Clinical paper

Airway management in pediatric patients at referring hospitals compared to a receiving tertiary pediatric ICU

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Objective: To describe the current practice of pediatric airway management at referring hospitals and the associated adverse events compared to a receiving tertiary pediatric ICU.

Method: Retrospective chart and transport record review of all emergency critical care transports to our Pediatric ICU over 3 years. Data regarding tracheal intubation procedure, pre-defined adverse Tracheal Intubation Associated Events (TIAEs), and airway events before, during, and after the inter-hospital transport were collected using a standard National Emergency Airway Registry for children (NEAR4KIDS) definition. Tracheal intubation outcomes were compared to in-hospital PICU intubations.

Results: 253/1489 (17%) of critical care transports had airway management, all by tracheal intubation. The most common condition was seizure (34%), followed by pulmonary/lower airway disease (16%). 49 (19%) had TIAEs; the most common event was mainstem bronchial intubation (13%). Incidence of TIAEs was similar to PICU (p = 0.69). Thirteen had an inappropriate tracheal tube position upon PICU arrival, but none experienced accidental extubation during transport. An uncuffed tracheal tube was used in 108/172 (63%) of patients < 8 years, significantly higher than PICU (20%, p < 0.0001). 124 (49%) were extubated within 24 h, 153 (60%) within 48 h. Two patients had the tracheal tube changed to cuffed from uncuffed due to air leak.

Conclusion: Provider reported adverse TIAEs are common during airway management in children requiring critical care transport, but not higher compared to PICU intubations. Most inter-hospital transport patients are intubated with an uncuffed tracheal tube. Subsequent tracheal tube change from uncuffed to cuffed tube is rarely required.

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1. Background

Sick children often present to community hospitals. Those patients require initial stabilization which often includes emergency airway management. This airway management is also often required to safely transfer critically ill children to a tertiary care center. Pediatric emergency airway management at community hospitals is considered an infrequent yet high risk procedure. The practitioners may not be familiar with pediatric airway anatomy and pediatric specific physiology such as smaller functional residual capacity and shorter tolerable apnea time for direct laryngoscopy. Those anatomical and physiological differences may lead to more frequent adverse events such as critical hypoxia, when compared to adults. Nevertheless, little data exist to describe current pediatric airway management practices at various referring facilities. There are also scarce data to describe further airway maneuvers required at the receiving facility. The purpose of study is to describe our current community referral hospital practice and adverse tracheal intubation associated event (TIAE) risk in pediatric acute airway management in a high risk population who required critical inter-hospital transport with advanced airway support. We hypothesized that airway management performed at referring hospitals is associated with higher incidence of adverse TIAEs when compared to similar groups of patients intubated within our tertiary Pediatric ICU. We also hypothesized a higher proportion of uncuffed tracheal tube use compared to airway management in the PICU, and that this would result in tracheal tube change procedures after critical inter-hospital transport.
This retrospective study was designed to provide preliminary data for the future implementation of an airway assistance system to improve the safety and quality of airway management for children at referring community hospitals.

2. Method

With our Institutional Review Board approval, a single center retrospective cohort study was designed. All critically ill children during January 2006 to December 2008 who experienced a pediatric critical inter-hospital transport into our tertiary care non-cardiac Pediatric ICU with an advanced airway (i.e. tracheal tube, laryngeal mask, newly placed tracheostomy or cricothyrotomy) were evaluated.

2.1. Study population

Critical care inter-hospital transport record during the study period was obtained and screened for inclusion and exclusion criteria. Inclusion criteria were as follows: patients transferred into our tertiary Pediatric ICU with advanced airway defined as a tracheal tube, a laryngeal mask airway, a combitube, a fresh tracheostomy, or a cricothyrotomy. Exclusion criteria were: patients with chronic stable tracheostomy tube, and patients transported into Cardiac ICU since it may represent a specific population.

