Comparison of Video Laryngoscopy Versus Direct Laryngoscopy During Urgent Endotracheal Intubation: A Randomized Controlled Trial

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Objectives: In the critically ill undergoing urgent endotracheal intubation by direct laryngoscopy, multiple attempts are often required with a higher complication rate due to the urgency, uncontrolled setting, comorbidities, and variability in expertise of operators. We hypothesized that Glidescope video laryngoscopy would be superior to direct laryngoscopy during urgent endotracheal intubation.

Design: Single-center prospective randomized controlled trial.

Setting: Beth Israel Medical Center, an 856-bed urban teaching hospital with a 16-bed closed medical ICU.

Patients: Of 153 consecutive patients undergoing urgent endotracheal intubation by pulmonary and critical care medicine fellows, 117 met inclusion criteria.

Interventions: Patients undergoing urgent endotracheal intubation were randomized to Glidescope video laryngoscopy or direct laryngoscopy as the primary intubation device.

Measurements and Main Results: The primary outcome measure was the rate of first-attempt success. Acute Physiology and Chronic Health Evaluation II scores were similar between groups (20.9±8.2 vs 19.9±7.9). First-attempt success was achieved in 74% of the Glidescope video laryngoscopy group compared with 40% in the direct laryngoscopy group ($p < 0.001$). All unsuccessful direct laryngoscopy patients were successfully intubated with Glidescope video laryngoscopy, 82% on the first attempt. There was no significant difference in rates of complications between direct laryngoscopy and Glidescope video laryngoscopy: esophageal intubations (7% vs 0%; $p = 0.05$), aspiration events (7% vs 9%; $p = 0.69$), desaturation (8% vs 4%; $p = 0.27$), and hypotension (13% vs 11%; $p = 0.64$).

Conclusions: Glidescope video laryngoscopy improves the first-attempt success rate during urgent endotracheal intubation performed by pulmonary and critical care medicine fellows when compared with direct laryngoscopy. (*Crit Care Med* 2014; XX:00–00)

Key Words: airway management; endotracheal intubation; intubation; medical education; respiratory insufficiency

Historically, direct laryngoscopy (DL) has been the most common device for intubation. Recent evidence has suggested an increasing role of video laryngoscopy (VL) for emergency airway management. The Macintosh or Miller blade has reported success rates as high as 95% in expert practitioners under controlled conditions (1, 2). In the critically ill population undergoing urgent endotracheal intubation (UEI), first-attempt success rates are lower ranging from 54% to 94%, due to the urgency, uncontrolled setting, comorbidities, and variability in expertise of available practitioners (1, 3–8). As a result, complication rates in UEI are higher than in the routine operating room (OR) cases with reported prevalences of hypotension, hypoxemia, and death as high as 26%, 25%, and 3%, respectively (3, 9, 10). Given these high risks, it is important that critical care physicians achieve competence in airway management. Currently, there is no standardized training in airway management for critical care fellows (11).

Since the introduction of Glidescope video laryngoscopy (GVL; Verathon, Bothell, WA) in 2001, multiple reports have demonstrated improved glottic visualization during elective intubations in the OR (1, 2). However, increased success rates in the OR have only been demonstrated in patients with predicted difficult airways or among nonexpert practitioners (2). Sakles et al (8) showed an improvement in first-attempt success and decreased complications in the emergency department setting. Our group previously showed improved first-attempt success among nonexpert practitioners in a retrospective observational trial of UEI in the critically ill (4). We tested our hypothesis that GVL would be superior to DL in first-attempt success among nonanesthesiologists in a prospective, randomized controlled trial.

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MATERIALS AND METHODS

This was a prospective, randomized controlled trial of UEI performed by pulmonary and critical care medicine (PCCM) fellows. The study was performed at an 856-bed teaching hospital with a 16-bed closed medical ICU (MICU). This study was approved by the Beth Israel Medical Center Institutional Review Board, which waived requirement for informed consent (IRB# 139-12). The study was listed on ClinicalTrials.gov (NCT01683526).

