

Learning Curves for Direct Laryngoscopy and GlideScope® Video Laryngoscopy in an Emergency Medicine Residency

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Supervising Section Editor: John Ashurst, DO

Submission history: Submitted August 30, 2014; Accepted September 26, 2014

Electronically published October 29, 2014

Full text available through open access at http://escholarship.org/uc/uciem_westjem

DOI: 10.5811/westjem.2014.9.23691

Introduction: Our objective is to evaluate the resident learning curves for direct laryngoscopy (DL) and GlideScope® video laryngoscopy (GVL) over the course of an emergency medicine (EM) residency training program.

Methods: This was an analysis of intubations performed in the emergency department (ED) by EM residents over a seven-year period from July 1, 2007 to June 30, 2014 at an academic ED with 70,000 annual visits. After EM residents perform an intubation in the ED they complete a continuous quality improvement (CQI) form. Data collected includes patient demographics, operator post-graduate year (PGY), difficult airway characteristics (DACs), method of intubation, device used for intubation and outcome of each attempt. We included in this analysis only adult intubations performed by EM residents using a DL or a standard reusable GVL. The primary outcome was first pass success, defined as a successful intubation with a single laryngoscope insertion. First pass success was evaluated for each PGY of training for DL and GVL. Logistic mixed-effects models were constructed for each device to determine the effect of PGY level on first pass success, after adjusting for important confounders.

Results: Over the seven-year period, the DL was used as the initial device on 1,035 patients and the GVL was used as the initial device on 578 patients by EM residents. When using the DL the first pass success of PGY-1 residents was 69.9% (160/229; 95% CI 63.5%-75.7%), of PGY-2 residents was 71.7% (274/382; 95% CI 66.9%-76.2%), and of PGY-3 residents was 72.9% (309/424; 95% CI 68.4%-77.1%). When using the GVL the first pass success of PGY-1 residents was 74.4% (87/117; 95% CI 65.5%-82.0%), of PGY-2 residents was 83.6% (194/232; 95% CI 76.7%-87.7%), and of PGY-3 residents was 90.0% (206/229; 95% CI 85.3%-93.5%). In the mixed-effects model for DL, first pass success for PGY-2 and PGY-3 residents did not improve compared to PGY-1 residents (PGY-2 aOR 1.3, 95% CI 0.9-1.9; p-value 0.236) (PGY-3 aOR 1.5, 95% CI 1.0-2.2, p-value 0.067). However, in the model for GVL, first pass success for PGY-2 and PGY-3 residents improved compared to PGY-1 residents (PGY-2 aOR 2.1, 95% CI 1.1-3.8, p-value 0.021) (PGY-3 aOR 4.1, 95% CI 2.1-8.0, p<0.001).

Conclusion: Over the course of residency training there was no significant improvement in EM resident first pass success with the DL, but substantial improvement with the GVL. [West J Emerg Med. 2014;15(7):930-937.]

INTRODUCTION

Emergency physicians are expected to be able to manage the airways of critically ill and injured patients presenting to the emergency department (ED). As such, emergency medicine (EM) residents have to be trained, knowledgeable and skilled with a variety of intubation devices. These include both the conventional direct laryngoscope (DL) and indirect laryngoscopes such as the GlideScope® video laryngoscope (GVL). The intubation techniques of these two devices are considerably different.

With DL, the operator must compress and displace the tissues of the upper airway so that a direct line of sight to the airway can be achieved.¹ This can be technically challenging and thus achieving an adequate laryngeal view can often be difficult. However, once an adequate view is achieved directing the tube to the laryngeal inlet is usually fairly easy.