2.2. Data acquisition

Pre-transfer record: the transport record including the transcript of phone conversations between the referring facilities and the transport team, and the critical care transport team command officer, and actual written medical record of medical transfer team was reviewed from electronic medical record (Chartmaxx, MedPlus, Inc. Mason, OH), and electronic transport record system (Wellsoft, Wellsoft Corp., Somerset, NJ). The referring hospital records were reviewed when available. In the majority of the cases, they were abstracted as a part of transport records. The intra-hospital transport record is also reviewed and abstracted. The Pediatric ICU record and digital radiological images were reviewed using electronic medical record system. One data abstractor (NM) was trained and abstracted all records for consistency. All records were reviewed twice for accuracy. For controversial cases, both NM and AN (investigator) reviewed the case and came in agreement.

For the recommended tracheal tube size, the following formula in Pediatric Advanced Life Support was used for both cuffed and uncuffed tracheal tube for age 1–7 years old:

\[
\text{Cuffed tube size: age (year)/4 + 3 (mm: internal diameter)}
\]

\[
\text{Uncuffed tube size: age (year)/4 + 4 (mm: internal diameter)}
\]

For the comparison of the incidence of tracheal intubation associated events (TIAEs) against Pediatric ICU intubations, our single center local Pediatric ICU airway management registry: National Emergency Airway Registry for children (NEAR4KIDS) data were obtained from January 2005 to August 2008.\(^9\) This data registry collected all tracheal intubation events prospectively in pediatric ICU, with specific operational definitions and a redundant data crosscheck system by designated quality improvement personnel in place.\(^11\)

2.3. Statistical method

The sample size is primarily limited by the available inter-hospital transport log since January 2006. We estimate approximately 250 subjects are eligible during this proposed study period: January 2006 to December 2008. We estimate the tracheal intubation associated events during pre-transport would be at 30%, while the incidence proportion in PICU during the study period is 20%. Considering those with alpha = 0.05 and power = 0.8, and the ratio of tracheal intubation (transport vs. Pediatric ICU) = 1:2, we estimated the sample size as 230 intubations in transport group.

Descriptive statistics using median and interquartile range (IQR) were reported. Fisher’s Exact test was used for contingency table analysis. Wilcoxon rank-sum test was used to compare the non-parametric variables. Two-tailed alpha = 0.05 was used, p < 0.05 was considered as statistically significant. STATA version 11.0 (STATA Corp., College Station, TX) was used for statistical analysis.

3. Result

One thousand four hundred and eighty-nine critical intra-hospital transports to our Pediatric ICU occurred during the study period between January 2006 and December 2008. Among those, 253 (17%) cases had advanced airway during the transport, therefore met the study criteria.

3.1. Patient demographics and initial airway management at referring facility (Table 1)

The median age was 40 months (IQR: 14.1–127.9), and median weight was 15 kg (IQR: 10–34). A majority (78%) of the patients were transferred from a general Emergency Department to the tertiary Pediatric ICU. The most common causes for advanced airway management were: seizure (85 cases, 34%), pulmonary and lower airway disease (40 patients: 16%), and toxin/poison (32 patients, 13%). The majority of the patients were intubated with sedation and paralytics (Table 2). Cuffed tracheal tubes were used in 124 patients (49%) overall. Cuffed tracheal tubes were used only in 21% of patients less than one year old, and 40% of patients 1–7 years old (Fig. 1). Tracheal tube size was calculated as appropriate size in 64/122 (52%), larger than recommended in 43/122 (35%), and smaller than recommended in 15 (23%) in children between 1 and 7 years old.

3.2. Outcome and consequences of the airway management

Six percent (13/227) of the patients had inappropriate tracheal tube tip position upon arrival to the referral Pediatric ICU (2 patients at extrathoracic position, 9 patients at mainstem bronchus, 2 patients at carina), requiring urgent adjustment. No accidental extubation occurred during inter-hospital transport. 85% (216/253) of patients were successfully extubated in the Pediatric ICU, 11% (27/253) died in the ICU prior to extubation, and 3% (7/253)
required tracheotomy prior to discharge. Three patients were transferred out from Pediatric ICU before extubation. Among those surviving to extubation, 57% (123/216) were extubated within 24 h, and 70% (151/216) were extubated within 48 h. The median duration until extubation after PICU arrival was 15.2 h (IQR: 6.6–60.8).

