The Impact of a Soiled Airway on Intubation Success in the Emergency Department When Using the GlideScope or the Direct Laryngoscope

John C. Sakles, MD, G. Judson Corn, MD, Patrick Hollinger, MD, Brittany Arcaris, Asad E. Patanwala, PharmD, and Jarrod M. Mosier, MD

ABSTRACT

Background: The objective was to determine the impact of a soiled airway on firstpass success when using the GlideScope video laryngoscope or the direct laryngoscope for intubation in the emergency department (ED).

Methods: Data were prospectively collected on all patients intubated in an academic ED from July 1, 2007, to June 30, 2016. Patients ≥ 18 years of age, who underwent rapid sequence intubation by an emergency medicine resident with the GlideScope or the direct laryngoscope, were included in the analysis. Data were stratified by device used (GlideScope or direct laryngoscope). The primary outcome was firstpass success. Patients were categorized as those without blood or vomitus (CLEAN) and those with blood or vomitus (SOILED) in their airway. Multivariate regression models were developed to control for confounders.

Results: When using the GlideScope, the firstpass success was lower in the SOILED group (249/306; 81.4%) than the in CLEAN group (586/644, 91.0%; difference = 9.6%; 95% confidence interval [CI] = 4.7%–14.5%). Similarly, when using the direct laryngoscope, the firstpass success was lower in the SOILED group (186/284, 65.5%) than in the CLEAN group (569/751, 75.8%; difference = 10.3%; 95% CI = 4.0%–16.6%). The SOILED airway was associated with a decreased firstpass success in both the GlideScope cohort (adjusted odds ratio [aOR] = 0.4; 95% CI = 0.3–0.7) and the direct laryngoscope cohort (aOR = 0.6; 95% CI = 0.5–0.8).

Conclusion: Soiling of the airway was associated with a reduced firstpass success during emergency intubation, and this reduction occurred to a similar degree whether using either the GlideScope or the direct laryngoscope.

Airway management in the emergency department (ED) frequently requires intubation of the trachea, and typically this is accomplished using a rapid sequence intubation technique.[1–9] Unfortunately, critically ill patients requiring emergency intubation often have an airway soiled with blood or vomitus, which can potentially make intubation more difficult by obscuring the relevant anatomy during laryngoscopy.[10–14] Surprisingly, there is a paucity of data on how soiling of the airway impacts intubation success in the clinical environment. Although emergency intubation has typically been performed with a direct laryngoscope, evidence suggests that video laryngoscopes are being used with increasing frequency in the ED.[2,9] The GlideScope (Verathon Inc, Bothell, WA) is one of the more commonly used video laryngoscopes in the ED.[2] Due to

From the Department of Emergency Medicine (JCS, GJC, PH, JMM) and the Department of Medicine, Section of Pulmonary, Critical Care, Allergy and Sleep (JMM), The University of Arizona College of Medicine (BA); and the Department of Pharmacy Practice and Science, The University of Arizona College of Pharmacy (AEP), Tucson, AZ.
Received October 21, 2016; revision received January 1, 2017; accepted January 14, 2017.
Dr. Sakles discloses that he serves as a consultant to Verathon Inc.
Supervising Editor: Rob Reardon, MD.
Address for correspondence and reprints: John C. Sakles, MD; e-mail: sakles@aemrc.arizona.edu.
ACADEMIC EMERGENCY MEDICINE 2017;24:628–636.

ISSN 1069-6563
PII ISSN 1069-6563583

doi: 10.1111/acem.13160

the presence of a micro video camera on the undersurface of its blade the GlideScope might be expected to be easily contaminated and thus perform less effectively than the direct laryngoscope in the presence of a soiled airway. In this investigation we sought to determine the impact of a soiled airway on the firstpass success of emergency intubation and, in particular, to compare the intubation success of the GlideScope and the direct laryngoscope under these circumstances.

METHODS

Study Design and Setting

This is a single-center prospective observational study of ED intubations performed over the 9-year period from July 1, 2007, to June 30, 2016, recorded in a continuous quality improvement database. The study design complied with recommendations of the Strengthening the Reporting of Observational Studies in Epidemiology statement.[15] This project was granted exemption by the University of Arizona institutional review board.

This study was conducted at a 61-bed tertiary care academic ED and Level I trauma center with an annual census that varied between 50,000 and 70,000 patients during the study period. This institution has residents from a university-based 3-year emergency medicine training program, a community-based 3-year emergency medicine training program, and a 5-year university emergency medicine/pediatric training program that are accredited by the Accreditation Council for Graduate Medical Education. Intubations in this ED are performed primarily by emergency medicine residents, under direct supervision of emergency medicine faculty. The university-based residents participate in a comprehensive airway curriculum that includes ongoing didactics, frequent simulation experience in a laboratory with high-fidelity simulators, and a 1-month clinical anesthesia rotation in the operating room. The community-based emergency medicine residents receive the same training, except that they do not participate in the anesthesia rotation. Residents are taught how to use multiple devices for intubation including direct and indirect laryngoscopes. When confronted with a soiled airway, residents are instructed to aggressively suction the airway with a Yankauer suction catheter before initiating laryngoscopy. If using a video laryngoscope, they are instructed to keep the blade pressed firmly along the base of the tongue to avoid contamination from material pooled in the posterior oropharynx. This study included only adult patients 18 years of age and older that underwent rapid sequence intubation in the ED by an emergency medicine resident using the reusable GlideScope or the direct laryngoscope. Both the direct laryngoscope and the GlideScope were both continuously available during the entire 9-year study period.

