Effect of Recent Refresher Training on *in Situ* Simulated Pediatric Tracheal Intubation Psychomotor Skill Performance

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Abstract

Objective: Maintenance of competence in orotracheal intubation skills is challenging for non-anesthesiologists who do not practice intubation routinely. We hypothesized that discipline, recent training, and experience would affect immediate skill improvement during refresher training. **Methods:** Experienced pediatric providers refreshed intubation skills in six simulated infant trauma scenarios with cervical spine protection. Time (T) to successful intubation (in seconds) was used to calculate refresher training immediate effectiveness as a function of time to success at second vs. first session (T2/T1). **Results:** Twenty-six providers performed 156 intubations. Time to successful intubation (T1) was 33.8 ± 9.4 seconds (s) for the first scenario and for subsequent scenarios: (T2) 29 ± 6.4s, (T3) 27.4 ± 5.6s, (T4) 29.8 ± 9.2s, (T5) 28 ± 5.4s, and (T6) 25.6 ± 5.1s, with the largest improvement between T1 and T2. Immediate refresher training effectiveness (T2/T1) was associated with recent training ≤3 months ($P = 0.025$) but not with discipline ($P = 0.40$) or clinical experience >3 years ($P = 0.93$). Recent training remained significant ($P = 0.017$) in multivariable regression. The number of intubation attempts and the number of tracheal intubation-associated events were not different in recent training, discipline, or clinical experience. **Conclusion:** Recent tracheal intubation training, but not years of experience or discipline, is associated with immediate refresher training effectiveness.

Introduction

High-reliability organization theory supports a high number of operations, intensive training of personnel and teams, and intensive critiques of performance during operations and training in order to maintain a very low failure rate in high-hazard organizations.[1, 2, 3] However, in busy clinical settings, the allocation of workforce and education resources faces significant challenges. For better allocation of resources to improve patient safety in organizations, it would be helpful to know which factors are associated with the learning effect of refresher training to maintain clinical competence.

Many tasks required to maintain competence in clinical settings involve psychomotor skills with appropriate-level medical knowledge. Several studies have revealed that psychomotor skills required for crisis management, such as cardiopulmonary arrest, rapidly decay over time,[4, 5, 6, 7, 8] and do so faster than cognitive skills (medical knowledge).[5, 6, 7, 8]

Pediatric tracheal intubation is a critical psychomotor skill for pediatric resuscitation.[9, 10] It is also considered important to decrease the rate of failure to rescue, since many pediatric emergency conditions are associated with respiratory compromise, in contrast to cardiac problems in adult patients.[11] Therefore, providing airway training for practitioners to maintain this critical skill is routinely done in clinical settings. For example, competence in this skill is considered essential for pediatric residency training in the United States, as defined by the Accredited Commission for Graduate Medical Education (ACGME).[12]

The acquisition of this complex psychomotor skill requires significant training,[13, 14] and providers who conduct these procedures on a daily basis, such as anesthesiologists, are considered most competent. Furthermore, maintaining competence may require frequent refresher training,[15] since non-anesthesiology pediatric practitioners and trainees practice this psychomotor skill infrequently in actual clinical settings.[16, 17] Also, it has been reported that this essential skill is practiced less often by pediatric residents in clinical settings due to practice pattern changes, such as change of guidelines in neonatal resuscitation.[16] To keep clinical practice safe, we need to identify the most effective way for non-anesthesiologists to achieve and maintain psychomotor skill competence in this infrequently practiced but critical procedure.[18]

However, we do not know how rapidly pediatric tracheal intubation psychomotor skills decline, how often refresher training should be provided to maintain a high level of competence, or which factors are associated with refresher training effectiveness in non-anesthesiology practitioners who do not practice intubation regularly.