With the GVL, the hyperangulated blade and the presence of a micro video camera on the blade allow the operator to look around the structures that would impede a direct view and thus obviate the need to displace the tissues of the upper airway. An excellent view of the laryngeal inlet is almost always achieved when using the GVL.^{2,3} However, directing the tube to what the operator is seeing on the video screen can be quite challenging, as the operator must direct the tube along the curved path of the hyperangulated blade. To facilitate this process, the manufacturer of the GVL has produced a specially designed rigid stylet (GlideRite®) that matches the curvature of the GVL blade.⁴

The techniques employed in using these two intubating devices are very different, so one might expect that their learning curves would likely also be different. The goal of this investigation was to compare the learning curves for DL and GVL over the course of an EM training program.

METHODS

Study Design

This was a retrospective analysis of intubations performed on adults in the ED by EM residents with the DL or the standard reusable GVL over the seven-year period between July 1, 2007 and June 30, 2014. This project was granted exemption from informed consent requirements by the university's institutional review board (IRB) prior to conducting the study.

Study Setting and Population

This study was conducted at a tertiary care academic ED, which currently has 61 beds and approximately 70,000 annual ED visits. We collected data on all patients requiring intubation in this ED. Only adult patients (age 18 or older) who underwent an initial intubation attempt by EM residents using the DL or the standard GVL were included in this study (Figure 1).

This ED is a Level 1 trauma center with a three-year EM residency program and a five-year combined emergency medicine/pediatrics (EM/Peds) residency program. For the purposes of this study, we included only categorical EM

residents (post-graduate year [PGY]-1, 2, 3) in the analyses. The typical EM class size is 15 per year (range 11-16) for a total of approximately 45 residents (range 40-47) in the EM program at any given time. Over the seven-year study period, 129 EM residents have performed intubations. An EM resident, over the course of training in our program, performs an average of 21 adult intubations in the ED. All intubations performed by EM residents are supervised by an EM attending.

During the study period, there were between two and four GVL units available at any given time, as well as a full range of available Macintosh, Miller, and GrandView™ DL blades. Both standard malleable stylets and GlideRite® rigid stylets were available in the ED throughout the entire study period. The decision regarding the method of intubation and initial device selection were at the discretion of the EM resident and EM attending.

EM residents in this program receive formal instruction on the use of multiple airway devices and techniques. These include DL, GVL, C-MAC, flexible fiberoptic scope, intubating laryngeal mask airway, and cricothyrotomy. Resident training involves both didactic material as well as hands on experience in the simulation lab. All interns complete a mandatory rotation in anesthesiology where they perform roughly 25 intubations on stable patients, which are primarily performed using DL. The technique taught to EM residents regarding GVL intubation has been previously described in detail.⁵ Briefly, residents are instructed to insert the device in the midline and navigate slowly towards the airway as they systematically identify landmarks as they advance the blade. They are strongly encouraged to use the GlideRite® stylet for all GVL intubations.

Study Protocol

After each intubation, a continuous quality improvement (CQI) form was completed by the operator to document clinically important information. Data collected included patient age and sex, operator PGY, difficult airway characteristics of the patient, indication for and method of intubation, drugs used for intubation, device used and reason for device selection and outcome of each attempt.

Difficult airway characteristics assessed by the operator included the following: cervical immobility, facial or neck trauma, airway edema, small mandible, obesity, large tongue, short neck, restricted mouth opening, blood in airway, vomit in airway.

The three different intubation methods were classified on the form as rapid sequence intubation (RSI) in which a paralytic agent was used, oral intubation in which only a sedative agent was used (SED), and oral intubation in which no medications were used (NO MEDS).

Options for the reason for device selection were “standard” (routine airway, no suspected difficulty), “difficult” (difficult airway anticipated) or “education” (device selected for educational reasons).

Primary outcome was the first pass success of DL and GVL per PGY. We defined an intubation attempt as the insertion of the laryngoscope blade into the mouth of the patient, regardless whether an attempt was made to insert a tracheal tube. First pass success was defined as tracheal intubation with a single laryngoscope blade insertion.

