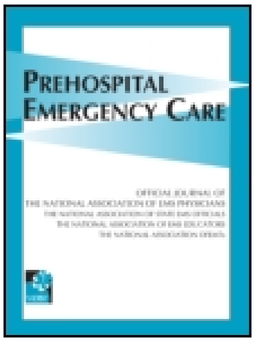

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Risk Factors for Failed Tracheal Intubation in Pediatric and Neonatal Critical Care Specialty Transport

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Abstract

Objective. Nearly 200,000 pediatric and neonatal transports occur in the United States each year with some patients requiring tracheal intubation. First-pass intubation rates in both pediatric and adult transport literature are variable as are the factors that influence intubation success. This study sought to determine risk factors for failed tracheal intubation in neonatal and pediatric transport. **Methods.** A retrospective chart review was performed over a 2.5-year period. Data were collected from a hospital-based neonatal/pediatric critical care transport team that transports 2,500 patients annually, serving 12,000 square miles. Patients were eligible if they were transported and tracheally intubated by the critical care transport team. Patients were categorized into two groups for data analysis: (1) no failed intubation attempts and (2) at least one failed intubation attempt. Data were tabulated using Epi Info Version 3.5.1 and analyzed using SPSSv17.0. **Results.** A total of 167 patients were eligible for enrollment and were cohorted by age (48% pediatric versus 52% neonatal). Neonates were more likely to require multiple attempts at intubation when compared to the pediatric population (69.6% versus 30.4%, $p = 0.001$). Use of benzodiazepines and neuromuscular blockade was associated with increased successful first attempt intubation rates ($p = 0.001$ and 0.008, respectively). Use of opiate premedication was not associated with first-attempt intubation success. The presence of comorbid condition(s) was associated with at least one failed intubation attempt ($p = 0.006$). Factors identified with increasing odds of at least one intubation failure included, neonatal patients (OR 3.01), tracheal tube size $\leq$ 2.5 mm (OR 3.78), use of an uncuffed tracheal tube (OR 6.85), and the presence of a comorbid conditions (OR 2.64). **Conclusions.** There were higher rates of tracheal intubation failure in transported neonates when compared to pediatric patients. This risk may be related to the lack of benzodiazepine and neuromuscular blocking agents used to facilitate intubation. The presence of a comorbid condition is associated with a higher risk of tracheal intubation failure. **Key words:** tracheal intubation; neonate; pediatric; specialty transport

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Background

Approximately 200,000 newborns, infants, and children in the United States are transported to a higher level of care each year.[1] Airway management is an essential component of resuscitation efforts and nearly half of pediatric or neonatal critical care transports require some form of respiratory intervention prior to or during the transport.[2–7]

Tracheal intubation can be fraught with complications even in the most controlled environment, such as the operating room.[8,9] In the fields of prehospital and interfacility transport medicine, the setting is often less controlled and multiple variables may decrease the opportunities to perform a successful tracheal intubation.[4,10] Lack of pediatric intubation expertise, limited resources, and a less-than-ideal intubation environment further reduce the success rate.[6,7]

Clinical outcome data within emergency medical services (EMS) literature have demonstrated that prehospital tracheal intubation by paramedic teams offers little benefit compared to bag-valve mask ventilation.[11] Children, however, are known to have increased oxygen consumption, decreased oxygen reserve, and increased gastric distention with bag-valve mask ventilation regardless of nasogastric tube placement.[7,12] Desaturation and bradycardia during bag-valve mask ventilation in an already unstable patient can result in significant morbidity and mortality.[11,12] In pediatric and neonatal critical care transport, it is often necessary to ensure a more stable airway to optimize oxygenation and ventilation during transport.

Studies have cited first-pass success rates for pediatric tracheal intubation ranging from 33 to 95% for transport and emergency department personnel (paramedics, trainees, and attending

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Author contributions: KS, MG, MB were involved in study design, data collection, data analysis, data review, and manuscript preparation; HS, JG, and MF were involved in study design, data review, and manuscript preparation.