### 3.3. Incidence of tracheal intubation associated events: TIAEs in pre-transport airway management

Self-reported TIAEs were documented in 49 (19%) of the patients during pre-transport airway management: 13 (5%) had severe TIAEs and 36 (15%) had minor TIAEs (Table 3). Three patients had both severe and minor TIAEs. The most common TIAE was mainstem bronchial intubation (34 patients: 13.4%), followed by emesis with aspiration (4 patients: 1.6%), and pneumothorax/pneumomediastinum (4 patients: 1.6%). The incidence of TIAEs was not significantly different among referring units (Emergency Department: 19%, Pediatric ICU: 26%, Pediatric ward: 21%, p = 0.46, Fisher’s Exact).

### 3.4. Comparison to Pediatric ICU airway practice

The pre-transport advanced airway management was compared to the airway management in the Pediatric ICU during January 2005 to August 2008 through the Pediatric ICU NEAR4KIDS airway database. A total of 406 primary tracheal intubations were reported during this period. Patient age and weight were not different from the pre-transport airway management cohort (median age 40 months, weight 15 kg).

Cuffed tracheal tubes were used more often (Pre-transport: 35% vs. Pediatric ICU: 76%, p < 0.001) for patients less than 8 years. The overall incidence of TIAEs were similar (Pre-transport: 19% vs. Pediatric ICU: 21%, p = 0.69). The proportion of severe TIAEs was not different (p = 1.00, Table 3). In the minor TIAE category, pre-transport airway management was associated with higher incidence in mainstem bronchial intubation (13% vs. 4%, p < 0.001, Table 3). The esophageal intubation with immediate recognition was not documented in any cases in pre-transport airway management, while this was commonly observed in Pediatric ICU (0% vs. 9%, p < 0.001, Table 3).

### 4. Discussion

Our study describes the current landscape of emergency airway management at the referring hospitals for children who were transferred to our tertiary care Pediatric ICU by a pediatric critical care transport system. Unwanted tracheal intubation associated events (TIAEs) were commonly documented in this emergency setting (19%), but without significant difference from our Pediatric ICU incidence reported by our National Emergency Airway Registry (NEAR4KIDS). Mainstem bronchial intubation was more common at the referring hospitals, while the esophageal intubation with immediate recognition was not documented in any case. Uncuffed tracheal tubes were used for young children at referring hospitals much more commonly than in our Pediatric ICU (35% vs. 76%).

Contrary to our hypothesis, a majority of patients who had an uncuffed tracheal tube did not require tracheal tube change to auffed tube after inter-hospital transport. This appears to be due to short duration of expected mechanical ventilation in our patient population. This is probably also due to majority of patient condition being non-respiratory causes so that patients did not require a high inspiratory pressure for adequate ventilation.

Easley et al. prospectively studied 250 critically ill pediatric patients who required tracheal intubation before admission to
the PICU.12 40% of their patients were from the ED in the same hospital without inter-hospital transport. A half of tracheal intubation at outside referring hospitals did not use paralytics, while majority (80%) of intubations at their own ED utilized paralytics for intubation. They reported process variences (mainstem bronchial intubation, multiple attempts, airway trauma, etc.) in 37% of patients who received tracheal intubation at referring hospitals, which was significantly higher than the patients who had tracheal intubation at their own hospital ED (17% experienced process variences). Our study reported much lower incidence of TIAE (20%) in tracheal intubation at referring hospitals comparing to their study. We speculate this may be due to the reporting bias, and the retrospective nature of our study. A further study with prospective data collection is necessary to clarify this issue. This difference also can be explained by the geographic difference of the referring hospitals. The majority of the referring hospitals locates at urban and suburban regions in our study, and those hospitals might be staffed with more pediatric-trained practitioners.