The senior author reviewed every CQI form for completion, and in the case of an incomplete form, the operator was interviewed to complete the data collection. To ensure complete compliance, missing data forms were identified through a cross-referencing system. We used various methods throughout the study period to identify missing forms, including cross referencing billing records, pharmacy records, and a customized intubation report in the electronic medical record. If an intubation was performed in the ED that was missing a form, the operator was given a blank CQI form to complete.

Data Analysis

Patient and intubation characteristics are presented descriptively in the DL and GVL groups for each PGY of training. We reported continuous variables as means, and categorical variables as percentages. For categorical data we included 95% confidence intervals (CI) calculated using the “exact” method. The proportion of cases with first

pass success was reported as a percentage for each year of residency training. We used a logistic mixed-effects model to determine the association between PGY of residency training and first pass success. A mixed-effects model was used because the data are clustered according to the resident performing each intubation. Thus, the individual resident was added to the model as a mixed effect. The primary predictor of interest was PGY of residency training, categorized as PGY-1, PGY-2 and PGY-3. There was a significant interaction between PGY and device (DL versus GVL) with regard to the effect on first pass success, meaning the effect of PGY on first pass success depended on the device used. Thus, we constructed models separately for DL and GVL. Based on previous investigations the following confounders were selected a priori and included in each model: reason for intubation (cardiac arrest versus non-cardiac arrest) and number of difficult airway characteristics (included as an ordinal variable).^{5,6} These variables have been shown to be significantly associated with first pass success. We also included calendar year as a possible confounder, given the possibility for improvement over time with continued use of the devices in the ED. We performed all statistical analyses with STATA version 13 (College Station, Texas).

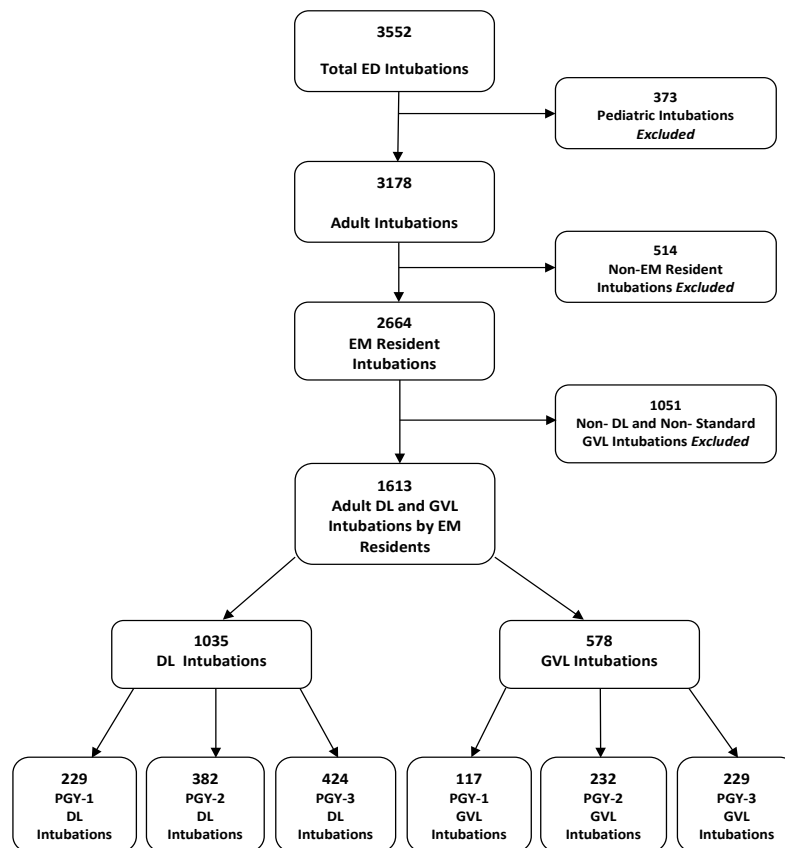


Figure 1. Flow diagram of patients in DL and GVL cohorts. ED, emergency department; EM, emergency medicine; DL, direct laryngoscope; GVL, GlideScope® video laryngoscope; PGY, post-graduate year

RESULTS

Over the seven-year study period, EM residents performed a total of 1,613 intubations using the DL or the GVL. Of these, 1,035 were initially attempted using the DL and the 578 were attempted with GVL (Figure 1). Patient and intubation characteristics of each cohort are reported in Table 1a and Table 1b. In the GVL cohort, more patients were trauma patients and more patients had difficult airway characteristics.