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physicians).[5,6,13,14] The reasons for the variable intubation success rates among these studies have not been adequately explored. In this study, we sought to identify risk factors for failed tracheal intubation in neonatal and pediatric transport patients.

METHODS

This single institution retrospective study was reviewed and approved by the Akron Children's Hospital institutional review board. The transport team is a combined neonatal/pediatric transport team with a mix of dedicated and unit-based critical care transport services. Online medical control is provided by pediatric emergency or critical care physicians as well as neonatologists. The composition of the team includes a pediatric or neonatal transport nurse, a transport paramedic, and a transport respiratory therapist. The critical care team transports approximately 2,500 patients annually. The local critical care transport paradigm includes the use of local EMS for the regional transfer of non-critically ill patients to our tertiary regional children's hospital and reserves the use of the critical care transport team for patients with active or high risk for development of critical care issues including cardiac, respiratory, or neurologic failure. The patients are transported via one of four ground units or one dedicated helicopter servicing 12,000 square miles in northeastern/eastern/central Ohio.

Intubation is primarily the responsibility of the respiratory therapist, though all team members are trained and maintain intubation competencies. The transport team is accredited by the Commission on Accreditation of Medical Transport Systems (CAMTS) and meets or exceeds intubation training competency using a combination of live-patient intubations in the critical care settings, the transport settings, and the operating rooms, plus additional simulated intubation experience. The local pediatric transport team intubation protocols delineate the standard use of a sedative and a neuromuscular blocking agent prior to intubation. The neonatal intubation protocols do not standardize the use of a sedative and/or a neuromuscular blocking agent, but rather defer that decision to the medical control physician on a case-by-case basis.

Study patients included all neonatal and pediatric patients less than 18 years of age who were intubated by the Akron Children's critical care transport team from January 2007 through June 2009. Neonates were defined as patients less than 30 days of age transferred from local newborn nurseries or delivery hospitals. Pediatric patients were those greater than 30 days of age or patients less than 30 days who had been discharged from the newborn nursery. Data were extracted by a single pediatric resident in her second post-graduate year of training (KS). Data were then entered into a customized data collection tool using Epi Info Version 3.5.1 (www.cdc.gov). The database included detailed trip information, such as mode and length of transport, indication for intubation, medications, self-reported complications of intubation, and patient comorbidities. The person performing the intubation and his/her experience level was extracted from departmental employment records.

Patients were cohorted a priori into two groups for comparison and analysis: 1) patients with no failed intubation attempts and 2) patients with at least one failed intubation attempt. An intubation attempt was defined by an attempt at laryngoscopy, regardless of an attempt to pass a tracheal tube. A failed intubation attempt was defined as either laryngoscopy with no attempt at tracheal tube placement or laryngoscopy with esophageal placement of a tracheal tube. There was no real-time record of desaturation during each intubation attempt, though intubation practice includes preoxygenation and abandonment of intubation attempt with desaturation below 90%. Successful placement was confirmed with end-tidal colorimetric capnometry, symmetric breath sounds by auscultation, and chest radiography, when available. Data collected were analyzed using appropriate statistical tests, including two-sample *t*-test, nonparametric analog (Kruskal-Wallis) test for non-normally distributed data, and Pearson chi-square test via SPSSv17.0 (SPSS, Chicago). Odds ratios with 95% confidence intervals were also computed for factors significantly associated with intubation failure. Factors that were significantly ($p < 0.05$ via two-sided testing) associated with at least one intubation failure were included in a multivariate logistic regression model. To minimize the effects of multicollinearity since several significant factors were correlated, a backward stepwise elimination procedure was performed to exclude insignificant predictor variables of failed intubation and therefore identify the strongest predictor variables when taken in concert.