Medical simulation has been recognized as an effective tool to improve patient safety. Recently, the Agency for Healthcare Research and Quality (AHRQ) called for support for medical simulation research to improve patient safety.[19] Simulation has been utilized for various purposes, such as basic-to-advanced task training or team training—e.g., in crisis resource management. Recently, several studies found that simulation-based training effectively improved clinical operational performance with fewer adverse events.[20, 21] The U.S. Food and Drug Administration (FDA) now requires simulation-based training for a certain intravascular surgery device.[22]

Medical simulation has been used often to evaluate competence and training for emergencies.[23, 24] Objective competence measurement through simulation is more reliable compared to self-efficacy (a trainee's degree of confidence in performing a procedure evaluated by self-assessment).[3, 25] Recent studies suggest that competence measurement through simulation is valid and translates into operational performance in clinical settings.[3, 26, 27]

The purpose of this study was to investigate the factors associated with the effectiveness of refresher training in pediatric emergency intubation. Since pediatric intubation is a complex, risky procedure that does not occur on a regular basis for most non-anesthesiology practitioners, medical simulation was determined to be the best technique for this intubation training study. A high fidelity simulator was used in a simulated clinical setting to maximize the realism, to accurately reflect competence, and to maximize the learning effect.[28]

Methods

This study was conducted in an *in situ* simulation room auxiliary to the pediatric intensive care unit (PICU) of an urban children's hospital.[29] The simulation room was originally structured for acute patient care, similar to other PICU patient care rooms with two sets of suction, a monitor, and other patient care equipment in place. Non-anesthesiology pediatric practitioners who are credentialed in tracheal intubation in our institution were asked to participate voluntarily in this study from October 2006 to February 2007. Pediatric residents were not enrolled in this study, since their intubation rate and success rate have been low in the local airway registry data, and they are not the primary intubators on our transport team. A written consent was obtained from each subject.

A priori-defined pretraining data—including discipline, date of prior training involving pediatric intubation, years of experience performing pediatric intubations, and basic demographics (age, sex, and ethnicity)—were collected using a questionnaire at the time of training.

Each subject was asked to participate in six simulation sessions with identical objectives, all of which required pediatric advanced airway management, including orotracheal intubation for an infant trauma patient with C-spine stabilization. In each session, a subject performed as the primary airway provider. The team leader asked the subject to perform orotracheal intubation, randomized to one of three different cervical spine protection techniques: No physical protection (N), C-collar (C), or Manual in-line immobilization (M).[10] Each protection strategy was repeated once in the immediate next session. The order was randomized. For example, one subject performed orotracheal intubation with cervical protection strategy ordered N, N, C, C, M, M, where N = no protection; C = C-collar; M = manual inline immobilization (Appendix 1).

Each session was designed to last approximately 5 minutes, and the entire simulation evaluation consisted of six consecutive sessions and lasted approximately 1 hour in total.

To improve the accuracy of competence measurement and maximize the training effect, this study was conducted using a realistic, high fidelity infant simulator (SimBaby®, Laerdal, Norway).[28] The simulator was programmed to reproduce physical findings, quantify the specific functions, and perform specific prospectively designated measurements for this study (Appendix 2). End-tidal CO_2 was measured by a portable end-tidal detector (Handheld Capnograph/Oximeter Model 715, Respironics Novametrix, Inc., Wallingford, CT).

Scenario

Briefly, the scenario was as follows: A 6-month-old infant is involved in a motor vehicle crash. She arrives in the emergency department in a car seat and C-collar (Stifneck®, Laerdal Medical Corp., Wappinger's Falls, NY). She appears obtunded, with oxygen saturation of 93 percent, despite 100 percent oxygen via a properly fitted face mask. She has been moved to a stretcher for primary evaluation and advanced airway management. Minor, prospectively configured variations of this same scenario were repeated identically six times.

The simulator was preprogrammed to demonstrate saturation and heart rate changes during advanced airway management, with realistic timelines and triggers for response (Appendix 1).

For orotracheal intubation, a standard Miller 1 blade and a 3.5 uncuffed tracheal tube with appropriate sized stylet were provided.

