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Pediatric Trainees Managing a Difficult Airway: Comparison of Laryngeal Mask Airway, Direct, and Video-Assisted Laryngoscopy

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Abstract

Objective. Difficult airway management is a key skill required by all pediatric physicians, yet training on multiple modalities is lacking. The objective of this study was to compare the rate of, and time to, successful advanced infant airway placement with direct laryngoscopy, video-assisted laryngoscopy, and laryngeal mask airway (LMA) in a difficult airway simulator. This study is the first to compare the success with 3 methods for difficult airway management among pediatric trainees.

Study Design. Randomized crossover pilot study.

Setting. Tertiary academic medical center.

Methods. Twenty-two pediatric residents, interns, and medical students were tested. Participants were provided 1 training session by faculty using a normal infant manikin. Subjects then performed all 3 of the aforementioned advanced airway modalities in a randomized order on a difficult airway model of a Robin sequence. Success was defined as confirmed endotracheal intubation or correct LMA placement by the testing instructor in $\leq$120 seconds.

Results. Direct laryngoscopy demonstrated a significantly higher placement success rate (77.3%) than video-assisted laryngoscopy (36.4%, P = .0117) and LMA (31.8%, P = .0039). Video-assisted laryngoscopy required a significantly longer amount of time during successful intubations (84.8 seconds; 95% CI, 59.4-110.1) versus direct laryngoscopy (44.9 seconds; 95% CI, 33.8-55.9) and LMA placement (36.6 seconds; 95% CI, 24.7-48.4).

Conclusions. Pediatric trainees demonstrated significantly higher success using direct laryngoscopy in a difficult airway simulator model. However, given the potential lifesaving implications of advanced airway adjuncts, including video-assisted laryngoscopy and LMA placement, more extensive training on adjunctive airway management techniques may be useful for trainees.

Keywords

video-assisted laryngoscopy, direct laryngoscopy, laryngeal mask airway, simulation, medical education, difficult airway

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Establishment of an advanced pediatric airway requires nuanced training and frequent clinical encounters to acquire and maintain competency. Up to 10% of

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newborns require resuscitation in the newborn period, of which interventions include establishment of an advanced airway in addition to basic and advanced cardiac life support.[1] The American Academy of Pediatrics Neonatal Resuscitation Program recommends that intubation be completed in ≤20 seconds, and even experienced practitioners frequently take longer to establish an airway.[2,3] Video-assisted laryngoscopy and laryngeal mask airway (LMA) are important adjunctive measures to direct laryngoscopy for definitive airway management.[4,5] Pediatric subspecialties in the fields of anesthesiology, emergency medicine, surgery, critical care, and otolaryngology–head and neck surgery allow for effective training and consistent use of multiple ways to establish an advanced airway; however, others do not likely receive the same opportunities. Currently, neonatal intubation is part of the Accreditation Council for Graduate Medical Education program requirements for pediatrics, with simulation intubation cited as an example for a senior-level milestone under problem-based learning.[6] Yet, this study is the first on the utilization of 3 methods of airway management in a difficult airway scenario with pediatric trainees.

Previous studies testing inexperienced medical personnel have shown initial successful endotracheal intubation rates with direct laryngoscopy to be between 35% and 65% in live subjects.[7,8] Video-assisted laryngoscopy has shown this rate to increase to ≥90% in normal manikin airways.[7] Previous work by our research group demonstrated that this rate among new intern physicians with <5 previous live intubations increased to 100% in a difficult intubation scenario, entailing cervical spine immobilization with oral tongue and tongue base edema[4]; however, this scenario was on an adult patient simulator and thus not necessarily generalizable to a pediatric training scenario or real-world situation.

LMA is a defined treatment in the management algorithm of a pediatric airway, both as a primary treatment as well as a backup in the case of failed endotracheal intubation.[9] A previous study testing prehospital emergency medical services providers demonstrated a successful LMA placement rate of 90.5%, with decreased time to effective ventilation.[5]

Inexperienced pediatric providers may be called to a situation in which they are first responders and need to establish an advanced airway. The goal of this pilot study was to compare success of pediatric department trainees' advanced airway placement in a difficult airway scenario using direct laryngoscopy, video-assisted laryngoscopy, and LMA.