For DL, the first pass success of PGY-1 residents was 69.9% (160/229; 95% CI 63.5%-75.7%), for PGY-2 residents 71.7% (274/382; 95% CI 66.9%-76.2%), and for PGY-3 residents 72.9% (309/424; 95% CI 68.4%-77.1%). For GVL the first pass success of PGY-1 residents was 74.4% (87/117; 95% CI 65.5%-82.0%), for PGY-2 residents 83.6% (194/232; 95% CI 76.7%-87.7%), and for PGY-3 residents 90.0% (206/229; 95% CI 85.3%-93.5%) (Figure 2).

In the mixed-effects model for DL, first pass success for PGY-2 and PGY-3 residents did not improve compared to PGY-1 residents (PGY-2 aOR 1.3, 95% CI 0.9-1.9; p-value 0.236) (PGY-3 aOR 1.5, 95% CI 1.0-2.2, p-value 0.067) (Table 2a). However, in the model for GVL first pass success for PGY-2 and PGY-3 residents improved compared to PGY-1 residents (PGY-2 aOR 2.1, 95% CI 1.1-3.8, p-value 0.021; PGY-3 aOR 4.1, 95% CI 2.1-8.0, p<0.001) (Table 2b). Also, for each calendar year increment, the odds of first pass success did not increase with DL (aOR 1.0, 95% CI 0.9-1.1, p-value 0.878). However, GVL performance improved over time with continued use in the ED (aOR 1.2, 95% CI 1.1-1.4, p-value 0.009).

DISCUSSION

In this study we sought to determine the learning curves for two commonly used intubating devices in the ED, the direct laryngoscope and the GlideScope® video laryngoscope. Our results show that the first pass success for DL was approximately 70% for PGY-1 residents and increased to 73% for PGY-3 residents. This difference was not statistically significant or clinically meaningful. The first pass success for GVL was approximately 75% for PGY-1 residents, a value that was similar to DL for the same level of training. However, this improved significantly to 90% for PGY-3 residents. To account for potential confounders we developed a logistic mixed-effects model, which demonstrated that there was no significant improvement in DL performance (aOR 1.5) between PGY-1 and PGY-3 residents, but considerable improvement in performance with GVL (aOR 4.1). This suggests that the learning curve for DL is fairly flat, with little improvement in success with training over time. On the other hand, GVL has a very steep learning curve with significant improvement over the course of residency training. This was true despite the fact that EM residents performed many more DL than GVL intubations in the ED during the study period.

The difference in the learning curves between the DL and the GVL is remarkable and may be related to inherent

differences in their design and use. When performing DL, obtaining a view of the laryngeal inlet requires great skill and technically can be very challenging, but once that view is achieved intubation is usually straightforward. On the other hand, when performing GVL, an excellent view can usually be easily attained, but directing the tube to the image of the laryngeal inlet that is visualized on the video monitor can be very challenging. For DL, optimizing the laryngeal view requires subtle changes in technique and positioning, and with the experience a resident receives during their training, they may not be able to acquire this skill. With GVL, achieving an excellent view is usually easy, and the learning curve is primarily dependent on acquiring the skill of directing the tube to the image that is seen. This skill appears to be more easily acquired over the course of residency training.