The key actions were prospectively identified and defined as follows: Time of initiation of tracheal intubation was cessation of bag-valve-mask ventilation. Initiation of direct laryngoscopy was defined when the laryngoscope was inserted into the oral cavity of the simulator; initiation of tracheal tube insertion was defined when the tracheal tube visibly entered beyond the gum inside the oral cavity. As used in the procedural definitions for the National Emergency Airway Registry (NEAR),[30] duration of an intubation attempt was prospectively defined by the process starting at the cessation of bag-mask ventilation to time of confirmation of successful tracheal tube placement. A successful orotracheal intubation was defined as tracheal intubation with confirmed endotracheal tube position with primary (chest rise and auscultation) and secondary confirmation (positive end-tidal CO_2).[9]

The time to each key action (in seconds) was recorded by an investigator at the scene in a simulation event log. This was later reviewed to document the lowest saturation during each scenario and any tracheal intubation-associated event(s) that occurred during the scenario. Tracheal intubation-associated events were prospectively defined as:

- SpO_2 <60 percent.
- Bradycardia: heart rate <60 beats per minute.
- Hypotension: systolic blood pressure <70 mmHg.[9]
- Intubation failure:
  - No intubation success within 15 minutes.
  - Esophageal intubation with immediate recognition (prior to removal of laryngoscope).
  - Esophageal intubation with delayed recognition (after removal of laryngoscope, but recognized by a subject).
  - Missed esophageal intubation (never recognized by a subject).
  - Mainstem intubation with immediate recognition (prior to removal of laryngoscope).
  - Mainstem intubation, with delayed recognition (after removal of laryngoscope, but recognized by a subject).
  - Missed mainstem intubation (never recognized by a subject).[30, 31]

The same investigator attended all study sessions, to ensure consistency of simulation and entry of key action.

Statistical Analysis

The immediate effectiveness of refresher training was prospectively defined as the ratio of time required for successful intubation at the second vs. first session (T2/T1).

The time to successful intubation (in seconds) and immediate effectiveness of refresher training were considered as continuous parametric variables. Parametric data were described as mean ± standard deviation (SD); nonparametric data were described as median and interquartile range (IQR). To avoid confounding by intermittent periods of time required for appropriate rescue bag-mask ventilation, the sessions where subjects required more than one intubation attempt for success were analyzed separately.

As safety practice indicators, the number of intubation attempts required for intubation success and the number of predefined tracheal intubation-associated events were also analyzed as a secondary outcome.

Recent pediatric advanced airway management training (within 3 months)[15] and pediatric intubation experience (>3 years) were analyzed as dichotomous variables as defined *a priori*. Demographic data were compared with Fisher's exact test. Parametric variables were analyzed with unpaired Student's t-test or ANOVA. Nonparametric variables were analyzed with Wilcoxon rank-sum test or the Kruskal-Wallis test. Multivariable linear regression analysis was conducted to evaluate the impact of *a priori* selected independent variables. All statistical tests were performed with two tails, alpha = 0.05 as significant. STATA® 9.0 (Stata Corp, College Station, TX) was used for statistical analysis.

Results

Twenty-six skilled non-anesthesiology providers with a duty to provide advanced airway management at our tertiary care children's hospital (16 pediatric transport nurses, 4 pediatric emergency medicine fellows, and 6 pediatric critical care fellows) performed 156 intubations. The median length of pediatric intubation experience was 3.5 years (IQR: 2 - 5); the median duration from the most recent intubation training was 3.5 months (IQR: 0 - 8.5) (Table 1).

Three transport nurses, no emergency medicine fellows, and no pediatric critical care fellows needed two intubation attempts for successful orotracheal intubation at the first session (p=0.272, Fisher's exact test, among disciplines). All participants were successful at the first attempt in the second session. Overall, time (mean ± SD) to successful tracheal intubation (limited to those with first attempt success) at the first session (T1) was 33.8 ± 9.4 seconds (s), and for the subsequent sessions: (T2) 29.0 ± 6.3s; (T3) 27.4 ± 5.6s; (T4) 29.8 ± 9.2s; (T5) 28.0 ± 5.4s; and (T6) 25.6 ± 5.1s (Figure 1). The largest improvement was seen between the first (T1) and second sessions (T2). T2, T3, T5, and T6 were significantly shorter compared to T1 (t-test, $P < 0.05$, $P < 0.01$, $P < 0.01$, and $P < 0.01$, respectively); however, T4 was not (t-test, $P = 0.14$). The

