The Anticipated and Unanticipated Pediatric Difficult Airway: Lessons Learned from the Pediatric Difficult Intubation (PeDI) Registry

Pete G. Kovatsis, M.D.
Senior Associate in Anesthesia
Children’s Hospital Boston
Assistant Professor of Anaesthesia
Harvard Medical School

Airway management is a fundamental aspect in the practice of anesthesia and plays essential roles in the intensive care unit, emergency room, inpatient units as well as out in the field. Patients’ airways and airway pathology have remained unchanged over the course of recorded history. However techniques & equipment have evolved dramatically in the modern era producing ever more complex airway procedures and interventions. We now appear to have an infinite amount of possible combinations of preparation and intervention for airway management. To complicate matters further, the definition of a difficult airway is inconsistent and varies not only in meaning and application but from one practitioner to another depending on their skill set and background. A clinician who cares only for adults may find neonatal airway fearful if not outright difficult when compared to an experienced Pediatric Anesthesiologist. Evidence based medicine for pediatric difficult airway management is poor at best comprised of anecdotal reports or small series from single institutions. Large database analyses primarily in adults such as from the United Kingdom and Denmark reveal that we are generally poor at predicting airway difficulty and are prone to many types of errors in assessment and intervention.3-5

Children undergoing anesthesia experience higher rates of airway-related adverse events than adults. Analysis of the American Society of Anesthesiologists Closed Claims database demonstrated that respiratory events were more common and with higher mortality in children.6 Although this increased mortality is well-recognized in general pediatric anesthesia practice, a significant knowledge gap of practices and outcomes exists in children with difficult direct laryngoscopy (DDL). The Fourth National Audit Project (NAP4) conducted by the Royal College of Anaesthetists in conjunction with the Difficult Airway Society studied major complications of airway management over a year’s time in the United Kingdom.3,4 They reported only 10 events in children, 4 of which were related to difficult intubation and complications included subglottic narrowing, aspiration and death. To address this knowledge gap, a multicenter Pediatric Difficult Intubation (PeDI) Collaborative was formed followed by the development of the PeDI Registry (PeDI-R).1 The PeDI-R is designed and implemented as a risk assessment tool and to catalogue outcomes of children with DDL. Our first overall analysis of 1018 patient encounters for intubation exposed a disturbingly high rate of 1 in 68 cardiac arrests1 which is significantly and unacceptably higher than the 1.4 in 10,000 incidence reported in the general pediatric anesthesia population.7 Furthermore, 20% of patients
experienced at least one complication and 9% experienced significant hypoxemia. Finally, the current tracheal intubation failure rate in this population is extraordinarily high (65% of all tracheal intubation attempts currently fail) which we believe is mainly due to the rapid desaturations of pediatric patients together with underlying gaps in providers’ knowledge and skills. The analysis also revealed that patients less than 10 kg and those that have more than two tracheal intubation attempts, short thyromental distance, and three direct laryngoscopy attempts before moving to an advance technique have a statistically significant higher complication rate. The more intubation attempts tried, the higher the rate of complications (Figure 1).  

The PeDI Collaborative estimated an incidence of between 2 to 5 difficult intubations per 1000 pediatric anesthetics. As this includes all anesthetics, the incidence would be even higher if only those cases were intubations were attempted are included. A high percentage of cases in the PeDI-R were anticipated to be difficult direct laryngoscopies (80%). This should have allowed the team to prepare better than in the unanticipated group which is supported by a lower median number of attempts in the anticipated compared to the unanticipated group (median [IQR]: 2 [1-3] vs 3 [2-4] respectively). However, increased attempts and lower body weight were associated with more complications in both groups. In the anticipated group, over 20% had 4 or more attempts with over 4% having 7 or more attempts, whereas the unanticipated group, nearly 71% had 4 or more attempts with over 15% having 7 or more attempts. These increased in overall attempts in the unanticipated group were associated with more severe complications suggesting that preparation does matter but we still need to improve our care in both groups.  

The median number of years of experience of the attending (or supervising) anesthesiologist was 8 years. Although the 1st attempt provider was similar between groups, the attending was the more successful provider in the 71% of the unanticipated difficult airway cases compared to the 38% in the anticipated. When analyzing cases with 5 intubation attempts to better understand the role of the device and personnel had in the airway management, standard DL was still used in 21% of fifth attempts despite DL’s extremely poor overall success rate of 12%. Attendings were the successful laryngoscopist in over 44% of these cases yet they only made the first attempt in 21%. Of
note, trainees made 20% of 5th intubation attempts (Figure 2). Given that more intubation attempts are associated with more complications including severe complications, are we taking training too far? If these additional attempts are performed for a trainee’s educational benefit, the experienced gained in these high risk intubations must be weighed against the potential for increased complications associated with each attempt. Together with the realization that the intubation has become difficult placing the patient into the highest risk category for complications, the transition to the most experienced provider must happen more quickly. This data is relevant to all providers who care for pediatric patients.\(^1\)