RESULTS

The critical care transport team performed 4,546 transports over this 2.5-year study period, with 904 requiring invasive or noninvasive ventilatory support. Of these, 736 were excluded because they were either intubated by the referring hospital, had a preexisting tracheostomy, or were managed using noninvasive ventilation. Data from the remaining 168 eligible patients were analyzed. During analysis, one additional patient was excluded due to incomplete data in the medical record, yielding 167 patients for final analysis.

Patient demographics are reported in Table 1 with 52% neonates and 48% pediatric. Neonates were more likely to require multiple intubation attempts compared to the pediatric cohort (69.6 versus 43.2%, $p = 0.001$) (Table 2). The clinical indication for intubation was not associated with intubation success or failure

TABLE 1. Demographics

Category/subcategory	At least one failed intubation attempt $n = 56$	No failed intubation attempts $n = 111$	*P*-value	Overall $n = 167$
Gender, *n* (%)				
Male	35 (62.5)	66 (59.5)		101 (60.5)
Race, *n* (%)				
White/Caucasian	43 (76.8)	87 (78.4)		130 (77.8)
Black/African American	10 (17.9)	12 (10.8)		22 (13.2)
Nonwhite/Other	2 (3.6)	11 (9.9)		13 (7.8)
Nonwhite/Hispanic	1 (1.8)	1 (0.9)		2 (1.2)
Neonatal population, *n*	39	48		87
Gestational age (weeks), mean (SD)	32.1 (4.75)	32.5 (6.23)	0.30	32.3 (5.59)
Weight (kg), mean (SD)	2.0 (0.96)	2.2 (0.99)	0.27	2.1 (0.97)
Pediatric population, *n*	17	63		80
Age (months), mean (SD)	27.1 (66.17)	17.8 (43.98)	0.47	19.8 (49.18)
Weight (kg), mean (SD)	12.1 (21.13)	8.8 (10.17)	0.36	9.5 (13.17)

(Table 2). Tracheal tube size ≤2.5 mm and the use of uncuffed tracheal tubes were associated with multiple failed attempts at intubation ($p = 0.033$ and <0.001, respectively) (Table 2).

Furthermore, the use of benzodiazepines and neuromuscular blockade was associated with first-pass intubation success ($p = 0.001$ and 0.008, respectively), whereas the use of opiate premedication was not (Table 3). The presence of a preexisting comorbid condition was associated with intubation attempt failure ($p = 0.006$) (Table 3). The referring hospital's failed intubation attempt(s) prior to transport team arrival did not correlate with failure of intubation by the transport team (Table 3).

After univariate analysis, we identified several factors that increased the odds of at least one failed intubation attempt. These included neonatal patients (OR 3.01, 95% confidence interval 1.52–5.96), tracheal tube size less than or equal to 2.5 mm (OR 3.78, 95% confidence interval 1.52–9.40), use of an uncuffed tracheal tube (OR 6.85, 3.06–15.35), and preexisting comorbid conditions (OR 2.64, 95% confidence interval 1.30–5.38). Comorbid conditions identified in this study included abdominal wall defects, asthma, cerebral palsy, congenital heart disease, epilepsy, developmental delay, genetic syndromes, history of prematurity, laryngomalacia, and/or tracheomalacia. The use of benzodiazepine premedication (OR 0.34, 95% confidence interval 0.17–0.66) or neuromuscular blockade (OR 0.31, 95% confidence interval 0.15–0.61) were protective against at least one failed intubation attempt. Of the six significant univariate factors, three were significant in predicting intubation failure in the final, reduced logistic regression model: neonatal patient, uncuffed tube, and failure to use neuromuscular blocking (NMB) premedication. Each of the three remaining factors was significant ($p < 0.05$) in the final, reduced logistic regression model, indicating their significant additive influence on the accuracy of the final predictive model.