Methods

This study was performed at a tertiary academic medical center and received appropriate institutional review board approval (Naval Medical Center San Diego, Clinical Investigation Department, protocol 2012.0136). Twenty-two trainees, at any level of training, from the Department of Pediatrics at Naval Medical Center San Diego were recruited to participate in the study. There were no exclusion criteria for participation. All trainees in the Department of Pediatrics were briefed on the study, and those wishing to participate were enrolled. Participation included a training session and subsequent testing on a difficult simulator model (Robin sequence neonatal airway model), with 3 modalities for establishing an advanced airway.

Participants had relatively modest experience with the airway modalities in either live patient or simulation scenarios: 54.5% (n = 12 of 22) reported use of direct laryngoscopy; 27.3% (n = 6) previously used video-assisted laryngoscopy; and 31.8% (n = 7) had used the LMA.

Subjects first received a 15-minute in-person, one-to-one, hands-on training session reviewing the techniques of direct laryngoscopy, video-assisted laryngoscopy (GlideScope, Bothell Washington), and LMA placement, facilitated by 1 of 4 faculty otolaryngologists, anesthesiologists, or pediatric intensivists. All faculty trainers were proficient with all 3 methods being introduced. The training session was held immediately prior to the testing session and included approximately 5 minutes of instruction on each of the 3 methods. Training took place on a normal pediatric manikin airway simulator (Laerdal Medical, Wappingers Falls, New York) in a normal advanced airway scenario (Cormack-Lehane grade I).

Following the training session, subjects were then tested in a difficult advanced pediatric airway scenario using a Robin sequence manikin model (TruCorp Ltd, Belfast, Northern Ireland). This Robin sequence model was chosen because of its anatomic fidelity and potentially clinically useful simulation conferring a difficult scenario that may be encountered—micrognathia, glossoptosis, and high-arched cleft palate (Cormack-Lehane grade III). This model has previously been used in difficult airway scenarios with a variety of techniques for intubation.[10] Both the normal airway manikin and the Robin sequence manikin were the respective companies' neonatal models.

All subjects were tested using all 3 advanced airway modalities, with the order of the testing randomized via random number generator. Subjects were instructed to use the modality being tested to secure the airway successfully and as quickly as possible in only the difficult airway model. They were to verbally alert the proctor first when they had visualized the laryngeal inlet and then again when they requested evaluation for successful placement. The equipment used for the 3 scenarios was standardized to eliminate the potential confounding from participants choosing incorrect equipment. A size 1 LMA was used for the LMA scenario. A size 3-0 cuffed endotracheal tube (ETT) was used for the intubation scenario with direct and video-assisted laryngoscopy. A straight blade of appropriate size was used for direct laryngoscopy. The ETT was used with an unbent rigid stylet as a neutral starting position. Unlike the adult models for this video-assisted laryngoscope, there is no proprietary stylet with curvature aligned to the laryngoscope for the pediatric model. During the initial training session, participants were taught to bend the stylet appropriately prior to insertion.

During the testing scenarios, successfully securing the airway was defined as using the tested modality to place an

ETT or LMA with confirmation of correct location. Correct placement was confirmed in 2 ways: (1) clinically with a bag valve mask to test for prompt and adequate inflation of the model lungs bilaterally and (2) visually with flexible bronchoscopy through the LMA or ETT placed with direct or video-assisted laryngoscopy. Timing for the experiment commenced with advancement of the laryngoscope or LMA past the oral vestibule and ended with the participant's request for confirmation of correct placement or the maximum time allotted (120 seconds), whichever occurred first. An absolute failure time of 120 seconds, if advanced airway placement was not successfully placed, is consistent with existing simulator literature.[4,5] Once the participants requested confirmation of placement, the attempt was ended, and they were not permitted to adjust the airway further.