The PeDI Registry has shown hypoxemia as the most frequent complication in the management of pediatric difficult airways. Children are particularly vulnerable because of their smaller airways and increased rate of oxygen consumption. Trauma from repeated intubation attempts can cause severe airway obstruction and lead to hypoxemic cardiac arrest.\(^3,4\) Additionally, rapid desaturation in small children limits the time available to intubate the trachea. Due to this time pressure, tracheal intubation attempts are often interrupted because of oxygen desaturation. A retrospective cohort analysis of children age 3-12 years old undergoing rapid sequence induction revealed a 3.6% incidence of hypoxemia with severe hypoxemia in 1.7% and associated bradycardia of HR < 60 bpm at 0.5%.\(^10\) A preliminary retrospective review of infants undergoing pyloromyotomy uncovered an incidence of hypoxemia as high as 34% during intubation attempts and a possible association with more than one intubation attempt. Even when separating induction methods between a classic rapid sequence and a modified rapid sequence, the incidence of hypoxemia was still unacceptable high (40% and 24% respectively).

Remarkably little is known about how to improve outcomes in children with DDL despite the newly shown increased vulnerability of these children to peri-procedure adverse events including cardiac arrest, brain injury, and death due to failed attempts during difficult tracheal intubation.\(^1\) The PeDI Collaborative has a long term goal to improve safety of airway management in children with difficult intubations by reducing complications related to DDL. Our analysis of these difficult to intubate children shows a high complication rate that is multifactorial in origin. The patient-level factors
contributing to complications include abnormal airway physical examination and lower patient age and weight. Process factors associated with complications in this population included untreated oxygen desaturation and delay in transition from trainee to attending tracheal intubation attempts. The PeDI Collaborative is in the process of designing and implementing defined quality improvement (QI) processes targeted to reduce hypoxemia and multiple tracheal intubation attempts which is feasible and adoptable across our centers. The aim is a significant decrease tracheal intubation related complications by decreasing multiple tracheal intubation attempts. A simple first step in this goal is the use of supplemental or apneic oxygenation during the intubation attempt – i.e. providing pharyngeal oxygen insufflation while intubating. This should not only be implemented in the management of difficult airways but the PeDI Collaborative strongly recommends this in any early infant undergoing intubation.

Increasing evidence supports the utility of apneic oxygenation through increases in tolerable apneic time and decreases the incidence of hypoxemia in adults\textsuperscript{11-16} and in children.\textsuperscript{17,18} If the patient is apneic, bulk flow allows constant oxygen to alveolar units when the airway is open. A tracheal intubation attempt in children usually results in an open airway; direct laryngoscopy, video-laryngoscopy, fiberoptic intubation and most other airway techniques require that soft tissue is distracted and the tongue is out of the way to facilitate the intubation. Unless the child has laryngospasm or tissue displacement is ineffective for the chosen airway technique, apneic oxygenation would be expected to increase the time allowed for tracheal intubation and possibly decrease complications associated with multiple attempts and hypoxemia. The TruView EVO2, a video-laryngoscope with a passive oxygen insufflation port, resulted in oxygen saturations which were better maintained during infant intubations than a standard laryngoscopy performed with a Macintosh blade.\textsuperscript{19} The American Society of Anesthesiologists (ASA) advises to "administer facemask pre-oxygenation before initiating management of a difficult airway.\textsuperscript{20-22} The ASA further states that practitioners should "actively pursue opportunities to deliver supplemental oxygen throughout the process of difficult airway management". Although pre-oxygenation is routinely practiced in the PeDI Registry, few practitioners (10%) in the participating centers had provided supplemental oxygen during the actual intubation. The PeDI Collaborative now recommends that practitioners utilize one of three oxygenation/ventilation methods during the actual attempts at tracheal intubation for those with an anticipated or unanticipated difficult DL: (1) standard nasal cannula or if available supra-high flow nasal systems, (2) modified nasal airway with oxygen delivery throughout a difficult tracheal intubation or (3) continuous oxygenation through a supraglottic airway being used as a conduit for tracheal intubation.\textsuperscript{1} The supraglottic airway can also be used to support spontaneous ventilation or provide assisted or controlled ventilation throughout the intubation process.\textsuperscript{23,24} Despite our findings and strong recommendation to provide intubation attempt oxygenation, preliminary review of our registry has only seen an increase in its use from 10% to 20%.
Although this is a doubling of the oxygenation, we still feel that this is insufficient to 
maximize our safety goals in these high risk patients.