Another possible explanation for the lack of DL improvement over training is the rapid abandonment of DL. In the past, if DL failed, there were no other options for rescue intubation, so DL was attempted again. This allowed the operator to learn from the initial DL failure and receive another learning experience on the additional DL attempt. Currently there are multiple airway devices available for rescue intubation attempts, particularly video laryngoscopes, and operators are more likely to abort the use of DL after a failed intubation and switch to video laryngoscope (VL). Thus the opportunity for residents to learn from their mistakes and advance their DL skills after failed first intubation attempts is lost.

Our results are supported by other studies that have evaluated the learning curves for DL and GVL. Ambrosio et al. conducted a randomized trial comparing DL and GVL intubation performance on a difficult airway manikin among novice physicians with little to no prior intubation experience.⁷ These novice physicians had 47.4% success with DL and 100% success with GVL. Nouruzi-Sedeh et al. also compared the success of DL to GVL in untrained medical personnel performing intubations on stable patients in the operating room.⁸ They found that these novices had success of only 51% with DL but 90% with GVL.

Our results, considered in the context of previous research, suggest that for operators with less experience, the GVL is more quickly learned and is associated with higher first pass intubation success than DL.

LIMITATIONS

There are several limitations to this study. First, because it was observational the selection of operators and devices was not randomized. There was likely some selection bias regarding the choice of airway devices with user preference and comfort dictating which devices were selected. Also, patient characteristics could impact the device selection, as demonstrated by the high use of the GVL in patients with difficult airway characteristics. We attempted to control for these confounders by using a logistic mixed-effects model. A randomized controlled study would be ideal and would

Table 1a. Patient and intubation characteristics by PGY in DL cohort.

Patient characteristic	PGY-1 (%)	95% CI*	PGY-2 (%)	95% CI*	PGY-3 (%)	95% CI*
Mean age, years	52.9	50.3-55.6	51.0	47.5-54.5	49.6	47.6-51.6
Sex						
Male	60.7	54.1-67.1	68.3	63.4-73.0	65.6	60.8-70.1
Medical/trauma						
Trauma patients	18.3	13.6-24.0	36.7	31.8-41.7	42.2	37.5-47.1
Difficult airway characteristic						
None	51.5	44.9-58.2	37.7	32.8-42.8	38.4	33.8-43.3
≥1	48.5	41.8-55.2	62.3	57.2-67.2	61.6	56.7-66.2
Cervical immobilization	12.7	8.7-17.7	21.5	17.5-25.9	31.1	26.8-35.8
Blood in airway	16.6	12.0-22.1	22.3	18.2-26.8	22.9	19.0-27.2
Vomit in airway	12.7	8.7-17.7	13.9	10.6-17.8	12.5	9.5-16.0
Facial/neck trauma	4.4	2.1-7.9	8.1	5.6-11.3	10.1	7.4-13.4
Obesity	14.4	10.2-19.6	18.6	14.8-22.9	16.3	12.9-20.1
Short neck	11.8	7.9-16.7	11.8	8.7-15.4	11.3	8.5-14.7
Large tongue	9.2	5.8-13.7	10.5	7.6-14.0	13.0	9.9-16.6
Airway edema	2.6	1.0-5.6	1.6	0.6-3.4	3.1	1.6-5.2
Small mandible	6.6	3.7-10.6	4.7	2.8-7.4	5.4	3.5-8.0
Restricted mouth opening	0		0		0.2	0-1.3
Reason for intubation						
Airway protection	62.5	55.8-68.7	63.9	58.8-68.7	58.3	53.4-63.0
Respiratory failure	19.7	14.7-25.4	16.8	13.2-20.9	18.4	14.8-22.4
Cardiac arrest	10.5	6.8-15.2	10.0	7.1-13.4	14.9	11.6-18.6
Patient control	5.2	2.7-9.0	8.6	6.0-11.7	6.8	4.6-9.7
Hypoxia	2.2	0.7-5.0	0.8	0.2-2.3	1.7	0.7-3.4
Reason for device selection						
Standard	95.2	91.6-97.6	94.2	91.4-96.4	92.9	90.1-95.2
Difficult	2.2	0.7-5.0	1.8	0.7-3.7	3.3	1.8-5.5
Education	2.6	1.0-5.6	3.9	2.2-6.4	3.8	2.2-6.1
Method of intubation						
Rapid sequence intubation (RSI)	89.1	84.3-92.8	88.0	84.3-91.1	83.3	79.4-86.7
Sedative agent was used (SED)	0		0.8	0.2-2.3	0.7	0.2-2.1
No medications were used (NO MEDS)	10.9	7.2-15.7	11.3	8.3-14.9	16.0	12.7-19.9
Paralytic agent						
Succinylcholine	48.9	42.3-55.6	41.9	36.9-47.0	39.6	34.9-44.5
Rocuronium	40.2	33.8-46.8	46.1	41.0-51.2	43.2	38.4-48.0
Induction agent						
Etomidate	84.7	79.4-89.1	83.8	79.7-87.3	79.0	74.8-82.8
Ketamine	0.9	0.1-3.1	1.8	0.7-3.7	2.4	1.1-4.3
Propofol	0.9	0.1-3.1	0.8	0.2-2.3	0.7	0.2-2.1