A Cochran *Q* nonparametric test of significance was performed to compare the success rates of all 3 groups. Pairwise comparisons were made with McNemar's test. For the purposes of data analysis, only the testing scenarios were included (ie, all 3 modalities with the Robin sequence manikin). The sample size for this pilot study was determined by all available pediatric residents, interns, and medical students at the time.

Results

Twenty-two trainees from the Department of Pediatrics at Naval Medical Center San Diego were recruited for the study. This group consisted of 6 medical students on their pediatric rotation, 7 first-year residents, 4 second-year residents, and 5 third-year residents.

Successful Airway Placement

Direct laryngoscopy demonstrated significantly higher success rate (77.3%; **Figure 1**) than video-assisted laryngoscopy (36.4%, *P* = .0117) and LMA (31.8%, *P* = .0039). Of the failures with direct laryngoscopy (n = 6 of 22), 3 failed to intubate once the laryngeal inlet was visualized due to time running out; the other 3 had placed the ETT in the esophagus. For failed video-assisted laryngoscopy attempts (n = 14 of 22), only a 1 person (7.1%) actually failed to visualize the laryngeal inlet, whereas the remaining 13 (92.8%) were unable to intubate in the time allotted once they visualized the inlet. Of LMA failures (n = 16 of 22), 10 (62.5%) overinserted the airway, causing kinking in the oropharynx and hypopharynx, whereas 6 (37.5%) underinserted the airway into the posterior oral cavity and oropharynx.

Airway Placement Time

Video-assisted laryngoscopy required a significantly longer amount of time during successful placement (84.8 seconds; 95% CI, 59.4-110.1; **Figure 2**) versus direct laryngoscopy (44.9 seconds; 95% CI, 33.8-55.9) and LMA placement (36.6 seconds; 95% CI, 24.7-48.4).

Discussion

Establishment of an advanced pediatric airway is a critical skill for all pediatric hospital providers and is a key component in pediatric resuscitation. Neonatal intubation is specifically noted to be an integral aspect of training for pediatric residency. It has been recognized in the Accreditation Council for Graduate Medical Education program requirements and as an example for a senior-level milestone.[6] In addition to normal pediatric airway scenarios, these skills are further challenged in patients with difficult airways, as in trauma or previously attempted intubations, as well as in patients with craniofacial abnormalities.[9,11]

Part of the difficulty in successful intubation—especially in patients with a difficult airway, such as craniofacial or

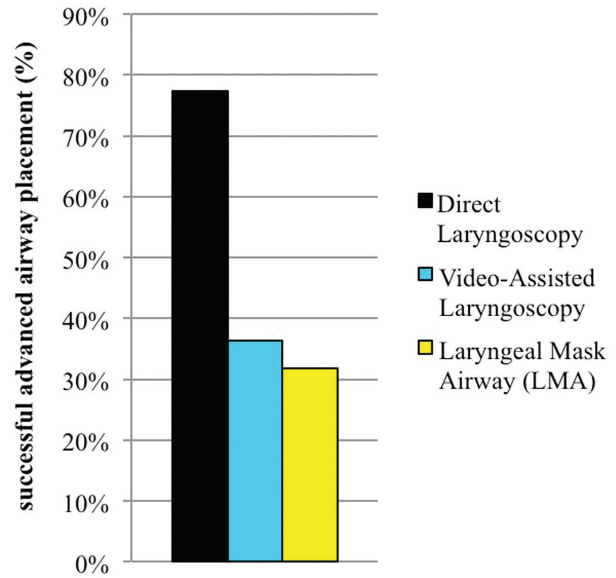

Figure 1. Direct laryngoscopy demonstrated a significantly higher placement success rate (77.3%) than video-assisted laryngoscopy (36.4%, *P* = .0117) and laryngeal mask airway (31.8%, *P* = .0039).