DISCUSSION

This study provided a detailed review of all pediatric and neonatal critical care transport team intubations occurring over 2.5 years. We identified multiple risk

TABLE 2. Intubation indications and tracheal tube characteristics

Category/subcategory	At least one failed intubation attempt $n = 56$	No failed intubation attempts $n = 111$	*P*-value[a]
Patient population			0.001
Neonatal, *n* (%)	39 (69.6)	48 (43.2)	
Pediatric, *n* (%)	17 (30.4)	63 (56.8)	
Clinical indication for intubation, *n* (%)			0.095
Respiratory distress/work of breathing	49 (87.5)	95 (85.6)	
Mental status	2 (3.6)	12 (10.8)	
Other, not specified	3 (5.4)	1 (0.9)	
Hypoxemic respiratory failure	2 (3.6)	1 (0.9)	
Shock, cardiac	0 (0)	2 (1.8)	
Tube size (mm, inner diameter), *n* (%)			0.033
≤2.5	14 (25)	9 (8.1)	
≥2.5	42 (75)	102 (91.9)	
Tube type, *n* (%)			<0.001
Cuffed	9 (16.1)	63 (56.8)	
Uncuffed	47 (83.9)	48 (43.2)	

[a] *P*-value from Pearson's chi-square test.

TABLE 3. Preintubation characteristics

Category/subcategory	At least one failed intubation attempt $n = 56$	No failed intubation attempts $n = 111$	*P*-value[a]
Benzo used for premedication, *n* (%)			0.001
Midazolam	18 (32.1)	65 (58.6)	
None	38 (67.9)	46 (41.4)	
NMB used for premedication, *n* (%)			0.008
Rocuronium	5 (8.9)	20 (18)	
Succinylcholine	10 (17.9)	40 (36)	
Vecuronium	1 (1.8)	3 (2.7)	
None	40 (71.4)	48 (43.2)	
Narcotic used for premedication, *n* (%)			0.384
Morphine	3 (5.4)	3 (2.7)	
None	53 (94.6)	108 (97.3)	
Comorbid condition, *n* (%)			0.006
Yes	42 (75)	59 (53.2)	
No	14 (25)	52 (46.8)	
Previous attempts to intubate, *n* (%)			0.091
At least one previous attempt	8 (14.3)	14 (12.6)	
No previous attempts	48 (85.7)	97 (87.4)	
Number of intubation attempts prior to transport, median (range)			0.469
	0 (0–7)	0 (0–7)	

[a] *P*-value from Pearson's chi-square test for categorical variables. *P*-value from two-sample Student's *t*-test for numeric variables. Benzo, benzodiazepine; NMB, neuromuscular blocking agent.

factors associated with increased risk of at least one failed intubation attempt.

Additional risk inherent to the transport setting is the emergency nature of transport intubations. Anesthesia data have long-established that 1 in 10 emergency intubations (regardless of the personnel performing the intubation) required multiple (more than 3) attempts and with each additional attempt, the patient is at an increased risk for hypoxemia, regurgitation, and esophageal intubation.[10,15,16] In a recent study of pediatric patients, Timmermann et al. found that prehospital intubations by anesthesia-trained physicians resulted in infrequent intubation failure (1.7%)[17] and higher hospital survival rates compared to published literature.[18,19] In our cohort, no patients failed transport team intubation.

Most notable in this study is the finding that neonatal intubations are associated with higher failure rates. There are inherent anatomic and physiologic features of neonates that contribute to difficulty when endotracheally intubating them. Anatomically, the neonatal airway is more complex, with a small oropharynx and a high, anteriorly placed larynx, which makes the vocal cords difficult to visualize.[20–22] In addition, neonates tend to have large occiputs, short necks, and relatively large tongues compared to adults and older pediatric patients – all factors that make intubation more challenging.[20,23] Physiologically, neonates have smaller functional residual capacities and are more sensitive to apnea and hypoxemia. Overall, this amounts to less respiratory reserve than that of their older counterparts.[4,22,23]