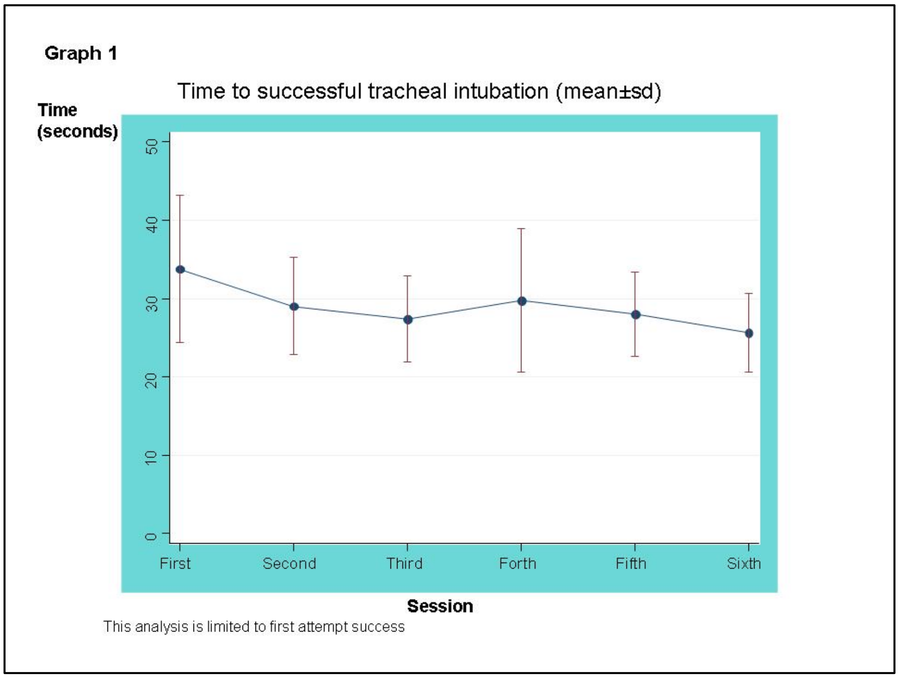

Figure 1. Time to successful tracheal intubation (mean ± SD).

improvement between two consecutive sessions was only significant between T1 and T2 (t-test, $P < 0.05$); subsequent improvement was not statistically significant (T2 vs. T3: $P = 0.36$; T3 to T4: $P = 0.29$; T4 to T5: $P = 0.41$; T5 to T6: $P = 0.11$).

Overall immediate effectiveness of refresher training assessed by T2/T1 was 88 ± 24 percent, indicating that a 12-percent reduction in time (seconds) to successful intubation was observed at the second scenario compared to first scenario.

Univariate analysis revealed the immediate effectiveness of refresher training was significantly associated with recent pediatric advanced airway training (with recent training 0.74 ± 0.17 vs. no recent training 0.98 ± 0.26, $P = 0.025$, unpaired t-test) but not with provider clinical experience in pediatric intubation >3 years (with >3 years experience, 0.88 ± 0.23 vs. ≤3 years experience, 0.89 ± 0.26, $P = 0.93$, unpaired t-test) or discipline (transport nurse 0.94 ± 0.24 vs. emergency medicine fellow, 0.81 ± vs. 0.18; critical care fellow 0.80 ± 0.29, $P = 0.40$, ANOVA) (Table 2).

Recent pediatric advanced airway training (within 3 months) remained significant ($P = 0.017$) in a multivariable linear regression model with *a priori* selected variables (discipline, recent pediatric advanced airway training, clinical pediatric intubation experience). However, discipline and provider's clinical intubation experience remained nonsignificant (Table 2).

The number of intubation attempts for a total of six sessions did not differ significantly among disciplines (transport nurse: median six attempts, IQR (6 - 6.5) vs. emergency medicine fellows: six attempts vs. critical care fellows: six attempts, $P = 0.57$, Kruskal-Wallis), with or without provider clinical experience >3 years (Wilcoxon rank-sum, $P = 0.87$) or with or without recent (within 3 months) pediatric advanced airway training status (P = 0.48, Wilcoxon rank-sum) (Table 3).