PGY, post-graduate year; DL, direct laryngoscope; RSI, rapid sequence intubation; SED, sedative agent was used; NO MEDS, no medications were used

*95% CIs calculated with the "exact" method.

Table 1b. Patient and intubation characteristics by PGY in GVL cohort.

Patient characteristic	PGY-1 (%)	95% CI*	PGY-2 (%)	95% CI*	PGY-3 (%)	95% CI*
Mean age, years	49.4	45.7-53.1	47.3	44.8-49.8	48.6	46.0-51.2
Sex						
Male	70.9	61.8-79.0	69.4	63.0-75.3	68.1	61.7-74.1
Medical/trauma						
Trauma patients	47.0	37.7-56.5	58.2	51.6-64.6	62.5	55.8-68.7
Difficult airway characteristic						
None	25.6	18.0-34.5	24.1	18.8-30.2	21.4	16.3-27.3
≥1	74.4	65.5-82.0	75.9	69.8-81.2	78.6	72.7-83.7
Cervical immobilization	42.7	33.6-52.2	48.7	42.1-55.3	50.2	43.6-56.9
Blood in airway	26.5	18.8-35.5	29.3	23.5-35.6	27.1	21.4-33.3
Vomit in airway	14.5	8.7-22.2	11.6	7.8-16.5	12.2	8.3-17.2
Facial/neck trauma	24.8	17.3-33.6	25.4	20.0-31.5	22.7	17.5-28.7
Obesity	19.7	12.9-28.0	20.3	15.3-26.0	17.5	12.8-23.0
Short neck	18.8	12.2-27.1	19.0	14.1-24.6	15.7	11.3-21.1
Large tongue	15.4	9.4-23.2	11.2	7.5-16.0	13.5	9.4-18.7
Airway edema	4.2	1.4-9.7	4.7	2.4-8.3	4.4	2.1-7.9
Small mandible	3.4	0.9-8.5	8.2	5.0-12.5	9.2	5.8-13.7
Restricted mouth opening	1.7	0.2-6.0	12.9	0.3-3.7	1.8	0.5-4.4
Reason for intubation						
Airway protection	65.8	56.5-74.3	65.5	59.0-71.6	62.0	55.4-68.3
Respiratory failure	12.0	6.7-19.3	14.7	10.4-19.9	14.4	10.1-19.6
Cardiac arrest	8.6	4.2-15.2	10.8	7.1-15.5	14.9	10.5-20.1
Patient control	9.4	4.8-16.2	7.3	4.3-11.5	8.3	5.1-12.7
Hypoxia	4.3	1.4-9.7	1.7	0.5-4.4	0.4	0-2.4
Reason for device selection						
Standard	29.9	21.8-39.1	39.7	33.3-46.3	31.0	25.1-37.4
Difficult	54.7	45.2-63.9	52.6	46.0-59.2	63.3	56.7-69.6
Education	15.4	9.4-23.2	7.8	4.7-12.0	5.7	3.1-9.5
Method of intubation						
Rapid sequence intubation (RSI)	89.2	82.8-94.6	83.6	78.2-88.1	82.5	77.0-87.2
Sedative agent was used (SED)	3.4	0.9-8.5	2.2	0.7-5.0	1.8	0.5-4.4
No medications were used (NO MEDS)	6.8	3.0-13.0	14.2	10.0-19.4	15.7	11.3-21.1
Paralytic agent						
Succinylcholine	47.0	37.7-56.5	44.0	37.5-50.6	43.7	37.2-50.4
Rocuronium	42.7	33.6-52.2	39.2	32.9-45.8	38.9	32.5-45.5
Induction agent						
Etomidate	81.2	72.9-87.8	78.0	72.1-83.2	76.9	70.9-82.2
Ketamine	5.1	1.9-10.8	3.0	1.2-6.1	3.1	1.2-6.2
Propofol	1.7	0.2-6.0	2.2	0.7-5.0	1.3	0.3-3.8