Sagarin et al. reported 156 pediatric intubations at 11 EDs from National Emergency Airway Registry.5 They reported 17% (27/156) TIAE rate in pediatric intubation in the EDs. The most commonly self-reported adverse event was mainstem bronchial intubation, followed by esophageal intubation with immediate recognition. They also reported 2 cases with significant desaturation, one case with pneumothorax, and one case with pneumomediastinum. While their study is also subject to reporting bias, the incidence and characteristics of TIAEs were quite similar to our study.

Walls et al. recently reported the ED intubation practice in more than 8000 encounters including both adults and children from 31 EDs.13 ‘Encounter’ is defined as one episode of completed advanced airway management intervention, including tracheal intubation. Rapid sequence intubation defined as use of sedatives and paralytics was the initial method chosen in 69%, 84% of encounters received at least one intubation medication. Those rates are similar to the method of intubation reported in our study (Table 2). We believe our data reflect the current practice in pediatric airway management in the EDs.

Our study documented inappropriate tracheal tube position in 13 patients (5.1%) in the first chest radiograph after arrival to PICU. Clearly both the referring hospital providers and the transport teams contributed to the tracheal tube position upon arrival to Pediatric ICU.

Orf et al. evaluated the appropriate tracheal tube position during the flight transport.14 They retrospectively reviewed 216 patients and identified 113/199 (57%) tracheal tube was not positioned appropriately, and majority (109/113) were too deep, based on the currently recommended guidelines using Pediatric Advanced Life Support-based guidelines.9 They reported the receiving hospital adjusted the tracheal tube depth in 72/216 (33%). In contrast to their study, our study documented a quite low rate of inappropriate tube position. This seems to be due to the confirmation of the tracheal tube position by a radiograph prior to the transfer, not with the empirical formula to estimate appropriate depth.

Despite the fact that the tube size might be inappropriate based on the commonly recommended formula, most of our patients did not require tracheal tube change, since the majority were extubated within 48 h. While the cuffed tracheal tube may be preferred in the ventilator management in PICU, only a few cases experienced tube change due to air leak around the tracheal tube. This highlights the definite indication of cuffed tracheal tube: airway disease or lung disease with poor compliance or significant oxygenation challenges.

This study result needs to be interpreted in light with important limitations.

First, this study was conducted as retrospective data and chart review. The accuracy of the report is substantially augmented by a realtime annotation in Wellsoft system by trained personnel in our transport system. However, it is quite possible that the referring hospitals tend to self-report and document TIAEs less than actually occurred, especially for minor events. We speculate this was the explanation for the non-existence of ‘esophageal intubation with immediate recognition’ events in referring hospital airway management. The actual incidence of TIAEs are referring hospitals would be higher than reported here.

Second, we did not have method to re-confirm the medication administration at the referring hospital.

Third, we were not able to identify the practitioner’s discipline or training level at the referring hospital. The airway provider’s discipline and training level is known to be one of important predictors for airway management success and tracheal intubation.

Table 3
Tracheal intubation associated events (TIAE) in pre-transport airway management vs. Pediatric ICU.

