Comparison of indirect video laryngoscopes in children younger than two years of age: A randomized trainee evaluation study

Marissa G. Vadi*, Elizabeth A. Ghazal**, Bryan Halverson** and Richard L. Applegate II**

Background: Gaining proficiency with various airway management tools is an important goal for anesthesiology training. Indirect video laryngoscopes facilitate tracheal intubation in adults, but it is not clear whether these findings translate to children. This study evaluates the total time to successful intubation when performed by anesthesiology trainees using GlideScope Cobalt® video laryngoscopy (GlideScope), Storz DCI® video laryngoscopy (Storz), or direct laryngoscopy (Direct) in children <2 years old with normal airway anatomy.

Methods: Sixty-five children presenting for elective surgery were randomly assigned to undergo tracheal intubation using GlideScope, Storz, or Direct. Laryngoscopists were anesthesiology trainees in clinical anesthesia year ≥2 who had proven basic proficiency with each laryngoscope on an infant airway manikin. Total time to successful intubation (TTSI, seconds), rate of successful intubation on first laryngoscopy attempt, and the change in intubation time from manikin to clinical settings were recorded. An intubation time difference >10 seconds was defined as clinically significant.

Results: TTSI was longer for Storz (42.1; 34.0 to 59.0) than for Direct (21.5; 17.0 to 34.3; p=0.002). We were not able to demonstrate a difference >10 seconds between the GlideScope and the other laryngoscopes. Median manikin intubation time was <10 seconds and increased significantly in the clinical setting for all laryngoscopes (all p <0.0001).

Conclusions: Anesthesiology trainees completed manikin tracheal intubation rapidly with all laryngoscopes studied, but required a clinically significant longer time to tracheally intubate children <2 years. Our findings suggest in vivo training should be included to facilitate proficiency with device-specific intubation techniques.

* MD, M.P.H.
** MD.

Department of Anesthesiology, Loma Linda University School of Medicine, Loma Linda, CA, U.S.A.

Corresponding Author: Marissa G. Vadi, M.D., M.P.H., Loma Linda University Department of Anesthesiology, 11234 Anderson Street, Room 2532 Loma Linda, CA 92354, U.S.A., Phone: 909-558-4475, Fax: 909-558-4143. E-mail: mvadi@llu.edu

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Introduction

Tracheal intubation is a central component of competency-based curricula in anesthesiology training programs, and includes gaining proficiency with a number of airway management tools. Failed or prolonged tracheal intubation attempts constitute major causes of anesthetic morbidity and mortality. Development of technical proficiency in pediatric airway management poses unique challenges for anesthesiology trainees. The neonate or infant has a large occiput and tongue, a more cephalad larynx, a long and floppy epiglottis, and a shorter trachea and neck when compared to an older child or adult. These anatomical differences may increase the difficulty of obtaining optimal glottic views in small children. Pediatric patients tolerate apnea for a shorter time than adults and may especially benefit from atraumatic, single-attempt laryngoscopy and tracheal intubation.

Indirect video laryngoscopes, designed to allow a view of the glottis without requiring alignment of the oral, pharyngeal, and tracheal axes, have become accepted as effective tools for airway management. These laryngoscopes have been shown in adults to improve glottic view and facilitate guidance to novice laryngoscopists, though it remains unclear whether these advantages translate to pediatric airways. The GlideScope Cobalt® (Veraphon Medical, Bothell, WA) and Storz DCI® video laryngoscopes (Karl Storz, Tuttlingen, Germany) are both available for pediatric use. The GlideScope Cobalt® video laryngoscope features a reusable video baton and single-use curved laryngoscopy blades while the pediatric Storz DCI® video laryngoscope allows use of Miller-like laryngoscope blades equipped with a video lens in the blade tip to provide high-resolution images on a video monitor. Dynamic video feedback allows supervising physicians to appropriately guide trainees and confirm proper tracheal tube placement.

Trainee proficiency can be judged based on the rate of successful tracheal intubation. For example, anesthesia trainees were found to need at least 57 intubation procedures to achieve first or second attempt tracheal intubation success using direct laryngoscopy in 90% of adult patients. Investigations of indirect video laryngoscopy use by trainees in the pediatric clinical setting yield variable intubation times and success rates. Much of the literature on pediatric indirect video laryngoscopy use focuses on older children, manikin studies, small case series, or use by expert laryngoscopists. It remains unclear whether indirect video laryngoscopy improves tracheal intubation proficiency among more novice laryngoscopists when used in small children. Thus, the primary aim of this study was to compare tracheal intubation times by anesthesiology trainees in children under age 2 years with expected normal airway anatomy using the GlideScope Cobalt® video laryngoscope, the Storz DCI® video laryngoscope, or standard direct laryngoscopy.