Eight fellows participated, with training levels ranging from postgraduate year 4 through 8. All PCCM fellows received standardized training in the performance of UEI with DL and GVL in the first month of their fellowship as previously described by our group (12). In summary, all first-year fellows attended a series of approximately 10 one-hour mandatory training sessions in team leadership skills for UEI in the first month of fellowship. The sessions included training in crew resource management, combined team organization, deliberate practice with both DL and GVL in tracheal intubation techniques using task trainers, and mastery of a checklist (**Supplemental Table 1**, Supplemental Digital Content 1, http://links.lww.com/CCM/B132) required for safe UEI. Sessions also focused on the pharmacology and dosing of induction agents as well as all components of a difficult airway algorithm. Fellows were trained in a replicated work environment using a computerized patient simulator (SimMan, Laerdal Medical, Laerdal, Norway) and were required to repeatedly practice their skills as team leaders for UEI in multiple scenarios of increasing complexity. At the end of the simulation training sessions, fellows were required to demonstrate perfect adherence to the checklist during each simulated scenario before being allowed to perform tracheal intubations. Once trained, fellows were assigned as first responders and team leaders for all UEIs during their rotations, covering medical emergencies on the medical wards as well as in the MICU. All UEI used a multiple team-based approach with the fellow and critical care attending as a "leadership/intubation" team, an "airway" team consisting of two residents trained to perform bag mask ventilation with a third resident assigned to call out vital signs, and a "nursing team" responsible for preparation and administration of medications including sedatives and vasopressors. All intubations were set up for both DL and GVL. Multiple-sized blades were available (Macintosh 3 and 4, Miller 4, and Glidescope 3 and 4). A rigid stylet was used routinely for all GVL intubations.

A checklist was used for all tracheal intubations (10). When the operator was unsuccessful despite two attempts with any laryngoscope, they were required to switch devices or operators. The American Society of Anesthesiologists difficult airway algorithm was followed (13). Other devices, such as the bougie, bronchoscope, jet ventilation, and surgical airway equipment, were available if needed. The primary recommended induction agent for intubation was propofol at a dose of 1 mg/kg. Etomidate could be used by operator discretion in cases of severe preinduction hypotension. However, the choice of medication and dose was left to the discretion of the operator. Neuromuscular blockade was not used routinely in critically ill patients as per divisional protocol. By hospital policy, a PCCM attending or an anesthesiologist must be present to supervise all intubations whenever possible. In rare circumstances where intubation cannot be delayed, a PCCM fellow can commence intubation without direct supervision.

Study Population

Inclusion criteria for randomization were all patients who required urgent or emergent intubation in which the PCCM fellow was team leader either in the MICU or on the wards as part of the rapid response or code teams.

Patients were excluded if the intubation was elective for a procedure or had 1) a known history of difficult intubation, 2) presence of limited mouth opening, oropharyngeal masses, or swollen tongue, suggesting the inability to use a DL or GVL, or 3) oxygen saturation less than 92% after bag valve mask ventilation. Cardiac arrest patients were not excluded.

Randomization Strategy

An even/odd numbered randomization strategy was used. PCCM fellows were instructed to randomize the use of a Glidescope video laryngoscope or DL (Macintosh or Miller blade) during all UEI meeting inclusion criteria. All odd intubations were done using DL as first-attempt device (i.e., the first patient intubated by each fellow was attempted using a DL as the initial device). All even numbered intubations were done using a VL as the initial device (i.e., the second patient intubated by each fellow was attempted using a VL as the initial device). All subsequent intubations were attempted using an initial device that alternated between DL and VL. In excluded patients, intubation devices were selected according to the clinical situation and PCCM fellow preference. All UEI data from one fellow were excluded due to failure to alternate intubations between GVL and DL as per prespecified study protocol.