PGY, post-graduate year; GVL, GlideScope® video laryngoscope; RSI, rapid sequence intubation; SED, sedative agent was used; NO MEDS, no medications were used

*95% CIs calculated with the "exact" method.

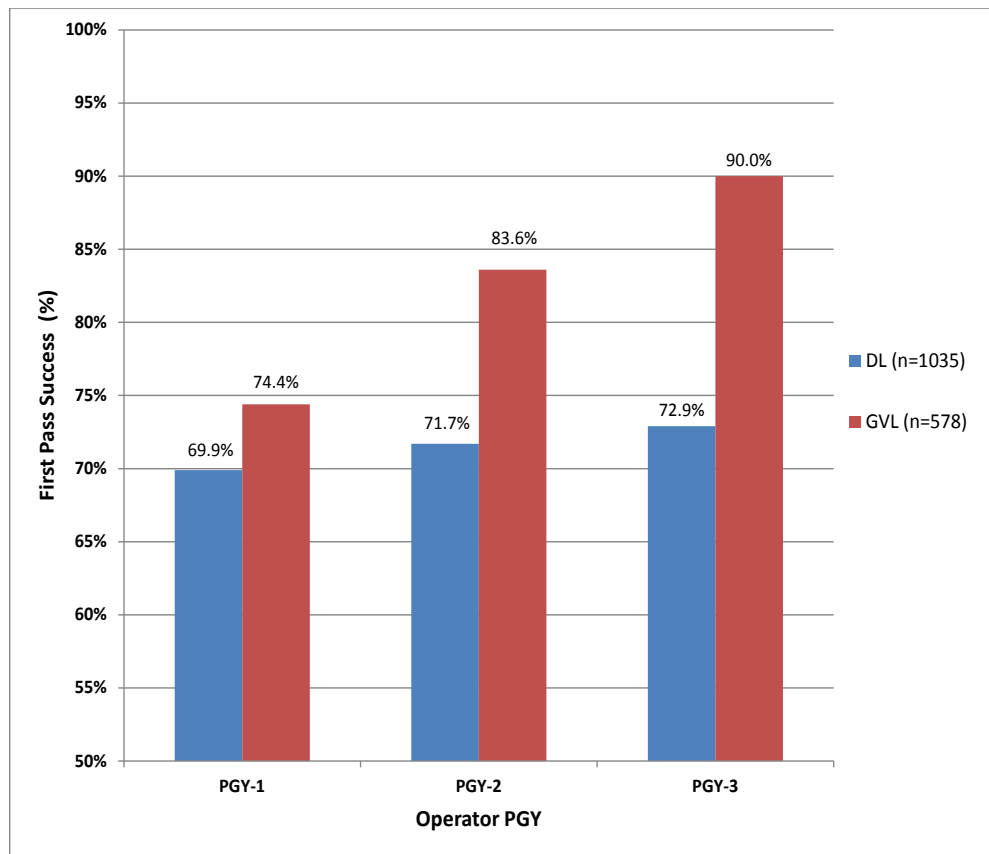


Figure 2. First pass success by PGY in DL and GVL cohorts. PGY, post-grad year; DL, direct laryngoscopy; GVL, GlideScope® video laryngoscope

Table 2a. Mixed-effects model for improvement in first pass success with DL.

Variable	Adjusted odds ratio	95% CI	p-value
Reason for intubation			
Non-cardiac arrest	[Reference]		
Cardiac arrest	0.7	0.5-1.2	0.178
Difficult airway characteristics	0.6	0.6-0.7	<0.001
Operator PGY			
PGY-1	[Reference]	0.9-1.9	0.236
PGY-2	1.3	1.0-2.2	0.067
PGY-3	1.5		
Calendar year	1.0	0.9-1.1	0.878

DL, direct laryngoscopy; PGY, post-graduate year

Table 2b. Mixed-effects model for improvement in first pass success with GVL.

Variable	Adjusted odds ratio	95% CI	p-value
Reason for intubation			
Non-cardiac arrest	[Reference]		
Cardiac arrest	0.3	0.1-0.5	<0.001
Difficult airway characteristics	0.7	0.6-0.9	<0.001
Operator post-graduate year (PGY)			
PGY-1	[Reference]	1.1-3.8	0.021
PGY-2	2.1	2.1-8.0	<0.001
PGY-3	4.1		
Calendar year	1.2	1.1-1.4	0.009

GVL, GlideScope® video laryngoscope; PGY, post-graduate year

overcome this limitation; however, the randomization of device selection would be difficult and impractical in the ED setting where intubations are often performed precipitously. Furthermore, randomization may in fact be dangerous by forcing an operator to perform a difficult intubation with a device they feel is not suitable for the patient.

Another study limitation is the use of self-reported data. After each intubation the operator filled out a data form about the procedure. It is possible that information was reported inaccurately and that under-reporting of certain events occurred. However, data collection forms were reviewed as they were received and the operator was interviewed and/or the medical record was reviewed if there appeared to be incongruous information. To overcome this limitation of self-report bias, a designated research observer