Table 1. Demographics of participants

Discipline	Subjects (N)	Median age (IQR)	Sex (M vs. F)	Median years experience in pediatric intubation[a] (IQR)	Median months from last intubation training[b] (IQR)
Transport	16	40 (37 – 47)	4 vs.12	3 (2 - 5.2)	2.5 (0 – 9)
PEM fellow	4	31 (30 - 38)	1 vs. 3	3.5 (1.8 - 5.8)	5 (2 - 9)
PCCM fellow	6	31 (30 – 32)	3 vs. 3	4 (3 - 5)	3 (0 – 4)

a Experience in pediatric intubation was not significantly different among three disciplines ($P > 0.5$, ANOVA)

b Duration from last intubation training was not significantly different among three disciplines ($P > 0.5$, ANOVA).

PEM fellow = Pediatric Emergency Medicine fellow.

PCCM fellow = Pediatric Critical Care fellow.

IQR= Interquartile range.

Table 2. Univariate and multivariate analysis for immediate training effectiveness (T2/T1)[a]

	Univariate analysis		Multivariate analysis[b]	
Variable	**T2/T1**	***P*-value**	**Coefficient (95% CI)**	***P*-value**
Discipline				
Transport nurse	0.94 ± 0.24		0 (Reference)	
PEM fellow	0.81 ± 0.18	*P* = 0.40	-0.199 (-0.483, 0.086)	*P* = 0.16
PCCM fellow	0.80 ± 0.29		-0.141 (-0.386, 0.104)	*P* = 0.24
Previous experience				
≤3 years	0.89 ± 0.26	*P* = 0.93	0 (Reference)	*P* = 0.79
>3 years	0.88 ± 0.23		-0.027 (-0.245, 0.190)	
Last training				
≤3 months	0.74 ± 0.17	*P* = 0.025[c]	-0.274 (-0.494, -0.055)	*P* = 0.017[c]
>3 months	0.98 ± 0.26		0 (Reference)	

a Analysis restricted to first successful intubation attempt.

b Linear regression model. R square = 0.3576, number of observation = 21, probability >F = 0.112.

c *P*-value <0.05,

PEM fellow = Pediatric Emergency Medicine fellow.

PCCM fellow = Pediatric Critical Care fellow.

The frequency of tracheal intubation-associated events did not differ significantly among disciplines (transport nurse: median 2 events, IQR (1.5, 2.5) vs. emergency medicine fellows: 2 events (1.5, 3.5) vs. critical care fellows: 1.5 events (0, 3) *P* = 0.72, Kruskal-Wallis); provider clinical experience (*P* = 0.49, Wilcoxon rank-sum); or recent pediatric advanced airway training (*P* = 0.78, Wilcoxon rank-sum) (Table 3). The most common intubation-associated event was mainstem bronchus intubation without immediate recognition, which was observed in 42 sessions.

Discussion

Psychomotor skill is a critical component for crisis management in clinical settings.[23, 32] Several studies have examined skill retention after cardiopulmonary resuscitation training. Those studies showed that both cognitive and psychomotor skills decay over time, but psychomotor skill decays faster.[4, 5, 6, 7, 8] This finding is critical from a training implementation standpoint, since this will determine how frequently trainees need to take refresher training.

Although under some circumstances the initial training effect can be augmented by initial intensive overtraining,[33] the intensity of refresher training required to maintain competence is still unknown. It is also unclear what factors influence the effectiveness of refresher training.

Table 3. Number of intubation attempts and tracheal intubation-associated events

Variable	Median intubation attempts (IQR)		Median tracheal intubation-associated events (IQR)	
Discipline				
Transport nurse	6 (6, 6.5)		2 (1.5, 2.5)	
PEM fellow	6 (6, 6)	*P* = 0.57[a]	2 (1.5, 3.5)	*P* = 0.72[a]
PCCM fellow	6 (6, 6)		1.5 (0, 3)	
Previous experience				
≤3 years	6 (6, 6)	*P* = 0.87[b]	2 (1, 3)	*P* = 0.49[b]
>3 years	6 (6, 6)		2 (2, 2)	
Last training				
≤3 months	6 (6, 6)	*P* = 0.48[b]	2 (1.5, 3)	*P* = 0.78[b]
>3 months	6 (6, 6)		2 (1.5, 2.5)	

a Kruskal-Wallis test.
b Wilcoxon rank-sum test.
IQR = Interquartile range.
PEM fellow = Pediatric Emergency Medicine fellow.
PCCM fellow = Pediatric Critical Care fellow.

