Apneic Oxygenation during Rapid Sequence Intubation in Critically Ill Children

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Abstract

Keywords

- ▶ apneic oxygenation
- ▶ hypoxemia
- ▶ airway management

This prospective case series documented hypoxemia and potential complications associated with apneic oxygenation in critically ill pediatric patients during rapid sequence intubation. Forty-four patients received apneic oxygenation via nasal cannula at rates of 5, 10, and 15 L/min for ages <4, 4 to 12, and 12 to 18 years, respectively. Pre- and postintubation attempt mean SpO_2 were 98.9 ± 2.95 and $90.7 \pm 1.95\%$, respectively. Postintubation $\text{SpO}_2 < 80\%$ were significantly less with one intubation attempt, compared with multiple attempts ($p < 0.001$). No serious complications were noted. Apneic oxygenation was well tolerated in critically ill children.

Introduction

In critically ill children, emergency airway management with endotracheal intubation is challenging. These patients are at a high risk for significant hypoxemia due to their underlying lung pathology, increased metabolic demands, altered respiratory drive, anemia, aspiration risk, hypoxemic baseline, and frequently an unstable airway.^{1,2} Rapid sequence intubation (RSI) is the preferred strategy to address these limitations. RSI involves an induction agent, neuromuscular blockade (NMB), and the absence of apneic bag mask ventilation to prevent gastric distention. However, hypoxemia (oxygen saturations [SpO_2] $< 80\%$) was still documented in 48% of difficult and 15% of nondifficult intubations in pediatric intensive care units (PICUs).³ Cardiac arrest, dysrhythmia, and death have been associated with severe hypoxemia ($\text{SpO}_2 < 70\%$),^{4,5} and have an expected incidence of 1.7, 1.5, and 0.4%, respectively.⁶ These observations suggest that methods to prevent desaturations are vital.¹

An emerging strategy to mitigate desaturations following RSI is apneic oxygenation. Oxygen is provided by nasal cannula prior to the administration of NMB and until confirmation of endotracheal tube placement. Despite paralysis, the oxygen diffuses into alveoli and is absorbed within pulmonary capillaries, providing a continual alveolar-capillary gradient that “pulls” oxygen from the hypopharynx to distal alveoli.^{1,2} A review of eight studies from primarily

obese adult operative patients documented prolonged duration of normal saturation during apnea and no reported complications.¹ Reported barriers have been requirements for two sources of oxygen, and the potential for the nasal cannulas interfering with airway management.⁷

Apneic oxygenation in critically ill patients is not entirely novel. In an injured lung experimental animal model, apneic oxygenation markedly prolonged the time to severe desaturations.⁸ In a recent adult study, air medical crews reported a decreased incidence of desaturations with apneic oxygenation.⁹ In pediatrics, apneic oxygenation is required for brain death guidelines, as $\text{SpO}_2 > 85\%$ is maintained in the absence of ventilation.¹⁰ However, to our knowledge there have been no prospective studies or case series reported on apneic oxygenation in critically ill pediatric patients.

The purpose of this study was to document the degree of hypoxemia and potential complications associated with apneic oxygenation of critically ill pediatric patients, in a pediatric emergency department and medical surgical ICU.

Methods

Pediatric patients intubated between August 2014 and February 2015 at Winnipeg Health Sciences Centre, Canada, were examined in this prospective case series.

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The University of Manitoba granted ethics approval for this project.

Subjects

All patients <18 years of age who were intubated in the PICU or emergency department received apneic oxygenation, and data were prospectively collected. Exclusion criteria from this case series included nonurgent airway management, rare anatomical abnormalities that were not compatible with nasal cannula, or significant intrapulmonary or cardiac shunting with $\text{SpO}_2 < 90\%$ just prior to NMB.

Definitions

An intubation attempt was defined as any advancement of the laryngoscope blade past the patient's teeth. The initiation of apnea was determined at the loss of spontaneous chest rise, or no chest rise following bag and mask ventilation. The apneic period ended with the clinical verification of correct endotracheal tube placement (bilateral chest rise, auscultation of chest and epigastrium, physiologic capnograph, and tube fogging), and ability to bag and mask ventilate.

Intubation Procedure

Preoxygenation was performed for at least 3 minutes on all patients with either high-flow nasal cannula at 15 L/min O_2 , or continuous positive airway pressure (CPAP) mask ventilation at a minimum of 8 cm H_2O and 10 L/min O_2 , or bag and mask ventilation with flow-inflating bags and 15 L/min O_2 . CPAP or high-flow nasal cannula was only utilized if the patient had noninvasive ventilation requirements prior to intubation. Bag and mask ventilation was utilized if patients required ventilatory support or could not maintain $\text{SpO}_2 < 95\%$ with CPAP or high-flow nasal cannula. Prior to induction, the patient was positioned flat in the sniffing position, with their tragus on a similar plane as their sternal notch, chin lifted and jaw thrust. Ketamine, fentanyl, midazolam or propofol with 1 mg/kg of rocuronium, respectively, were the hypnotic and NMB agents used for RSI. To facilitate training, the initial intubation attempt was attempted by a resident and followed by a pediatric intensivist if necessary. After confirmation of a correctly placed endotracheal tube, mechanical ventilation was initiated, and sedation was maintained with a continuous intravenous infusion of fentanyl and/or midazolam. All patients were monitored with continuous cardiorespiratory monitoring, cycling noninvasive blood pressure, and peripheral pulse oximetry during the intubation, with end tidal CO_2 monitoring immediately after intubation.

