadelphia Institutional Review Board, and thus, this study of NEAR4NEOS data was not subject to Institutional Review Board approval.

The Children's Hospital of Philadelphia is an urban, academic, training hospital in the US. The Children's Hospital of Philadelphia NICU is a level IV, 98-bed referral center with a small percentage of inborn patients with prenatally diagnosed congenital anomalies. Only intubations occurring in the NICU setting were included; intubations occurring in the specialized delivery center or other hospital units were excluded. Endotracheal tube exchanges (ie, upsizing or replacing an existing endotracheal tube in an intubated patient) were excluded from this analysis. Patients remain intubated throughout most of the tube exchange procedure, and, thus, the process is distinct from a traditional intubation in a nonintubated patient. Intubations performed by neonatologists, neonatology fellows, pediatric residents, and other NICU staff (nurse practitioners, physician's assistants, and hospitalists) were included. Our unit has a general guideline that limits the number of intubation attempts per provider (up to 2 attempts) and encourages the use of premedication for intubation. The types and dosages of premedication are at the discretion of the neonatologist. An attending neonatologist supervises the majority of NICU intubations.

The exposure of interest was the first laryngoscopy device used for the intubation encounter: video laryngoscopy vs conventional laryngoscopy. The most commonly used video laryngoscope in our unit was the C-MAC (Karl-Storz, Tuttlingen, Germany), introduced into our unit in July 2014. The decision to use the C-MAC for intubation was based on the provider's discretion. Intubations using devices other than the C-MAC video laryngoscope or conventional laryngoscope (ie, other types of video laryngoscope or fiberoptic bronchoscope) were excluded, as these intubations were rare and typically occurred in patients with difficult airways.

We used NEAR4NEOS operational definitions.[1,6] Briefly, an "encounter" is a single intubation procedure beginning with delivery of premedication and ending 20 minutes after

NEAR4NEOS	National Emergency Airway Registry for Neonates
NICU	Neonatal intensive care unit
TIAE	Tracheal intubation associated event

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securement of endotracheal tube. A "course" is defined as one method of intubation, including the initial device, approach, and medications used. An "attempt" begins with the insertion of a laryngoscope into the patient's mouth and ends when the laryngoscope is withdrawn. There can be many attempts during a course and multiple courses within an encounter. Only the first course of each intubation encounter was included in this analysis as the study question related to the initial approach to intubation. If a patient underwent multiple intubation encounters in the NICU throughout the study period, the first course of each of these encounters were included in the analysis.

Adverse tracheal intubation associated events (TIAEs) are categorized by NEAR4NEOS as nonsevere or severe. Examples of nonsevere TIAEs include mainstem bronchial intubation, esophageal intubation with immediate recognition, dysrhythmia (including heart rate <60 beats per minute), lip trauma, and pain or agitation requiring additional medication with delay in intubation. Examples of severe TIAEs include cardiac arrest with or without return of spontaneous circulation, esophageal intubation with delayed recognition, pneumothorax, pneumomediastinum, and laryngospasm. Severe oxygen desaturations are defined as ≥20% decrease in SpO_2 (oxygen saturation) from the highest value prior to the procedure to the lowest value recorded at any point during the intubation. The highest SpO_2 value is obtained just prior to the intubation, during bag mask ventilation and premedication administration (if administered). Severe oxygen desaturation events are collected separately from TIAEs.

The primary outcome of this study was any adverse TIAE occurring during the first intubation course. Secondary outcomes included severe TIAEs, severe oxygen desaturation events, first attempt success rate, number of attempts during the intubation course, and overall success rates in the first course.