Tracheal intubation is a complex psychomotor skill, similar to cardiopulmonary resuscitation; there is a learning curve to acquire intubation skills, and it usually requires significant practice.[14, 34] Furthermore, this complex skill decays over time if not practiced repeatedly.[17]

Initial and refresher tracheal intubation training using patients may be challenging, since intubation by trainees may have higher complication rates,[35] patients may not tolerate the long duration of the procedure, and the learning effects may diminish under high-stress clinical situations.[36]

Our study was conducted to investigate factors associated with the effectiveness of immediate refresher training in an attempt to overcome the challenges described above and to improve safety in pediatric advanced airway management. Determining the effectiveness of immediate refresher training in intubation skills is clinically important because many actual intubations require more than one attempt,[16, 30] and it is reasonable to assume that clinical providers are actually "refreshing" at their first attempt. Since multiple attempts at intubation may be harmful, the immediate refresher effect is critically important. Therefore, we chose this as a primary outcome of our study design.

This study showed that the effectiveness of immediate refresher training was significantly associated with recent psychomotor training. Unlike many studies in cardiopulmonary resuscitation training with volunteer lay rescuers, all participants in this study were credentialed in pediatric advanced airway training—including orotracheal intubation—and many had received training relatively recently (Table 1). The transport team members participated in bi-annual intubation training in the operation room. The pediatric emergency medicine fellows and pediatric critical care fellows perform advanced airway management as a part of their fellowship training, although it is less frequent, compared to that of anesthesiologists.

Our local airway registry data in Pediatric Intensive Care Unit showed that tracheal intubation occurs every 3 to 7 days in a busy tertiary PICU with 45 beds (data not published). Despite that training, the intubation in the first session took significantly longer compared to other sessions.

This study finding was similar to the recent report on chest compression refresher training for pediatric in-hospital staff.[37] Those researchers compared the time to achieve simulated high quality cardiopulmonary resuscitation (CPR) with an automated feedback system among providers who received frequent "rapid 3-minute refresher" CPR training (two or more times a month) vs. providers trained less than two times a month. The group with more frequent "rapid refresher" training had significantly shorter times to achieve excellent chest compression performance evaluations.[38, 39]

Since the improvement after the second session was smaller in our study, it is prudent to say that short refresher psychomotor training—even as short as two sessions—is effective. The first session serves as refresher training and the second as a competence measurement. The second session needs to be repeated for those judged not sufficiently competent.

We also should consider that the required number of refresher training sessions might change,\ when we have absolute competence cutoff (e.g., 20 seconds for neonatal intubation),[40] since participants improved their skills as the number of refresher training sessions increased. Therefore, this goal is achievable.

Woollard, et al., studied skill retention and skill reacquisition at the time of refresher classes in Basic Life Support with Automated External Defibrillator classes for lay volunteer rescuers.[41] They demonstrated psychomotor skill decay over time. However, skill reacquisition did not differ between a group that received training 7 months earlier compared with a group that had previous training as much as 12 months earlier. This finding is different from our study, in which the recent training was positively associated with an immediate learning effect.

Although the reason for this difference is not entirely clear, it is possible to speculate that: either the effect of previous training on immediate training effectiveness did not last longer than a few months in a difficult, complex psychomotor skill (i.e., intubation), or the refresher training was thorough enough so that the educational effect was maximized at each participant's capability, regardless of the other factors associated with refresher training effectiveness in Woollard's study.[41]

Kovacs, et al., studied the maintenance of airway management skills in emergency medicine residents.[15] They provided an initial 2-day intensive airway training course followed by 3 weeks of subsequent practice sessions. They then randomized participants to three groups: (1) no feedback at the time of testing nor further practice sessions, (2) feedback at followup testing and eight practice sessions over 10 months, and (3) feedback at followup testing without further practice sessions. They found that the group with feedback and subsequent practice sessions maintained their airway skills without decay and performed significantly better than the other two groups. The score of the airway skills dropped significantly at the first followup test (16 weeks) and stayed at similar levels in the control group (the first and the third group).