Applying a standard nasal cannula during mask ventilation may interfere with 
preoxygenation or mask ventilation after induction of anesthesia by increasing leak 
around the facemask. This will, in part, depend on the mask used as different 
manufacturers’ designs and materials may make it more difficult to adequately seal with 
nasal cannula in place. If this occurs, applying the nasal cannula at the end of facemask 
preoxygenation and prior to an intubation attempt is quick and still effective. Also, if 
providing mask ventilation with an inhalation agent, keep the nasal cannula oxygen flow 
off until mask ventilation has ceased and the intubation attempt starts to avoid diluting 
your inhalation agent by the nasal cannula oxygen flow. There are rare reports of gastric 
rupture with nasopharyngeal catheter delivered oxygen using normal flow rates in 
adults.25 The mechanisms of these cases of rupture remain unclear however they have 
been reported in adults ranging from age 35 -89 years of age. There is a long history of 
safe use of high flow nasal cannula oxygenation in children in neonatal and pediatric 
intensive care units with flow rates up to 20 to 30 l/min.26 There is little evidence basis 
for how much oxygen to give via standard nasal cannula. Most accept 1 – 2 L/kg/min as 
an acceptable range in children. Given that auxiliary oxygen ports on anesthesia 
machines generally have a maximum flow rate of 10L/min, the PeDI Collaborative, based 
on expert opinion, has agreed upon the following intervention flow rates:

**Recommended Oxygen Flow Rates:**

<table>
<thead>
<tr>
<th>Infant (&lt;12 months)</th>
<th>Standard nasal cannula (1-2L/kg/min)</th>
<th>Modified Nasal airway (L/Min)</th>
<th>Supraglottic Airway (L/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4-8</td>
<td>6</td>
<td>≥ 4</td>
</tr>
<tr>
<td>Child (&gt; 12months to 18yrs)</td>
<td>6-10</td>
<td>6</td>
<td>≥ 4</td>
</tr>
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Similar to the ICU, more sophisticated nasal apparatus may also be used 
which can significantly increase the flow rates to as high a 70L/min and provide 
humidification.27 In adults, these systems have also been shown to provide some measure 
of ventilation as well minimizing the buildup of CO₂.27,28 This latter finding is much less 
clear in the pediatric population.29

A recent analysis of PeDI Registry data comparing DL use with GlideScope® VL 
(GVL)² exposed that in this pediatric population with anticipated or newly discovered 
difficult DL:

- Standard DL was an overly used technique with an extremely low success rate in this high risk patient population.
- Initial DL success rate was only 4 % and overall success was 21% in those cases where the care team persisted with DL
- As expected, GVL was associated with a higher chance of success (initial success
= 53%, overall success = 82%) but these success rates were much lower in children and particularly children less than 10 kg (initial success = 39%, overall success = 73%) [figure 3] when compared with published adult data with success rates approximating 95%.30-32

- Complication rates between DL and GVL were similar.
- Each additional attempt with either device resulted in a two-fold increase in the complications.

Again, our data reveals that repeated attempts, even when utilizing video-laryngoscopy (VL), are associated an increased risk of complications.

![Figure 3: Initial and eventual success for GlideScope® videolaryngoscopy (GVL) and direct laryngoscopy (DL) for all patients and patients less than 10 kilograms. For all patients and also for patients less than 10 kg, GVL had significantly higher initial and eventual success rates than DL. For patients less than 10 kg, GVL had significantly lower initial and eventual success rates than for all GVL patients. Rates of intubation success did not differ significantly between DL patients less than 10 kg and all DL patients. *Statistically significant.](image)

Comparing VL to flexible fiberoptic intubation via a supraglottic airway (FOI-SGA) in the PeDI Registry showed that first attempt success rates were similar, albeit poor (51% vs 59%, respectively)24. Yet the FOI-SGA, when chosen as the 1st technique, had fewer overall attempts, less of a need for changes in intubation techniques, and higher overall success. Also within the infant subgroup, FOI-SGA had a statistically higher 1st attempt success rate (54% vs 36%). Complication rates were similar between the two techniques yet when continuous ventilation through the SGA was utilized, the incidence of hypoxemia was lower. This later finding adds further support to the benefit of using supplemental oxygenation during an intubation attempt.

In conclusion, the difficult airway is not straight forward in either its presentation
or definition. The management of the pediatric difficult airway requires clinical expertise and repeated practice both in mannequins as well as normal airways to gain the skill and expertise needed to then improve the safety and success of these high risk, difficult airway, pediatric patients. One easily implemented step that will hopefully provide this for us is the use of apneic oxygenation which is expected to result in a significant reduction in hypoxemia and tracheal intubation attempts leading to a decrease in both the frequency and severity of highly morbid complications such as cardiac arrest.

**Disclosures:** Medical Advisor to Verathon Medical, Inc.

**References:**

11. 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: 371-6
15. Sakles JC, Mosier JM, Patanwala AE, Dicken JM: Apneic oxygenation is associated with a reduction in the incidence of hypoxemia during the RSI of patients with intracranial hemorrhage in the emergency department. Intern Emerg Med 2016