Statistical Analyses

Statistical analysis was performed using STATA 14.0 (Stata Corp, College Station, Texas). Baseline characteristics between groups who were intubated with video laryngoscopy and conventional laryngoscopy were analyzed using χ^2, Fisher exact, and Wilcoxon rank-sum tests. Associations between the use of video laryngoscopy and adverse TIAEs, severe oxygen desaturation events, number of intubation attempts, and success rates were investigated using χ^2, Fisher exact, and Wilcoxon rank-sum tests. Logistic regression was performed to determine the independent effect of video laryngoscopy on the outcomes of all adverse TIAEs, severe TIAEs, and severe oxygen desaturation events. In post-hoc analysis, the regression models were adjusted for covariates that significantly differed ($P < .05$) between the video laryngoscopy and conventional laryngoscopy groups in univariable analysis.

Results

Of 805 tracheal intubation encounters performed during the study period, 644 (80%) were performed with conventional laryngoscopy and 161 (20%) were performed with video laryngoscopy (Table I). Compared with patients who underwent intubation with conventional laryngoscopy, patients intubated with video laryngoscopy were older (median 40 days, IQR [10-82] vs median 15 days, IQR [1-30], $P < .001$) and larger (median 3.0 kg, IQR [1.9-3.7] vs median 2.6 kg, IQR [1.6-3.3], $P < .001$) at the time of intubation. Upper airway obstruction was a more common indication for intubation using video laryngoscopy. Compared with the conventional laryngoscopy group, the video laryngoscopy group more commonly received sedative/analgesic (89% vs 78%, $P = .002$) and paralytic premedication (80% vs 44%, $P < .001$).

Table I. Comparison of patient, practice, provider characteristics, and outcomes

	Video laryngoscopy (n = 161)	Conventional laryngoscopy (n = 644)	*P* value
Patient characteristics			
Patient age, d (median, IQR)	40 (10, 82)	15 (1, 30)	**<.001**
Birth gestational age, wk (median, IQR) (n = 513)	33 (27, 38)	33 (27, 37)	.728
Current weight, kg (median, IQR)	3.0 (1.9, 3.7)	2.6 (1.6, 3.3)	**<.001**
Male sex	94 (58)	369 (57)	.803
History of a difficult airway	23 (14)	67 (10)	.162
Indication for intubation*			
Respiratory failure	36 (22)	208 (32)	**.014**
Apnea/bradycardia	18 (11)	95 (15)	.243
Upper airway obstruction	17 (11)	26 (4)	**.001**
Unplanned extubation	14 (9)	118 (18)	**.003**
Other indication†	40 (25)	195 (30)	.175
Practice characteristics			
Sedative/analgesic administration	143 (89)	501 (78)	**.002**
Paralytic administration	129 (80)	284 (44)	**<.001**
First airway provider			
Pediatric resident	7 (4)	75 (12)	**.023**
Neonatology fellow	55 (34)	196 (30)	
Neonatology attending	8 (5)	49 (8)	
Other (hospitalist, physician's assistant, nurse practitioner)	91 (57)	324 (50)	
Outcomes			
Any TIAE	10 (6)	124 (19)	**<.001**
Severe TIAE	3 (2)	30 (5)	.110
Severe oxygen desaturation	70/151 (46)	308/601 (51)	.283
First course number of intubation attempts (median, IQR)	1 (1, 2)	2 (1, 3)	**<.001**
First intubation attempt success	101 (63)	284 (44)	**<.001**
First course success	153 (95)	625 (97)	.203

Unless otherwise indicated, values represent patient n (%).
Numbers in bold represent statistically significant values, $P < .05$
*Each intubation may have more than 1 indication.
†Includes shock, procedural indication, hyperventilation, neurologic weakness, drug administration (including surfactant), and no airway protective reflex.