Apneic Oxygenation

During the 3-minute preoxygenation period of RSI, low-flow nasal cannulas were placed in the nares of each patient. If patients were supported with high-flow oxygen prior to intubation, their specialized cannulas were utilized instead. After the NMB agent was administered and apnea confirmed, patients <4, 4 to 12, and 12 to 18 years of age received oxygen at flow rates of 5, 10, and 15 L/min, respectively. These

graduated rates were based on recommendations from an advanced pediatric emergency medicine assembly,¹¹ and are consistent with recommended adult rates of 15 L/min.¹ If the intubation attempt was unsuccessful and the $\text{SpO}_2 < 90\%$, bag mask ventilation was initiated without the removal of the nasal cannula.

Variables

Baseline patient data including age and primary diagnosis were obtained. RSI data including preoxygenation support, pre- and lowest postintubation attempt SpO_2 , and complications were also recorded. The inability to create an adequate seal for bag mask ventilation was considered as an adverse event.

Statistics

Statistical analysis included frequencies, percentages, and means. Data were analyzed using SPSS version 22 (IBM Corp, Armonk, New York, United States). Proportions between groups were compared using a chi-square test. Differences of mean apneic time were calculated by an independent sample *t*-test. Statistical significance was considered at 0.05.

Results

The mean age of patients ($N = 44$) was 5.4 years (SD, 6.19) (► **Table 1**). Central nervous system ($n = 18$) and respiratory presentations ($n = 17$) represented the largest primary diagnoses. Three-minute preoxygenation strategies included bag and mask ventilation ($n = 16$), high-flow nasal cannula ($n = 16$), and CPAP ($n = 14$).

Table 1 Study population ($N = 44$)

Age (y)	
< 4, n (%)	26 (59)
4–12, n (%)	6 (14)
12–18, n (%)	12 (27)
RSI indications	
CNS, ^a n (%)	18 (41)
Respiratory, ^b n (%)	17 (39)
Cardiovascular, ^c n (%)	5 (11)
Airway pathology, n (%)	3 (7)
Neuromuscular, n (%)	1 (2)
Preoxygenation strategy	
Bag mask ventilation, n (%)	16 (36)
High-flow nasal cannula oxygen, n (%)	14 (32)
CPAP, n (%)	14 (32)

Abbreviations: CNS, central nervous system; CPAP, continuous positive airway pressure; RSI, rapid sequence intubation.

Note: Data reported as frequencies and percentages.

^aSeizures, stroke, traumatic brain injury, infection, hypoxic ischemic encephalopathy.

^bPneumonia, bronchiolitis, acute respiratory distress syndrome, mass.

^cCongenital heart disease, myocarditis, sepsis.

Eleven patients required two or more intubation attempts for a total of 58 attempts. Pre- and postintubation attempt mean SpO₂ values were 98.9 ± 2.95 and 90.7 ± 1.95%, respectively. Postintubation attempt SpO₂ < 80% were found in 10 attempts (19%) and was not associated with preoxygenation strategy (*p* = 0.59); all but one child was <4 years of age (–Table 2). The mean apneic time was significantly less for the postintubation attempt SpO₂ < 80% group (66 ± 19 vs. 86 ± 26 s; *p* = 0.04). The postintubation SpO₂ < 80% was significantly less with one intubation attempt, compared with two and three attempts (*p* < 0.0001) (–Table 3).

No serious complications including dysrhythmia, cardiac arrest, or death were noted. The presence of the cannula did not affect the seal for bag mask ventilation.

Discussion

The purpose of this prospective case series was to report recent experiences from 58 intubation attempts with apneic oxygenation during RSI. The mean postintubation attempt SpO₂ was 90.7 ± 1.95%. For 10 attempts (19%), the lowest postintubation SpO₂ was less than 80%. Postintubation SpO₂ < 80% were significantly less with one intubation attempt. No complications were documented, and the cannula did not negatively impact bag mask ventilation when required.

With apneic oxygenation, several points may be considered for the 19% of patients with SpO₂ < 80% postintubation attempt. First, this degree of hypoxemia had been previously documented with PICU intubations.³ In that multicenter study, 11% of patients had difficult airways (defined as requiring three or more intubation attempts), compared with 7% of our patients. Another multicenter PICU study reported a desaturation rate of 13.5% on initial intubations, and two or more attempts associated with severe intubation adverse events.⁶ Given that difficult airways

also have a much higher risk for hypoxemia,³ our findings may reflect a population that was easier to intubate. Second, all but one patient was <4 years of age, and all had preintubation SpO₂ of nearly 100%. Their unique lung pathology, increased metabolic demands, and lower functional residual capacity may be contributing factors. These findings may identify a higher risk cohort for hypoxemia and the subsequent requirement for more experienced operators for the initial intubation attempt. Finally, a shorter apneic period was paradoxically documented in this cohort, and multiple intubation attempts were associated with desaturations despite adequate preoxygenation for each subsequent attempt. Together, this may reflect either an increased level of patient acuity or a precipitous termination of an intubation attempt secondary to rapid desaturations, or both. A larger sample is required to better characterize these events, but these findings may help to stratify a high-risk group for hypoxemia and subsequent interventions during RSI. Nevertheless, large prospective experimental trials are necessary to demonstrate superior practice.