Methods

This single-center, prospective randomized non-blinded parallel group study received Institutional Review Board approval, and was registered at ClinicalTrials.gov. Written informed consent was obtained from parents or legal guardians of children under the age of 2 years scheduled for elective surgery requiring tracheal intubation at our tertiary care hospital in the United States. Children with a known or predicted difficult airway, corrected gestational age less than 37 weeks, severe bronchopulmonary dysplasia, elevated intracranial pressure, or increased aspiration risk were excluded.

Subjects were randomly assigned to undergo tracheal intubation with the GlideScope Cobalt® video laryngoscope (size 2 blade; GlideScope), the Storz DCI® video laryngoscope (Miller 1 video blade; Storz), or direct laryngoscopy (Miller 1 blade; Direct). Randomization was carried out using computer-generated random numbers in blocks of 21 and allocation concealment was performed with sealed opaque envelopes until after informed consent for study participation was obtained. Tracheal intubations were performed by anesthesiology trainees in clinical anesthesia year 2 or above who had completed at least one month of pediatric anesthesiology at our hospital. Laryngoscopists proved basic proficiency with each laryngoscope before study participation by performing at least 3 consecutive tracheal intubations in less...
than 30 seconds each on an infant airway manikin (Laerdal® Infant Airway Management Trainer, Stavanger, Norway). Manikin tracheal intubation times were recorded for each laryngoscopist. Prior in vivo video laryngoscope experience as reported by all laryngoscopists was recorded. All intubations were performed using styletted conventional tracheal tubes. Tracheal tubes for GlideScope intubations were shaped to approximate the curve of the size 2 Cobalt® blade while tracheal tubes for Storz or Direct intubations were shaped with a hockey-stick bend at the tip. Laryngoscopists were reminded to intubate safely, were aware they would be timed, and were instructed to direct their view to the video monitor during tracheal intubation when using GlideScope or Storz.

Anesthesia care included routine perioperative monitors per American Society of Anesthesiologists guidelines. Anesthesia induction was standardized to either inhalation of 70% nitrous oxide / 30% oxygen mixture and 4-8% sevoflurane followed by intravenous catheter placement; or by intravenous induction with propofol 3 mg.kg⁻¹ if intravenous access was established prior to induction of anesthesia. All patients received rocuronium 0.6 mg.kg⁻¹ IV followed by a saline flush to ensure administration; the first laryngoscopy attempt was not allowed to start for 90 seconds after administration as timed by a stopwatch.

An un-blinded research assistant announced intubation “start” (tip of laryngoscope passing the lips) and “stop” (removal of tip of laryngoscope past the lips) times to a second research assistant who was kept blinded to the laryngoscope in use and who recorded the time interval using a handheld stopwatch while facing the wall of the operating room. An intubation attempt was recorded each time the randomized laryngoscope was removed past the lips. If more than one intubation attempt was required, the patient was mask ventilated with 4-8% sevoflurane in 100% oxygen between attempts and the sum of the individual intubation times determined the total time to successful tracheal intubation (TTSI). The use of external laryngeal manipulation or shoulder rolls was recorded. The best Cormack-Lehane glottic view as reported by the laryngoscopist was recorded. An un-blinded member of the research team recorded technical factors complicating intubation which included visualization difficulty related to obscured view from fogging, secretions or blood in the airway; difficulty passing the tracheal tube past the vocal cords; inappropriate endotracheal tube size for the patient; or difficulty controlling the direction of the tracheal tube using the video display. The laryngoscope blade was inspected for the presence of blood and the mouth was inspected for signs of trauma following tracheal intubation. The lowest pulse oxygen saturation and lowest heart rate during intubation were recorded. Proper tracheal tube placement was confirmed by direct visualization, chest auscultation, and detection of end-tidal carbon dioxide.