The study by Kovacs, et al., demonstrated the rapid decay of intubation skills within 4 months and the effectiveness of frequent refresher training in advanced airway management.[15] Although we are not able to quantify the effect of time on intubation skill competence (since we do not have their previous competence level), we are able to quantify the effect of recent training on the immediate refresher training effectiveness at the time of refresher training (27 percent improvement in time to intubation success at the second session, compared to first session with recent training). Based on those findings, we conclude that previous training effect still exists up to 3 months later, and that frequent pediatric intubation refresher training every 3 months can be brief, since practitioners regain the skill quickly. Future study in pediatric intubation refresher training at various intervals with immediate training effectiveness measurement is warranted to further quantify the effectiveness of refresher training.

This study has some limitations. It was conducted with each participant performing tracheal intubation without feedback using any of three different C-spine stabilization techniques. Although this was randomized, this technique might have biased the results. We performed an ANOVA with repeated measures to evaluate the effect of C-spine protection method on time to successful intubation, which showed no significant effect ($P = 0.39$).[42]

The time to intubation was longer in T4 compared to T3, but T4 was not significantly different from T1. The reason for this is unclear. However, it is possible that this was due to the relative performance improvement of "less skilled" intubators. Their performance was eliminated in T1, since they required more than one attempt for intubation success, but it was included in T4, since they no longer required more than one attempt. There was a statistically significant difference between T1 and T4 ($P < 0.05$) when all time-to-intubation success was analyzed, regardless of the number of attempts, which supports this speculation.

The fidelity and realism (face validity) of the simulation used in the study was an important consideration. To enhance realism, we used the high fidelity simulator with real-time feedback in a simulation room similar to a patient care room and provided physiologic parameters that were prospectively set as triggers for success or failure. The realism of intubation with this simulator (SimBaby®) under similar conditions was demonstrated in another study to evaluate pediatric resident intubation skills.[28] Those investigators found the resident intubation attempt success rate to be 56 percent, which correlated with pediatric residents' performance in the emergency department (first intubation attempt success rate of 50 percent).[30]

Furthermore, one recent study showed that learning orotracheal intubation on simulators is equally as effective as learning on human subjects,[43] suggesting that our study results might be generalizable to the clinical setting. The potential for ascertainment bias (using volunteers from the pool of skilled practitioners) is possible, as for any convenience sample.

It also is possible that more "self-confident" practitioners volunteered for this study. This effect is unclear, since several studies suggest self confidence does not correlate well with objective competence measurement in medical practitioners.[44] In addition, in order to quantitatively measure refresher training effectiveness, we eliminated those events where tracheal tube intubation success required more than one attempt. This could potentially confound the results, since more skilled practitioners might not attempt to intubate with limited laryngeal visualization and would not attempt it a second time. However, the number of intubations was not associated with discipline, recent intubation training, previous experience, or any other demographic data that might be associated with intubation skills.

Conclusion

For non-anesthesiology pediatric providers who do not routinely perform tracheal intubation, recent tracheal intubation training within 3 months, but not practice discipline or previous years of experience, was significantly associated with the effectiveness of refresher training to rapidly improve provider excellence and patient safety in simulated advanced pediatric airway management. The training effect was the largest between the first and second scenario, suggesting that frequent short episodes of refresher training (e.g., as few as two scenarios, with the first session for refresher training and the second session to confirm competence) might be necessary to maintain complex psychomotor skill competence, such as that involved in orotracheal intubation. Long sessions or multiple repeated scenarios may have little incremental benefit for experienced providers. For practitioners who frequently refresh their psychomotor skills through either training or clinical practice, short and frequent refresher training with simulators may be effective.