Apneic oxygenation was not associated with any significant adverse events. Complications such as dysrhythmia, cardiac arrest, or death have been associated with hypoxemia,^{4–6} and were not reported with any intubation attempts. In all 10 patients who required more than one attempt, an effective seal was created with subsequent bag mask ventilation for preoxygenation. Although recognition of a poor seal and removal of nasal cannula should be simple and quick, even a short delay could be precarious for patients with steep hypoxemic trajectories.

The two major limitations of our case series are its small sample size and generalizability to other PICUs. However, to our knowledge, it is the largest case series yet reported in critically ill children. Furthermore, the principles of apneic oxygenation appear to address the pathophysiological considerations of critically ill children requiring RSI, but data from other PICUs would be necessary to potentially change widespread practice.

Apneic oxygenation during RSI in critically ill children was well tolerated in a medical surgical PICU, with no reported complications. Future experimental studies will be required to demonstrate whether apneic oxygenation reduces degree of hypoxemia during RSI.

Table 2 Postintubation desaturations < 80%

Age	Attempts	Desaturations, n (%)
<4 y	39	9 (23) ^a
4– 2 y	6	0 (0)
≥12 y	13	1 (8)

Note: Data reported as frequencies and percentages.
^a*p* = 0.2.

Table 3 Postintubation saturations < 80% for number of intubation attempts

Number of intubation attempts	Patients	Desaturations, n (%)
One	33	1 (3) ^a
Two	8	6 (75)
Three	3	3 (100)

Note: Data reported as frequencies and percentages.
^a*p* < 0.0001.

Conflict of Interest
None.

Financial Disclosure
None.

References
1 Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. *Ann Emerg Med* 2012;59(3):165–75.e1

- 2 Weingart SD. Preoxygenation, reoxygenation, and delayed sequence intubation in the emergency department. *J Emerg Med* 2011;40(6):661–667
- 3 Graciano AL, Tamburro R, Thompson AE, Fiadjoe J, Nadkarni VM, Nishisaki A. Incidence and associated factors of difficult tracheal intubations in pediatric ICUs: a report from National Emergency Airway Registry for Children: NEAR4KIDS. *Intensive Care Med* 2014;40(11):1659–1669
- 4 Davis DP, Hwang JQ, Dunford JV. Rate of decline in oxygen saturation at various pulse oximetry values with prehospital rapid sequence intubation. *Prehosp Emerg Care* 2008;12(1):46–51
- 5 Mort TC. The incidence and risk factors for cardiac arrest during emergency tracheal intubation: a justification for incorporating the ASA Guidelines in the remote location. *J Clin Anesth* 2004;16(7):508–516
- 6 Nishisaki A, Turner DA, Brown CA III, Walls RM, Nadkarni VM; National Emergency Airway Registry for Children (NEAR4KIDS); Pediatric Acute Lung Injury and Sepsis Investigators (PALISI) Network. A National Emergency Airway Registry for children: landscape of tracheal intubation in 15 PICUs. *Crit Care Med* 2013;41(3):874–885
- 7 Moran C, Karalapillai D, Darvall J, Nanuan A. Is it time for apnoeic oxygenation during endotracheal intubation in critically ill patients? *Crit Care Resusc* 2014;16(3):233–235
- 8 Engström J, Hedenstierna G, Larsson A. Pharyngeal oxygen administration increases the time to serious desaturation at intubation in acute lung injury: an experimental study. *Crit Care* 2010;14(3):R93 10.1186/cc9027
- 9 Wimalasena Y, Burns B, Reid C, Ware S, Habig K. Apneic oxygenation was associated with decreased desaturation rates during rapid sequence intubation by an Australian helicopter emergency medicine service. *Ann Emerg Med* 2015;65(4):371–376
- 10 Nakagawa TA, Ashwal S, Mathur M, Mysore M; Committee For Determination Of Brain Death In Infants Children. Guidelines for the determination of brain death in infants and children: an update of the 1987 task force recommendations-executive summary. *Ann Neurol* 2012;71(4):573–585
- 11 Gausche-Hill M. High flow nasal cannula during RSI: does it prevent desaturation? Advanced Pediatric Emergency Medicine Assembly. Available at: http://www.acep.org/uploadedFiles/ACEP/MeetingSites/PEM/Educational_Programs/Gausche-Hill%20-%20High%20Flow%20Nasal%20Cannula%202013%20rev.pdf. Accessed July 20, 2015