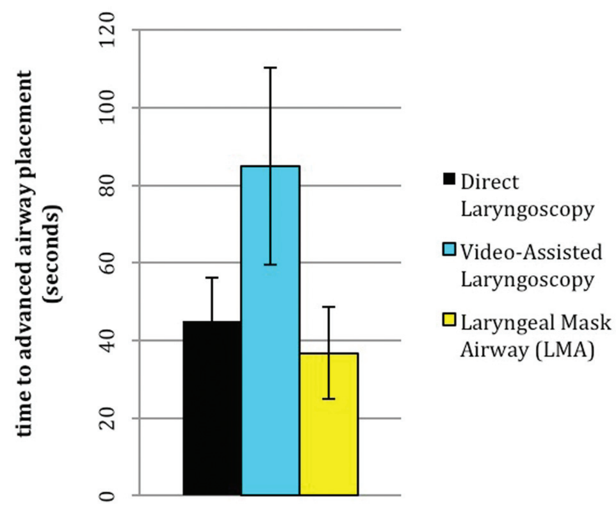

Figure 2. Video-assisted laryngoscopy required a significantly longer amount of time during successful placement (84.8 seconds; 95% CI, 59.4-110.1) when compared with direct laryngoscopy (44.9 seconds; 95% CI, 33.8-55.9) and laryngeal mask airway placement (36.6 seconds; 95% CI, 24.7-48.4).

functional pharyngeal or laryngeal edema—is adequate visualization of the laryngeal inlet. Video-assisted laryngoscopy and LMA placement both attempt to circumvent this difficulty, though in different ways.

Video-assisted laryngoscopy has the ability to give a user a clear view of the laryngeal inlet even in patients with difficult-to-visualize anatomy because of the camera at the tip of the laryngoscope. In a study of video-assisted laryngoscopy, Karsli et al found a significantly improved view of the laryngeal inlet, as compared with direct laryngoscopy, among 78% of children who were identified as previously having a difficult or failed intubation.[12] In the present study, despite the anatomic limitations conferred by the Robin sequence simulator, all but 1 subject were able to achieve a clear view of the laryngeal inlet using video-assisted laryngoscopy.

LMA provides indirect positive-pressure ventilation with a cuff-sealed mask resting in the hypopharynx.[5] It is a defined treatment in difficult and craniofacial pediatric airways and, once learned, becomes an expeditious way to secure an advanced airway without the need for direct visualization.[5,9] Furthermore, it has been documented as being utilized in combination with fiberoptic bronchoscopy as a primary step in endotracheal intubation in patients with difficult visualization.[13,14] Chen and Hsiao demonstrated 90.5% correct position placement by paramedic students in a normal airway during a simulated pediatric resuscitation scenario.[5] A study by Guyette et al demonstrated a 100% LMA insertion rate in testing paramedic students in a similar normal scenario.[15] In our difficult airway scenario, LMA placement success was similar to video-assisted laryngoscopy and significantly less than direct laryngoscopy. LMA, however, was associated with significantly less time to successful placement. Participants in our study were not allowed to adjust placement once they requested confirmation; allowing multiple tries likely would have increased the success rate.

As alluded to, the adult simulator literature has demonstrated an increase in intubation success, upward of 90%, among novice intubators using video-assisted laryngoscopy.[4,7] Our research showed a significantly higher success rate for video laryngoscopy users (100%) when compared with direct laryngoscopy users (52.6%; 95% CI, 30%-75.3%) in a difficult airway scenario that entailed cervical spine immobilization with simulated oral cavity and oropharyngeal edema.[4] The pediatric simulation literature, however, has not shown as conclusive results. White et al demonstrated no difference in intubation success between direct and video-assisted laryngoscopy in both normal and difficult scenarios.[16] Furthermore, Rabiner et al demonstrated no difference in intubation success by novice physicians in simple and difficult scenarios; video laryngoscopy in the difficult scenario was associated with a significantly higher intubation time.[17] In our difficult pediatric scenario, video-assisted laryngoscopy was also associated with significantly higher intubation time, though significantly less successful intubations, when compared with direct laryngoscopy. As may be expected, the failures with direct laryngoscopy came from not adequately visualizing the laryngeal inlet (with subsequent intubation of the esophagus) and failing to place the ETT after adequately visualizing the laryngeal inlet, while almost all of the failures with video-assisted laryngoscopy arose from inability to place the ETT with clear visualization of the laryngeal inlet.