Whether due to the emergent nature of tracheal tube placement, difficulty of successful intubation, or misconceptions about pain tolerance, many do not administer premedication to the neonatal population. In the United States prior to 2000, sedation and analgesia were rarely used during the process of intubation. Only 3% of neonatal intensive care units (NICUs) in 1994 reported using neurosedatives routinely in the practice of intubating.[20] More recently, European NICUs have reported using sedation and/or analgesia only 29% of the time, and mostly in term neonates. Our data suggest that the use of benzodiazepine premedication or benzodiazepine premedication PLUS neuromuscular blockade favor intubation success. The local pediatric transport team intubation protocols delineate the standard use of a sedative and a neuromuscular blocking agent prior to intubation. The neonatal intubation protocols don't standardize the use of a sedative and/or a neuromuscular blocking agent, but rather defer that decision to the medical control physician on a case-by-case scenario. This study supports the AAP position statement favoring premedication and neuromuscular blockade in neonatal intubation.[24]

Our data did not identify an increased risk of intubation failure associated with attempts prior to our team's arrival, nor did the total number of intubation attempts correlate with success or failure. Connelly et al. found that persistent attempts at laryngoscopy were ineffective, but did not draw the conclusion that repeated laryngoscopy increased likelihood of further failure.[25] In our study population, intubation attempt failure was not associated with increased rates of ICU length of stay, hospital length of stay, duration of mechanical ventilation, or mortality, despite other studies linking failed intubation attempts to additional morbidity.[8,26] Additional morbidities associated with multiple intubation attempts were not identified, as our study was not designed to draw conclusions on the clinical and physiologic impact of multiple failed intubation attempts prior to transport. Anecdotally, we believed that each intubation attempt made it "harder" for subsequent intubators to intubate. Our data did not support that.

We suggest utilizing these findings in two ways. First, patients with one or more of these risk factors should be identified in advance of the intubation attempt, permitting a higher attention to preparation and mitigation (if possible) of the modifiable risk factors. Second, the intubation risk factors might serve to inform training and simulation strategies for initial and maintenance of intubation competencies for critical care transport teams.

Limitations

Since this was a retrospective study, we were able to neither obtain direct input from the critical care transport team caring for each patient nor ensure data accuracy and completeness. Intubation attempts, success, and peri-intubation complications were self-reported. Data were extracted by a single individual who was instructed in transport documentation review, and though data fields were discrete, there is some potential for investigator bias. Additionally, the single-centered study design may not allow for generalizability to other institutions. Locally, the individuals responsible for transport intubations were respiratory therapists, so similar conclusions may be difficult for transport teams led by physicians, physicians-in-training, nurses, advance practice nurses, or paramedics. Also, published literature shows that pediatric and neonatal intubation can be complicated acutely by airway trauma, airway edema, desaturation, or hypercarbia.[4,7,15,27] This study did not examine the incidences of these events, although we acknowledge that these are important outcomes in addition to that of correctly placing and endotracheal tube. Neonatal intubation protocols locally allowed medical control discretion for the use of sedation or neuromuscular blockade, which could bias the results in an unknown direction if the medical control physician favored use or nonuse of these agents dependent on the intubation operator's skill and experience. Lastly, this study could be biased in an unknown direction by lack of detail related to the patients intubated at the referring hospital versus those intubated by the transport team. It is possible that those patients promptly intubated prehospitally or at the referring hospital prior to transport team arrival were sicker patients, with the remaining patients intubated by the transport team representing a less ill (possibly lower risk) cohort. Conversely, it is also possible that those patients where intubation was not performed at the referring hospital were sicker patients, possibly with anticipated difficult airways, or smaller patients (higher risk intubations), which could have influenced the referring hospital to delay the intubation decision at the referring hospital, resulting in a higher risk cohort requiring intubation by the transport team.

Conclusion

In our study population, there were higher rates of intubation failure in transported neonates compared to transported pediatric patients. The risk seemed to be increased by the lack of benzodiazepine premedication and the lack of a neuromuscular blocking agent. The presence of comorbid conditions, regardless of age, was associated with a larger risk of failure, although we could not stratify which specific conditions increased that risk. Inclusion of strategies for recognizing and modifying risks for failed intubations should be priorities for all critical care transport teams.

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