Data Collection

Data on the rates of first-attempt success, difficult intubations, esophageal intubations, number of attempts required, duration of the intubation sequence, and rates of attending intervention and complications were recorded. A medical resident was assigned as an independent "watcher" during the intubation sequence and was instructed to record data in real time on the number of attempts, nadir systolic blood pressure, nadir oxygen saturations, time to intubation, and complications. The fellow performing the intubation recorded the patient's airway assessment, demographics, doses of sedatives used, and types of blades used.

An attempt was defined as the action of inserting a laryngoscope into the oropharynx. Each instance of laryngoscope removal and reinsertion was counted as a subsequent attempt whether by the original or a more senior operator. First-attempt success was noted when the trachea was intubated during the first insertion of the laryngoscope. Duration of the intubation sequence was defined as the time from the first attempt at insertion of the laryngoscope to the confirmation of tube placement in the trachea by the use of a Co_2 detector. "Urgent" endotracheal intubation was defined as an intubation performed in the

setting of acute respiratory failure (presence of or impending inability to oxygenate or ventilate despite supplemental oxygen and/or noninvasive ventilatory support). "Emergent" endotracheal intubation was defined as an intubation performed in the setting of respiratory or cardiac arrest. "Elective" intubation was defined as an intubation performed solely for the purpose of ventilatory support during a procedure.

The primary outcome variable was the rate of first-attempt success. Secondary outcome variables included rates of severe desaturation, defined as an oxygen saturation less than 80%, hypotension, defined as a systolic blood pressure less than 70 mm Hg, and other complications such as aspiration (defined as emesis during intubation and/or a witnessed aspiration of oral contents into trachea) traumatic intubation, esophageal intubation, dental injury, and cardiac arrest. Secondary outcomes include number of attempts and time to intubation.

Statistics

We estimated at least a 15% improvement in first-attempt success rate with use of a GVL. Based on this assumption, we calculated that a sample size of 139 patients in each group would provide 90% power to identify a significant statistical difference in the primary outcome criteria (α-error, 5%). On midpoint review of data, the study was stopped for safety due to the low first-attempt success in the DL group (40%) versus the GVL group (74%). Categorical variables are reported as counts and percentages. Baseline data were compared by *t* tests for continuous variables and by chi-square test or Fisher exact test for categorical variables. The time to intubation and number of intubations were compared using the two-sample Wilcoxon rank-sum (Mann-Whitney) test. Primary and secondary outcomes and complications were binary, and the chi-square test or Fisher exact test was used to compare outcomes and complications in the GVL and DL groups. Statistical tests were performed with Stata 13.1 (Stata, College Station, TX).

RESULTS

There were a total of 153 consecutive UEI performed by PCCM fellows during the study period. Thirty-six were excluded (**Fig. 1**). One hundred seventeen met inclusion criteria, with 57 randomized to the GVL group and 60 to the DL group. Demographics and disease characteristics are shown in **Table 1**. Acute Physiology and Chronic Health Evaluation (APACHE) II scores reflected a significant degree of critical illness in both groups (20.9 ± 8.2 vs 19.9 ± 7.9). First-year fellows performed 71% of the intubations.

All patients were successfully intubated. The fellow successfully intubated all but two patients, with one in each group requiring critical care attending intervention. The rate of first-attempt success in the GVL group was 74% compared with 40% in the DL group ($p < 0.01$). Twenty-seven percent of UEI in the DL group required more than two attempts compared with 9% requiring more than two attempts in the GVL group ($p < 0.01$). All patients in the GVL group were successfully intubated with a GVL. All patients in the DL group who could not be intubated with a DL were intubated with a GVL, 82% on the first attempt. The time to intubation was 218 seconds in the DL group and 120 seconds in the GVL group ($p < 0.01$). The time to intubation when only one attempt was required was similar (74.5 vs 64.5 s; $p = 0.30$). The average number of attempts was 1.93 in the DL group versus 1.39 in the GVL group (95% CI, 0.23–0.86; $p < 0.01$). Further results are detailed in **Table 2**. The GVL group demonstrated an improvement in glottic view scored using the Cormack-Lehane grading system. All DL intubations were performed with the Macintosh 3 or 4. All intubations were performed with direct endotracheal tube placement, and a bougie was not used.