would need to be present at every intubation to record the data objectively, but this is not practical due to the infrequent and precipitous nature of ED intubations. Recall bias is another limitation that could impact the results; however, this effect is likely to be minimal as the vast majority of forms were filled out by the operators within a few days of the intubation.

Another limitation is that this study was conducted at a single EM residency training program site and aspects of this clinical and learning environment may differ from other training programs. For example, video laryngoscopes have been used in our ED since their introduction in 2001 and multiple video, fiberoptic and optical airway devices are available for use on a routine basis. EM residents in this program have a great deal of exposure and training with video laryngoscopes, which may not be the case in other training programs. Thus, our results may not be generalizable to other academic sites.

Only ED intubations at the primary training site were recorded and analyzed. EM residents have rotations in other EDs, the operating room, the intensive care unit, and on the wards where intubations are performed but are not accounted for in this study. These offsite intubations obviously have an effect on the resident's procedural experience and thus could have impacted the results we obtained.

CONCLUSION

Over the course of a three-year EM residency training program there was very little improvement in the performance of DL by EM residents, but substantial improvement in the performance of GVL. If the trend in VL use in the ED continues to increase at the current rate it is likely that this performance gap between DL and VL will increase over time.

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Conflicts of Interest: By the *WestJEM* article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. The authors received no funding from Verathon Inc., the manufacturer of the GlideScope® Video Laryngoscope system. The manufacturer has not participated in any way with this investigation.

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