Adverse TIAEs occurred in 134 intubations (17%) during the study period. The most common TIAEs were esophageal intubation with immediate recognition (10% of all encounters) and dysrhythmia including heart rate <60 beats per minute (3% of all encounters) (Table II; available at www.jpeds.com). Adverse TIAEs occurred less frequently in intubations performed with video laryngoscopy (6%) than conventional laryngoscopy (19%), $P < .001$. There was no significant difference in the rate of severe TIAEs or severe oxygen desaturations between groups. Patients in the video laryngoscopy group underwent fewer intubation attempts (median 1, IQR [1-2] vs

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Table III. Multivariable analysis of characteristics associated with tracheal-intubation adverse events

	Any tracheal intubation associated event	Severe tracheal intubation associated event	Severe oxygen desaturation event
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Video laryngoscopy	**0.43 (0.21, 0.87)**	0.70 (0.19, 2.53)	1.06 (0.73, 1.55)
Sedative/analgesic administration	0.81 (0.48, 1.37)	0.68 (0.28, 1.65)	0.84 (0.54, 1.30)
Paralytic medication	**0.35 (0.22, 0.56)**	**0.24 (.09, 0.66)**	0.83 (0.59, 1.16)
Current weight (kg)	1.00 (0.86, 1.17)	1.21 (0.92, 1.58)	**0.88 (0.79, 0.98)**
Indication for intubation			
Respiratory failure	1.02 (0.67, 1.56)	1.72 (0.79, 3.73)	**1.75 (1.26, 2.43)**
Upper airway obstruction	0.59 (0.21, 1.62)	1.14 (0.25, 5.28)	**2.32 (1.17, 4.60)**
Unplanned extubation	0.58 (0.32, 1.05)	1.17 (0.43, 3.17)	**1.99 (1.32, 3.01)**
First attempt provider role			
Neonatology fellow (reference)	—	—	—
Neonatology attending	1.60 (0.75, 3.42)	2.80 (0.90, 8.67)	1.58 (0.86, 2.91)
Pediatric resident	**2.55 (1.29, 5.05)**	1.12 (0.26, 4.85)	**2.05 (1.18, 3.58)**
Other NICU staff (nurse practitioner, physician's assistant, hospitalist)	**1.69 (1.02, 2.79)**	1.58 (0.62, 4.02)	1.20 (0.86, 1.68)

Numbers in bold represent statistically significant values, $P < .05$.
Models include variables that were statistically significant in univariable analysis. Postnatal age was not included, as this is collinear with patient weight.

median 2, IQR [1-3], $P < .001$). Overall success rates of the first course between groups did not differ (95% vs 97%, $P = .203$), but first attempt success was higher in the video laryngoscopy group (63% vs 44%, $P < .001$).

After adjusting for patient and practice characteristics that differed between groups in univariable analysis, (**Table III**), video laryngoscopy remained significantly associated with a reduction in adverse TIAEs (OR 0.43, 95% CI 0.21, 0.87), but not with a reduction in severe TIAEs (OR 0.70, 95% CI 0.19, 2.53) or severe oxygen desaturation events (OR 1.06, 95% CI 0.73, 1.55).

Discussion

We report on the effect of video laryngoscopy on comprehensive adverse events during neonatal intubation. In our cohort, video laryngoscopy was independently associated with a decreased risk for adverse TIAEs overall, but not with a decreased risk for severe TIAEs or severe oxygen desaturation events. Video laryngoscopy was also associated with an improved first attempt success rate and a decreased number of intubation attempts.

To date, the available studies of video laryngoscopy in neonatal intubation have largely focused on success outcomes; there are limited data regarding the influence of video laryngoscopy on adverse TIAEs. O'Shea et al performed a randomized trial of junior physicians performing neonatal intubation and found improved first attempt success rates when instructors could view the video laryngoscope screen during the procedure, compared with instructors without a visible screen (66% vs 41%). Lowest oxygen saturation, lowest heart rate, and duration of intubation did not differ between groups.[12] In a separate trial, Moussa et al also demonstrated that residents performing neonatal intubation had higher success rates with video laryngoscopy than conventional laryngoscopy (75% vs 63%), but the time to successful intubation was longer with video laryngoscopy (57 vs 47 seconds). Bradycardic episodes and minimum oxygen saturation did not vary significantly between groups. The rate of mucosal trauma was higher in the conventional laryngoscopy group (4% vs 0%).[13]