There was no significant difference in rates of complications between DL and GVL: esophageal intubations (7% vs 0%; $p = 0.05$), aspiration events (7% vs 9%; $p = 0.69$), desaturation (8% vs 4%; $p = 0.27$), and hypotension (13% vs 11%; $p = 0.64$). One dental injury occurred in the DL group. One death occurred in the GVL group. The cardiac arrest occurred after sedatives were administered prior to any intubation attempt. The five patients with a recognized difficult airway were all intubated successfully with the GVL on the first attempt. Of the 17 patients excluded for desaturation, 14 were intubated with the GVL on the first attempt and one on the second attempt. Two patients were intubated with the DL, one requiring two attempts.

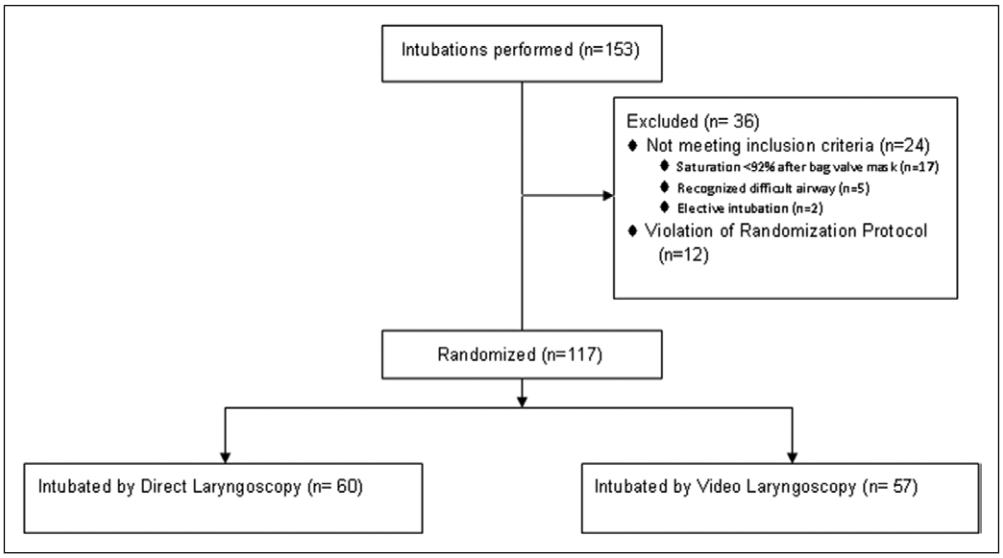

Figure 1. Flow chart of 153 consecutive patients that required intubation during the study period. After 36 patients were excluded for reasons stated above, 60 patients were randomized to direct laryngoscopy and 57 patients were randomized to video laryngoscopy.

DISCUSSION

In this prospective, randomized, controlled trial of UEI performed by PCCM fellows, the

TABLE 1. Baseline Characteristics of Patients Randomized to Direct Laryngoscopy or Video Laryngoscopy

Variables	Direct Laryngoscopy (*n* = 60)	Video Laryngoscopy (*n* = 57)
Age	69.6	65.4
Male sex	34 (57%)	27 (45%)
Weight (kg)	68	66
Body mass index	25	23
Acute Physiology and Chronic Health Evaluation II	20.9	19.9
Asthma	6 (10%)	3 (5%)
Diabetes mellitus	17 (28%)	15 (26%)
Hypertension	25 (42%)	28 (49%)
Coronary artery disease	9 (15%)	10 (18%)
Congestive heart failure	15 (25%)	9 (18%)
Chronic obstructive pulmonary disease	16 (27%)	12 (21%)
Renal failure	4 (7%)	6 (11%)
Stroke	8 (13%)	5 (9%)
Cirrhosis	4 (7%)	3 (5%)
HIV	5 (8%)	8 (14%)
Malignancy	16 (27%)	5 (9%)