Statistical Analysis

A 10 second difference in TTSI was considered clinically significant as previously published. Sample size calculation yielded 60 patients needed to complete study participation to show a greater than 10 second intergroup difference was statistically significant, with power of 0.8 and an alpha value of 0.05. Anthropometric data were determined by World Health Organization child growth standards (WHO Anthro for PC 3.2.2, World Health Organization, Geneva, Switzerland). Groups were compared for patient characteristic similarity. The primary outcome measure was intergroup difference in TTSI. Intubation attempts in which the attending anesthesiologist performed the final intubation were excluded from analysis of the primary outcome measure, but were included in analysis of appropriate secondary outcome measures. Secondary outcome measures included intergroup differences in: the number of first attempt successful tracheal intubations; TTSI for tracheal intubations completed on the first attempt; the total number of intubation attempts needed to successfully intubate the trachea; best Cormack-Lehane glottic view; and technical factors complicating intubation. Time to manikin tracheal intubation, change in tracheal intubation time from manikin to clinical settings and relationships of tracheal intubation times to laryngoscopist characteristics were also analyzed.

Data distribution was analyzed by Shapiro-Wilk, with p <0.05 indicating the distribution was not normal. Normally distributed continuous data were expressed as mean and 95% confidence interval and analyzed by
univariate ANOVA with Tukey’s method to compare means. Continuous data that were not normally distributed were expressed as median and 95% confidence interval and analyzed using Kruskal-Wallis test, with differences between medians compared by the Hodges Lehman method assuming data symmetry. Changes in time to successful intubation from the manikin to clinical settings were compared by paired Wilcoxon. Categorical data were analyzed by Chi-square. Statistical significance was taken at p <0.05 (JMP 10.0.0, SAS Institute, Cary, NC, USA).

Results

Seventy-seven children were screened and sixty-five aged 3 weeks to 23 months of age were enrolled during an 8 month period. One subject was excluded for intubation timing error and one additional subject was excluded for lack of video laryngoscope availability after randomization (Figure 1). There were no significant intergroup differences in patient characteristics (Table 1). The attending anesthesiologist completed the intubation in one Storz and two GlideScope patients, thus these were excluded from TTSI analysis. Intubation times were not normally distributed (Shapiro-Wilk, all p < 0.01). TTSI was significantly different between groups, longer for Storz (42.1; 34.0 to 59.0 seconds) than for Direct (21.5; 17.0 to 34.3 seconds; p = 0.002; Table 2). The 95% confidence intervals of median TTSI were narrower in Direct (Figure 2). We were not able to demonstrate a TTSI difference of at least 10 seconds between GlideScope (30.8; 24.1 to 46.4 seconds) and either Direct or Storz. Analysis limited to intubations successfully completed on the first attempt showed TTSI was longer in 16 Storz patients (34.3; 27.8 to 42.3 seconds) than in 17 Direct patients (19.3; 15.6 to 26.1 seconds; p=0.003), and 16 GlideScope patients (25.0; 19.4 to 31.9 seconds; p=0.04).

Manikin intubation time was not different based on year of training overall or within laryngoscope groups (all p >0.40). Similarly, TTSI was not different

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Consolidated Standards of Reporting Trials (CONSORT) flow diagram. TTSI = Total time to successful tracheal intubation.
Total time to successful tracheal intubation performed by anesthesiology trainees in children <2 years old was different for patients intubated using direct laryngoscopy, GlideScope or Storz video laryngoscopes in the clinical setting (p=0.006 Kruskall-Wallis). Intergroup comparison of medians by Hodges Lehman is shown. Median and 95% confidence interval are indicated for each group.

Total time to successful tracheal intubation plotted for individual anesthesiology trainees in manikin and clinical settings, with median times indicated by solid lines. Dotted lines connect manikin and clinical tracheal intubation times for individual laryngoscopists using assigned laryngoscopes. Tracheal intubation time increased significantly from the manikin to clinical setting within each laryngoscope group (paired Wilcoxon, all p <0.0001).
based on year of training overall (p = 0.27), or within laryngoscope groups (all p >0.20). TTSI increased from the manikin to the clinical setting for individual laryngoscopists within all groups (all p < 0.0001; Figure 3). The magnitude of this increase was larger in Storz than Direct (p = 0.01; Table 2).