In our cohort, after controlling for important baseline patient characteristics that differed between groups, video laryngoscopy remained significantly associated with a decrease in adverse TIAEs as a group but not severe TIAEs. Severe TIAEs were a rare event, occurring in only 4% of intubation encounters. The largest impact of video laryngoscopy on adverse TIAEs was observed in esophageal intubations with immediate recognition. Although in some regard esophageal intubations represent "failed" intubation attempts, they add potential for additional harm from the invasive instrumentation of the upper airway and esophagus during endotracheal tube placement. Thus, we believe that esophageal intubations may be more detrimental to patient safety and should be considered separately from failed intubation attempts when the endotracheal tube is not inserted.

Consistent with our results, a large retrospective cohort study of 8875 pediatric intubations found that video laryngoscopy was associated with a decreased risk of adverse TIAEs, but not with a decreased risk of severe TIAEs.[7] Similar to our findings, the authors reported a decrease in mainstem intubations and esophageal intubations with immediate recognition when using video laryngoscopy (**Table II**).

Observational studies and small trials of adult patients have shown improved intubation success rates with video laryngoscopy. However, in a post-hoc analysis of a large randomized trial conducted by Lascarrou et al, video laryngoscopy was associated with higher rates of adverse events.[7] It is possible that these contrasting results are due to anatomic differences in the neonatal airway, such as a more anterior glottis, which may lead to greater improvements in outcomes with video laryngoscopy in the neonatal population.[15]

Video laryngoscopy was not associated with a decrease in severe oxygen desaturations in our study. Previous studies have shown an increased or equivalent time to intubation when using video laryngoscopy compared with conventional

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laryngoscopy in pediatric and neonatal intubations.[13,16,17] We did not collect data about the duration of intubation attempts in this study. However, increased duration of intubation attempts with video laryngoscopy is a possible explanation for the lack of effect on severe oxygen desaturation events in this study.

Provider level and paralytic administration were also associated with adverse TIAEs (**Table III**), which is consistent with findings from previous studies.[1,18] Our results suggest that video laryngoscopy confers a further protective effect in addition to these factors.

One study limitation is this was a single site study in a level IV referral NICU. Our institution was one of the few NEAR4NEOS sites using video laryngoscopy and collecting data at the initiation of the study period, and our results may not be generalizable to all NICUs. A future prospective interventional trial is underway in the NEAR4NEOS network to assess the impact of video laryngoscopy on TIAEs. Also, TIAEs are self-reported by the clinical team in the NEAR4NEOS registry and may underestimate the true TIAE rate.

Study strengths include multivariable analysis of a large number of intubations using prospectively collected data in the NEAR4NEOS registry. In addition, this study evaluated a comprehensive list of adverse TIAEs using standardized operational definitions.

We found that video laryngoscopy was independently associated with decreased adverse events during neonatal intubation. These findings suggest video laryngoscopy is a helpful tool to optimize the safety and success of neonatal intubation in the NICU setting. ■

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Table II. Adverse tracheal intubation-associated events during the study period

	Video laryngoscopy (n = 161)	Conventional laryngoscopy (n = 644)
Esophageal intubation, immediate recognition	2 (1)	76 (12)
Dysrhythmia (includes heart rate <60 beats per minute)	6 (4)	18 (3)
Mainstem intubation	0	12 (2)
Esophageal intubation—delayed recognition	0	9 (1)
Chest compressions (<1 min duration)	1 (1)	7 (1)
Cardiac arrest—survived	1 (1)	6 (1)
Gum trauma	0	6 (1)
Emesis, no aspiration	2 (1)	4 (1)
Lip trauma	0	2 (<1)
Pain or agitation, requiring additional medications and delay	0	1 (<1)
Emesis with aspiration	1 (1)	1 (<1)
Hypotension requiring Intervention	0	2 (<1)
Laryngospasm	0	1 (<1)
Pneumothorax/pneumomediastinum	0	1 (<1)

More than 1 TIAE could occur during a given intubation.

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