TABLE 2. Success Rate and Complications of Direct Versus Video Laryngoscopy

Variables	Direct Laryngoscopy (*n* = 60)	Video Laryngoscopy (*n* = 57)	*p*
First-pass success	24 (40%)	41 (74%)	< 0.01
Required > 2 attempts	16 (27%)	5 (9%)	0.02
Average number of attempts	1.93	1.39	< 0.01
Time to intubation (s)	218	120	< 0.01
Time to intubation (s) when only one attempt required	74.5	64.5	0.30
Need for attending intervention	1 (2%)	1 (2%)	1.00
Witnessed vomiting or aspiration	4 (7%)	6 (9%)	0.69
Esophageal intubation	4 (7%)	0	0.05
Desaturation < 80%	5 (8%)	2 (4%)	0.27
Hypotension (systolic blood pressure < 70)	8 (13%)	6 (11%)	0.64
Cormack-Lehane grade 1 or 2	31/54 (57%)	50/54 (93%)	< 0.01

first-attempt success rate was significantly higher using a GVL than a DL. The time to insertion and the number of attempts required were all statistically better when GVL was used rather than the DL. The improved times with the GVL resulted from the need for fewer attempts given that similar times were observed during one-attempt intubations. The higher quality views of the glottis obtained by PCCM fellows with the GVL were associated with intubation success. In all cases of unsuccessful DL, the patient was successfully intubated with a GVL. Neither anesthesia intervention nor an emergent surgical airway was required during the study.

There were no statistically significant differences in complication rates between GVL and DL. The rates of hypoxemia and desaturation compare favorably with the rates achieved by highly trained anesthesiologists in the critically ill (3, 9). Although the similar complication rates between groups may have been the result of our multiple teams, checklist approach using a difficult airway algorithm, another possible explanation is that all failed DL were "rescued" and successfully intubated with the GVL. Although our study did not show a difference in complications, in other studies, increasing attempts are associated with higher complication rates (8, 14–16).Thus, the success of GVL in failed DL may have avoided the deleterious consequences associated with multiple attempt intubations (14, 15). Our results support the use of GVL in failed DL among trainees, a finding previously demonstrated among experienced practitioners after failed DL (17). In that study, GVL was used to successfully intubate failed DL in 94% of cases.

There were several strengths to this study. The randomized, controlled trial design optimally reduced bias from patient or operator selection. Equal training on each device was provided prior to the study. Data were collected prospectively by an independent observer in real time, removing both operator and recall bias. Clearly defined inclusion and exclusion criteria were used such that many patients with traditional predictors of difficult airway were included, excluding only those patients with features suggestive of an inability to insert laryngoscopes or with refractory desaturation. This fact, along with the high APACHE II scores in both groups, makes these results generalizable to the majority of UEI in the critically ill. Further, the even/odd randomization strategy avoided delays in allocation of groups, allowing for inclusion of patients requiring immediate, "crash" intubation.

Multiple studies and meta-analyses have been done comparing videolaryngoscopes with direct laryngoscopes in endotracheal intubation. Marked heterogeneity exists among the study designs, elective and urgent nature of intubations, trained and untrained operators, and devices (1, 2, 5–8, 18–21). Reviews and meta-analysis of these studies make clear several consistent findings, supported only infrequently by controlled trials. The meta-analysis by Griesdale et al (2) found that GVL led to improved glottic views in all operators and improved first-attempt success in two situations: 1) when used by inexperienced operators and 2) when used by experienced operators in difficult intubations. In a meta-analysis by Healy et al (1), this latter finding led to

a strong recommendation that GVL should be used in patients with predictors of difficulty among all practitioners.