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Appendix 1

High Fidelity Infant Simulator Function Utilized in this Study
Simulator Capability
• Trainee to perform bag valve mask ventilation.
• Trainee to perform tracheal intubation properly or improperly.
• Simulator to demonstrate chest rise with spontaneous ventilation or positive pressure ventilation.
• Simulator to demonstrate breath sounds.
• Simulator to demonstrate palpable pulses in left brachial, radial, and bilateral femoral artery locations.
• Simulator to exhale CO_2 from trachea with CO_2 tank.[a]
Monitor Capability
• To demonstrate pulse oximetry saturation number and waveform.
• To demonstrate heart rate and electrocardiography waveform.
• To demonstrate respiratory rate.
Simulator Measurement/Record Capability
• To measure cervical spine extension angle at every second.
• To detect appropriate ventilation after intubation.
• To record a simulation log with vital sign changes, with key actions recorded by an investigator during simulation.

a Exhaled CO_2 after appropriate endotracheal tube placement was detected by an end-tidal CO_2 detector.

Appendix 2

Simulation Scenario

A 6-month-old infant was involved in a motor vehicle crash and is restrained in an infant safety seat without obvious signs of traumatic injury. The infant is unconscious with labored breathing and coarse, equal breath sounds. There is no evidence of hemothorax or pneumothorax. The infant has no evidence of increased intracranial pressure. The attending physician requests that you prepare to perform tracheal intubation prior to CT scan evaluation of the brain.

The infant is given appropriate rapid sequence intubation medications, including appropriate paralytics and sedatives, and is currently unconscious and paralyzed. With preoxygenation and good bag-valve mask ventilation technique, the SpO_2 has risen to 92 percent, but you are unable to achieve higher oxygen saturation.

You are instructed by the attending physician to intubate the infant's trachea using an appropriate laryngoscope and endotracheal tube (e.g., Miller 1 laryngoscope blade and 3.5 mm cuffed tracheal tube). Please pay particular attention to cervical spine immobilization, confirm correct tracheal position (using clinical and exhaled CO_2 capnography) and oxygenate and ventilate the infant.

Given this scenario, participants will then perform tracheal intubation on the infant simulator with one of the three cervical spine protection methods:

1. Nonrestricted neck mobility.
2. Immobilization using manual inline stabilization by a second "rescuer."
3. Immobilization using a rigid cervical collar.

Order of Tracheal Intubation

Group	1st Set	2nd Set	3rd Set
1	No protection	Cervical collar	Inline manual
2	No protection	Inline manual	Cervical collar
3	Inline manual	No protection	Cervical collar
4	Inline manual	Cervical collar	No protection
5	Cervical collar	No protection	Inline manual
6	Cervical collar	Inline manual	No protection

Table key:

No protection (**N**) was defined as no particular cervical spine immobilization technique is applied to manikin during the scenario. Each subject was reminded to "pay attention to" the potential cervical spine injury, but a person was not assigned to immobilize the neck.

Cervical collar protection (**C**) was defined as a rigid cervical collar in place during the orotracheal intubation. Proper C-collar placement was confirmed before each scenario by a single investigator.

Inline manual immobilization (**M**) was defined as a second person holding both hands on the manikin's head, with the index or middle finger held approximately at the opening of the auditory canal to maintain the cervical spine in a neutral position without movement, as taught in the American College of Surgeons Advanced Trauma Life Support course. The person performing inline immobilization crouched to the directed side of the intubator.[21]

Programmed Saturation and Other Vital Sign Changes			
Time since last oxygenation (seconds)	**Oxygen saturation (%)**	**Event (precipitated by SpO_2)**	**Time to reach SpO_2 90% once reoxygenation is reached (seconds)**
10	99		--
30	98		--
60	90		--
90	80		10
120	70	Bradycardia	30
180	60	Hypotension	80
240	50		240

Columns 1 and 2 (time since oxygenation and SpO2) will be collinear. Hypoxia-induced events (column 3) will be entered into the simulation at predetermined SpO2 levels as indicated in the table. The time to reach an SpO_2 of 90 percent after reoxygenation is reestablished will be collinear with SpO_2.