<table>
<thead>
<tr>
<th>Severe TIAE</th>
<th>Pre-transport (n = 253)</th>
<th>Pediatric ICU (n = 406)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotension requiring treatment</td>
<td>2 (0.8%)</td>
<td>8 (2.0%)</td>
<td>0.33</td>
</tr>
<tr>
<td>Vomit with aspiration</td>
<td>4 (1.6%)</td>
<td>3 (0.7%)</td>
<td>0.44</td>
</tr>
<tr>
<td>Cardiac arrest (patient survived)</td>
<td>1 (0.4%)</td>
<td>5 (1.2%)</td>
<td>0.42</td>
</tr>
<tr>
<td>Cardiac arrest (patient died)</td>
<td>1 (0.4%)</td>
<td>2 (0.5%)</td>
<td>1.00</td>
</tr>
<tr>
<td>Esophageal intubation without immediate recognition</td>
<td>1 (0.4%)</td>
<td>1 (0.3%)</td>
<td>1.00</td>
</tr>
<tr>
<td>Laryngospasm</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Malignant hyperthermia</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Pneumomediastinum</td>
<td>4 (1.6%)</td>
<td>2 (0.5%)</td>
<td>0.21</td>
</tr>
<tr>
<td>Direct airway injury</td>
<td>1 (0.4%)</td>
<td>0 (0%)</td>
<td>0.38</td>
</tr>
<tr>
<td>Any severe TIAE</td>
<td>13 (5.1%)</td>
<td>21 (5.2%)</td>
<td>1.00</td>
</tr>
<tr>
<td>Minor TIAE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esophageal intubation with immediate recognition</td>
<td>0 (0%)</td>
<td>38 (9.4%)</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Mainstem bronchial intubation with delayed recognition</td>
<td>34 (13.4%)</td>
<td>16 (3.9%)</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Dental/lip trauma</td>
<td>1 (0.4%)</td>
<td>10 (2.5%)</td>
<td>0.06</td>
</tr>
<tr>
<td>Vomit without aspiration</td>
<td>3 (1.2%)</td>
<td>7 (1.7%)</td>
<td>0.75</td>
</tr>
<tr>
<td>Hypertension requiring treatment</td>
<td>0 (0%)</td>
<td>3 (0.7%)</td>
<td>0.29</td>
</tr>
<tr>
<td>Epistaxis</td>
<td>0 (0%)</td>
<td>1 (0.3%)</td>
<td>1.00</td>
</tr>
<tr>
<td>Medication error</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Dysrhythmia</td>
<td>1 (0.4%)</td>
<td>2 (0.5%)</td>
<td>1.00</td>
</tr>
<tr>
<td>Pain/agitation requiring additional medication and delaying intubation</td>
<td>1 (0.4%)</td>
<td>2 (0.5%)</td>
<td>1.00</td>
</tr>
<tr>
<td>Any Minor TIAE</td>
<td>39 (15.4%)</td>
<td>71 (17.5%)</td>
<td>0.52</td>
</tr>
</tbody>
</table>

n/a: not applicable.

* Note: some cases had more than one TIAE.

** p < 0.05.
associated events. We also attempted to collect the number of attempts at the referring hospitals; however, it was not documented in majority of the cases.

A well designed multi-center prospective study compatible to adult National Emergency Airway Registry (NEAR) should be able to address those limitations in the future study.

5. Conclusions

Our study describes the current airway management practice for children who required inter-hospital critical care transport to our tertiary ICU. Adverse tracheal intubation associated events (TIAEs) were commonly self-reported and documented by referring hospital providers, but the overall incidence was not higher than that in a receiving Pediatric ICU. Tracheal intubations at referring hospitals were associated with higher incidence of mainstem bronchial intubations. This may reflect providers’ unfamiliarity to pediatric airways at the referring hospitals. Disproportionally low incidence of ‘esophageal intubation with immediate recognition’ seems to be due to underreporting by the referring hospital providers. The actual incidence of TIAEs at the referring hospitals would be potentially higher than reported here.

A majority of patients were extubated within 48 h after inter-hospital transport. Most inter-hospital transport patients are intubated with an uncuffed tracheal tube by referring hospital providers, and subsequent tracheal tube change from uncuffed to cuffed tube is rarely required. We recommend considering cuffed tracheal tube use at referring hospital EDs at minimum for children with respiratory failure, or for children who are expected to have a long (>2 days) mechanical ventilation course.

Conflict of interest statement

All authors do not acknowledge any conflicts of interest that could inappropriately influence the work and results presented in this manuscript.

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References