Our results confirm the findings of improved first-attempt success among nonanesthesiology trainees in the critically ill using a randomized, controlled design. These results add to a growing body of studies of UEI by PCCM physicians published by our group and others (4, 5, 12). These groups of studies all use a similar approach to UEI based on extensive training in airway management principles and use of a combined teams, checklist approach. Using this model, several results have been consistently achieved: 1) low complication rates and 2) significantly higher first-attempt success with the GVL than the DL (4, 5).

One concern is the 40% first-attempt success rate using a DL. This is less than the 54%, 62%, and 68% first-attempt success rates using a DL reported in the aforementioned PCCM fellow UEI studies as well as an emergency department study of postgraduate year 1-3 trainees showing the first-attempt success rate of 69% using a DL (4, 5, 7, 8, 10). An important difference to note is that the first-attempt success rates using a DL in the PCCM studies were all achieved during periods where the DL was used exclusively. In this trial, PCCM fellows were trained using a strict alternating sequence which may have negatively influenced the well-defined "learning curve" described with the DL in training studies (22–24). This alternating of devices that use different configurations may prevent acquisition of skill in any one device over the study period. The distinct shapes require different approaches to both scope manipulation and tube insertion. Regularly alternating such techniques may serve as a barrier to acquisition of the requisite psychomotor skills required for successful intubation compared to approaches which train using one scope consistently.

An additional impact of the GVL on DL skill acquisition must also be considered; namely, that availability of the GVL as a "bail-out" device puts less emphasis on extensive manipulations and use of adjuncts with the DL given the operators perceived ease of use of the GVL. The less frequent experience in manipulating the DL to overcome difficulty may serve as a barrier to development of high-level DL skills. Further study on the effects of GVL availability on acquisition of DL skills should be undertaken, given that GVL is increasingly recommended and used in difficult intubations and in failed DL (1, 17).

Limitations of the study include the subjective assessments of laryngeal view by fellows using the Cormack-Lehane system, an assessment with known deficits in reproducibility, even among anesthesiologists (25). Some data were self-reported, so a recall or reporting bias was possible. Although patients were all assessed for and excluded with recognized difficult airway features, other predictors of difficult intubation were incompletely recorded due to the often emergent nature of the UEI and the inability of patients to cooperate with some of the assessments. It was decided by the department prior to the study that hypoxic patients whose oxygen saturation did not improve with bag valve mask ventilation would be excluded. All but two of these patients were intubated with the GVL. Paralytics were not routinely used for UEI. Although a common practice in some institutions, the use of paralytics may have improved the observed success rates of DL over GVL. It is also possible that any benefit gained from neuromuscular blockade would be transferred to the GVL as well. Despite this, the improvements in first-attempt success rates seen with the GVL were similar to a recent large trial where neuromuscular blockers were routinely used (6). Further, the complication rates we observed in both groups compare favorably to previously reported data in the anesthesia and critical care literature where neuromuscular blockers were used more frequently. Only one type of VL was studied, thus conclusions regarding efficacy may not be generalizable to all. An additional limitation is that the study was not powered to detect differences in complications. Finally, based on safety concerns due to the large differences in first-attempt success observed, the study was terminated early due to a change in ICU policy mandating GVL as the primary device for UEI.

In subspecialties such as critical care medicine where extensive experience in DL use during OR conditions cannot be gained, the steeper learning curve observed with GVL makes it a particularly suitable device for use in the critically ill given their high complication rates, extensive comorbidities, and lower cardiopulmonary reserve. However, there is concern that only learning the GVL leaves a skill gap that may be important in a situation where a GVL is not available, not working, or where a DL may be a more appropriate device.

CONCLUSIONS

In our study of in-hospital UEIs by critical care medicine trainees, the Glidescope video laryngoscope showed improved glottic view and first-attempt success compared with direct laryngoscopes in nonparalyzed patients. Based on the low overall first-attempt success rate using a DL observed in this trial design, further study of the influence of GVL use on DL skill acquisition should be undertaken.

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