Only 3 pulse oxygen desaturations to <92% were reported: Storz to 76% (n=1), which was felt to be secondary to bronchospasm; GlideScope to 85% (n=1) and Direct to 77% (n=1) due to prolonged intubation attempts. There were no bradycardias reported in any group, even in the setting of pulse oxygen desaturation. Atropine was given to 1 Direct and 1 GlideScope patient before laryngoscopy. Exclusion of these patients did not change results of lowest heart rate analysis. Blood was found on the laryngoscope blade after intubation in 2 Storz patients, but no major upper airway trauma was noted in any patient. Technical factors other than inappropriate endotracheal tube size were more likely to complicate tracheal intubation in Storz (p=0.04). There were no significant differences in other secondary outcome markers (Table 3).

Discussion

It is prudent to investigate the clinical efficacy of newly developed airway devices marketed for use in small children prior to recommendations for widespread use, as these devices are often miniature versions of adult equipment. Indirect video laryngoscopy has been previously shown to improve the rate of successful intubation by novice laryngoscopists in patients age >12 years33. However, in this study of anesthesiology trainees intubating younger children (age <2 years) with normal airway anatomy, TTSI was longer for Storz than for Direct. TTSI was nearly 10 seconds longer for GlideScope than Direct, although we did not find statistical significance for this difference. Tracheal intubation time using Direct or GlideScope by pediatric anesthesiologists who had performed >50 GlideScope intubations in infants were similar to what we found when intubations were performed by anesthesiology trainees10. These findings suggest the intergroup difference we found in time to intubate children <2 years of age was likely not based solely on longer TTSI when intubation is performed by anesthesiology trainees.

In addition to TTSI, it is reasonable to consider differences in first attempt success rates, total number of intubation attempts, and vital sign variability as important markers of laryngoscopist proficiency and device safety. We found no statistically significant difference in first attempt success rates or total number of intubation attempts between laryngoscope groups. The absence of vital sign variability and the minimal airway trauma observed during intubation are evidence that our trainees exercised appropriate caution during intubation attempts, even if measuring TTSI may have motivated them to intubate as rapidly as possible.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Patient characteristics</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Direct N = 19</td>
</tr>
<tr>
<td><strong>Age (months); median (95% confidence interval)</strong></td>
<td>8.1 (5.7-13.1)</td>
</tr>
<tr>
<td>Gender (F; M)</td>
<td>6; 13</td>
</tr>
<tr>
<td>ASA status (1; 2; 3; 4)</td>
<td>4; 9; 6; 0</td>
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<tr>
<td><strong>Weight (kg); mean (95% confidence interval)</strong></td>
<td>8.0 (6.9-9.2)</td>
</tr>
<tr>
<td><strong>Weight for length percentile; median (95% confidence interval)</strong></td>
<td>72.1 (47.6-84.0)</td>
</tr>
</tbody>
</table>

Continuous data were not normally distributed (Shapiro-Wilk p <0.05) and were expressed as median (95% confidence interval) and analyzed by Kruskal-Wallis except for weight, which is expressed as mean (95% confidence interval) and analyzed by ANOVA; categorical data were analyzed by Chi square. There were no significant intergroup differences.
The reasons for our findings are likely multifactorial. The Storz fiberoptic camera is positioned close to the tip of the laryngoscope, providing a magnified and detailed image of the glottis, but a narrow angle of view\textsuperscript{21}. Oral secretions may obscure the fiberoptic camera lens and the narrow angle of view may lead to difficulty placing the tracheal tube after obtaining a view of the glottis\textsuperscript{30,34}. Laryngoscopists reported the least prior experience with Storz when compared to the other laryngoscopes in this study thus these trainees might have lacked the hand-eye coordination necessary for rapid Storz intubation. While this study was not specifically designed to investigate this difference, technical factors complicated intubation in over one-third of video laryngoscope tracheal intubations compared to approximately one-fifth of Direct tracheal intubations. Several Storz required more than one intubation attempt due to inability to maneuver the tracheal tube past the vocal cords despite a grade I or II glottic view (n=6), or oral secretions obscuring the glottic view (n=2). The tracheal tube could not be maneuvered past the glottis in 3 GlideScope patients, but oral secretions complicated no GlideScope intubations. Use of the GlideScope Cobalt video laryngoscope size 2 blade has been reported to be occasionally complicated by a reflected image of the vocal cords. Such an optical illusion could lead the laryngoscopist to advance the tracheal tube towards a false view of the glottis, resulting in multiple intubation attempts\textsuperscript{35}.