Training with high-fidelity patient simulation has been shown to improve one's ability to establish an advanced airway.[7,18] Thus, it is not necessarily surprising that this group of trainees demonstrated a significantly higher rate of successful placement with traditional direct laryngoscopy given that over half of them had experience with this method of intubation. Despite the significantly higher success in direct laryngoscopy, faster successful placement of LMA, and slower ETT placement but nearly 100% clear view of the laryngeal inlet with video-assisted laryngoscopy, we do not suggest that this necessarily confers superiority or inferiority of any of the 3 methods. Rather, we contend that more extensive training will likely show a reduction in the differences among these 3 modalities. Video-assisted laryngoscopy can be a valuable teaching tool for establishment of an advanced airway, and video-assisted laryngoscopy and LMA are key adjunctive advanced airway measures, especially in scenarios where direct laryngoscopy is ineffective. However, as the pitfalls of the present pilot study point out, training with these useful adjuncts is likely lacking. While over half of our participants had performed direct laryngoscopy intubations before, fewer than one-third had ever used video-assisted laryngoscopy or LMA. If these modalities are to be included in difficult airway algorithms, supporting medical education must include adequate training in their use, in addition to training on traditional direct laryngoscopy.

Limitations of this study, consistent with simulation literature in general, include replicating the nuances involved with successful advanced airway placement, as well as anatomic fidelity, such as inability to simulate upper airway edema, secretions, and laryngospasm and the repetition to perform this task successfully. Furthermore, a small sample size and a varied prior experience (ie, some with no live intubation experience) limit the ability to necessarily generalize the findings of the study. A single attempt was granted, whereas multiple attempts may have allowed for higher rate of success, most notably with LMA, which required a relatively brief placement time. The training provided was also relatively brief, given the complexity of the training scenario; however, this does allow us to draw conclusions without a large practice effect that an in-depth training session may have provided.

Future work in this field should focus on the ability of novice intubators in training to use the 3 methods to secure a difficult airway in simulation and real-world scenarios. Additionally, most difficult airway scenarios rarely occur in a controlled isolated setting. Incorporating the use of various intubation methods in a more complex training scenario would elucidate training and efficiency in translating to more real-world situations, allowing trainees to work through a difficult airway algorithm.

Direct laryngoscopy is a well-established standard in pediatric airway algorithms and undoubtedly receives the most attention during medical training. Given the potential anatomic limitations allowing adequate exposure though, video-assisted laryngoscopy and LMA placement are potentially lifesaving alternatives. However, a lack of training and a degree of unfamiliarity to many novice providers may decrease the potential advantages. As such, more extensive training on adjunctive airway management techniques may be useful to bridge the potential knowledge gap and increase the abilities of pediatric providers to secure a difficult airway in an urgent or emergent situation.

Author Contributions

Art Ambrosio, conception and design of study, acquisition and data analysis, drafting and revising manuscript, final approval of manuscript for submission; **Kastley Marvin**, analysis and interpretation of data, drafting and revising manuscript, final approval of manuscript for submission; **Colleen Perez**, design of study, acquisition and analysis of data, drafting manuscript, final approval of manuscript for submission; **Chelsie Byrnes**, design of study, acquisition of data, drafting manuscript, final approval of manuscript for submission; **Cory Gaconnet**, design of study, acquisition of data, manuscript revision, final approval of manuscript for submission; **Chris Cornelissen**, design of study, acquisition of data, manuscript revision, final approval of manuscript for submission; **Matthew Brigger**, conception and design of study, data analysis, manuscript revision, final approval of manuscript for submission.

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