Multiple studies of indirect video laryngoscopes in the pediatric population derive their data from manikin evaluations that our results suggest may not accurately predict human results\textsuperscript{20-24}. In our study, intergroup differences in manikin intubation times, while statistically significant, were only a few seconds and not clinically significant. Trainees were rapidly able to intubate the manikin but TTSI in the clinical setting was significantly longer (Table 2). This suggests that manikin training may not be equivalent to in vivo training and thus perhaps should be seen as a precursor to, but not a replacement for clinical experience in infants and children less than 2 years.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
 & Direct & GlideScope & Storz & \\
 & N = 19 & N = 20 & N = 21 & \\
\hline
Time to successful tracheal intubation (seconds)
(Mean; 95% confidence interval) & 21.5(17.0-34.3) & 30.8(24.1-46.4) & 42.1(34.0-59.0) & 0.006 \\
\hline
Differences & Direct to Storz & 17.7 (7.4 to 30.7) & 0.002 & \\
 & Direct to GlideScope & 6.9 (-2.2 to 19.8) & 0.14 & \\
 & Storz to GlideScope & 10.4 (-2.0 to 23.7) & 0.09 & \\
\hline
Time to intubate manikin seconds & 6.8(5.2-8.1) & 7.3(5.6 to 12.0) & 9.7(7.7 to 13.3) & 0.10 & \\
\hline
Differences & Direct to Storz & 3.3 (0.2-7.1) & 0.04 & \\
 & Direct to GlideScope & 0.2 (-1.6-3.9) & 0.85 & \\
 & Storz to GlideScope & 1.5 (-0.8-6.5) & 0.13 & \\
\hline
Change in time manikin to clinical seconds & 15.0(11.1-26.7) & 23.5(16.9-38.6) & 31.2(23.1-48.8) & 0.05 & \\
\hline
Differences & Direct to Storz & 13.9 (3.1-26.5) & 0.01 & \\
 & Direct to GlideScope & 6.0 (-2.6-18.2) & 0.19 & \\
 & Storz to GlideScope & 7.0 (-5.5-19.3) & 0.26 & \\
\hline
\end{tabular}
\caption{Tracheal intubation times}
\label{table2}
\end{table}

Intergroup comparisons of tracheal intubation times when performed by anesthesiology trainees in an infant airway manikin or in children <2 years. Data were not normally distributed (Shapiro-Wilk all p <0.05) so are expressed as median (95% confidence interval) and were analyzed by Kruskal-Wallis; differences in medians were analyzed using Hodges Lehman assuming data symmetry. Total time to successful tracheal intubation in the clinical setting was longer in Storz than in Direct. Tracheal intubation time increased from the manikin to clinical setting within all groups (all p <0.0001); this difference was larger in Storz than Direct.
Several factors limit generalizing the findings of this study. Trainees reported more prior intubation experience using DL than the other laryngoscopes. This is expected since we studied trainees who had completed at least one year of anesthesiology residency. Because of this we were unable to equalize prior clinical experience with DL to that with the other laryngoscopes. We studied anesthesiology trainees, leading to a limited number of laryngoscopists at different stages of training. This limits assessment of any learning effect that may have occurred, since none of the 22 individuals studied performed more than 3 intubations with one type of laryngoscope within the study. We did not obtain a measure of neuromuscular relaxation such as train of four prior to intubation as this is not part of our standard practice in children <2 years old. As no intubation was associated with coughing or patient movement it is unlikely that a difference in neuromuscular blockade contributed to differences in time to successful intubation.

**Conclusion**

Mastery of multiple intubation techniques is a key goal of anesthesiology training. Anesthesiology trainees completed manikin tracheal intubation rapidly with all laryngoscopes studied, but required a clinically significant longer time to tracheally intubate children <2 years. Our findings suggest that adequate in vivo training should be included to facilitate achieving expert level with device-specific techniques including the required hand-eye coordination needed to pass the endotracheal tube beyond the vocal cords.
References


33. Howard-Qudiano KJ, Huang YM, Matevosian R, Kaplan MB and Steadman RH: Video-assisted instruction improves the success rate


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¹ Term of four
² PTC = train of four
³ Second twitch

REFERENCES:
1. BRIDION Summary of Product Characteristics (SPC)

Please see summary of product characteristics for full prescribing information.

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