Methods and Measurements

After each intubation, the operator completed an airway data collection form that captured patient, operator, and intubation characteristics. This included patient demographics, operator postgraduate year, indication for intubation, method of intubation, neuromuscular blocking agent, induction agent, device(s) used, reason for device selection, presence of specific difficult airway characteristics, number of attempts at intubation, and outcome of each intubation attempt. An intubation attempt was defined as the insertion of the laryngoscope blade into the mouth of the patient, regardless of whether an attempt was made to insert a tracheal tube. Firstpass success was defined as successful tracheal intubation on a single laryngoscope insertion. Difficult airway characteristics documented on the data form include blood or vomitus in the airway, presence of a cervical collar or cervical immobility, airway edema, facial or neck trauma, small mandible, short neck, large tongue, restricted mouth opening, and obesity. When using the GlideScope, operators assessed the degree of lens contamination using the following scale: none (no contamination), mild (airway easily visible), moderate (airway partially visible), or severe (airway not visible). The senior investigator (JCS) reviewed all data forms and any incomplete forms were returned to the operator for completion. There were no missing data forms based on cross-referencing with the electronic medical record and the hospital admission log. The data from the paper forms were entered into Excel for Windows 2013 (Microsoft) and then transferred and coded into STATA 13 (StataCorp) for statistical analysis.

Outcome Measures

The primary outcome measure was firstpass success. The secondary outcomes were ultimate success with the initial device used and, when using the GlideScope, the degree of lens contamination.

Primary Data Analysis

Patients were stratified into two cohorts based on device used: GlideScope or direct laryngoscope. In

each cohort, patients were categorized as no blood or vomitus in their airway (CLEAN) or a blood or vomitus contaminated airway (SOILED). The CLEAN and SOILED groups within each device cohort were compared descriptively. Categorical variables were reported as percentages and continuous variables were reported as means with standard deviation (SD). There was only one continuous variable in the study, which was age. Multivariate analyses were conducted within each stratum to determine the association between presence of a soiled airway and firstpass success. The following variables were considered to be potential confounders and were added to each model based on previous literature and clinical experience of the investigators: age, sex, trauma status, indication for intubation, reason for device selection, neuromuscular blocking agent used, induction agent used, and operator postgraduate year. The number of difficult airway characteristics was not added to the models because of collinearity between this variable and soiled airway status (e.g., all patients with a soiled airway have at least one difficult airway characteristic). The intent was not to create a parsimonious model; thus, all variables were added to each model. The models were checked for interactions and the goodness of fit of the models were assessed using the Hosmer-Lemeshow test. We tested for an interaction between presence of a soiled airway and device type in a combined sample of both strata. This was done to formally evaluate if the relative effect of the device changed based on the presence of blood or vomit. However, our intent was to present the data as two cohorts even if there was no interaction. Influential observations were identified by calculating Pregibon's Delta-Beta influence statistic. There was only one variable that was continuous (i.e., age). The assumption of linearity in the logit was checked for this variable. A two-sided alpha of <0.05 was considered to be statistically significant for all analyses. We used the rule of 10 events per variable to determine the adequacy of our sample.[16] Since we had 10 variables we would have required at least 100 events in each of the models. Assuming a firstpass success of 80% we estimated that 500 patients would be required in each cohort.

RESULTS

Characteristics of Study Subjects

A total of 4,626 intubations were performed in the ED over the 9-year study period and 2,641 met exclusion criteria (Figure 1). This left 1,985 patients in the study, of whom 590 (29.7%) had a soiled airway. Of the patients with a soiled airway, 359 (60.8%) had blood only, 178 (30.2%) had vomitus only, and 53 (9.0%) had both blood and vomitus. After stratifying by device, 950 patients (47.9%) were in the GlideScope cohort and 1,035 patients (52.1%) were in the direct laryngoscope cohort. In the GlideScope cohort 306 patients (32.2%) had a soiled airway and in the direct laryngoscope cohort 284 patients (27.4%) had a soiled airway (Figure 1). The baseline characteristics of the GlideScope and direct laryngoscope cohorts are summarized in Table 1.

Main Results

When using the GlideScope the firstpass success was lower in the SOILED group (249/306, 81.4%) than the CLEAN group (586/644, 91.0%; difference = 9.6%; 95% CI = 4.7%–14.5%). Similarly, when using the direct laryngoscope, the firstpass success was lower in the SOILED group (186/284, 65.5%) than the CLEAN group (569/751, 75.8%; difference = 10.3%; 95% CI = 4.0%–16.6%).

Breakdown of SOILED Group

In the SOILED group, 350 patients (59.3%) were intubated for traumatic conditions and 240 (40.7%) patients were intubated for medical conditions. In patients with traumatic conditions and a soiled airway, the firstpass success was 171/215 (79.5%) when the GlideScope was used and 90/135 (66.7%) when the direct laryngoscope was used. In the subset of trauma patients that had facial trauma and a soiled airway, the firstpass success with the GlideScope was 107/135 (79.3%) and with the direct laryngoscope was 37/54 (68.5%). In patients with medical conditions and a soiled airway, the firstpass success was 78/91 (85.7%) when the GlideScope was used and 96/149 (64.4%) when the direct laryngoscope was used. In the subset of medical patients with gastrointestinal hemorrhage and a soiled airway, the firstpass success with the GlideScope was 13/14 (92.9%) and with the direct laryngoscope 12/24 (50.0%).

Multivariate Regression Analyses

In the multivariate regression analyses, after potential confounders were adjusted for, the soiled airway was associated with a decreased firstpass success in the GlideScope cohort (adjusted odds ratio [aOR] = 0.4; 95% CI = 0.3–0.7) and in the direct laryngoscope

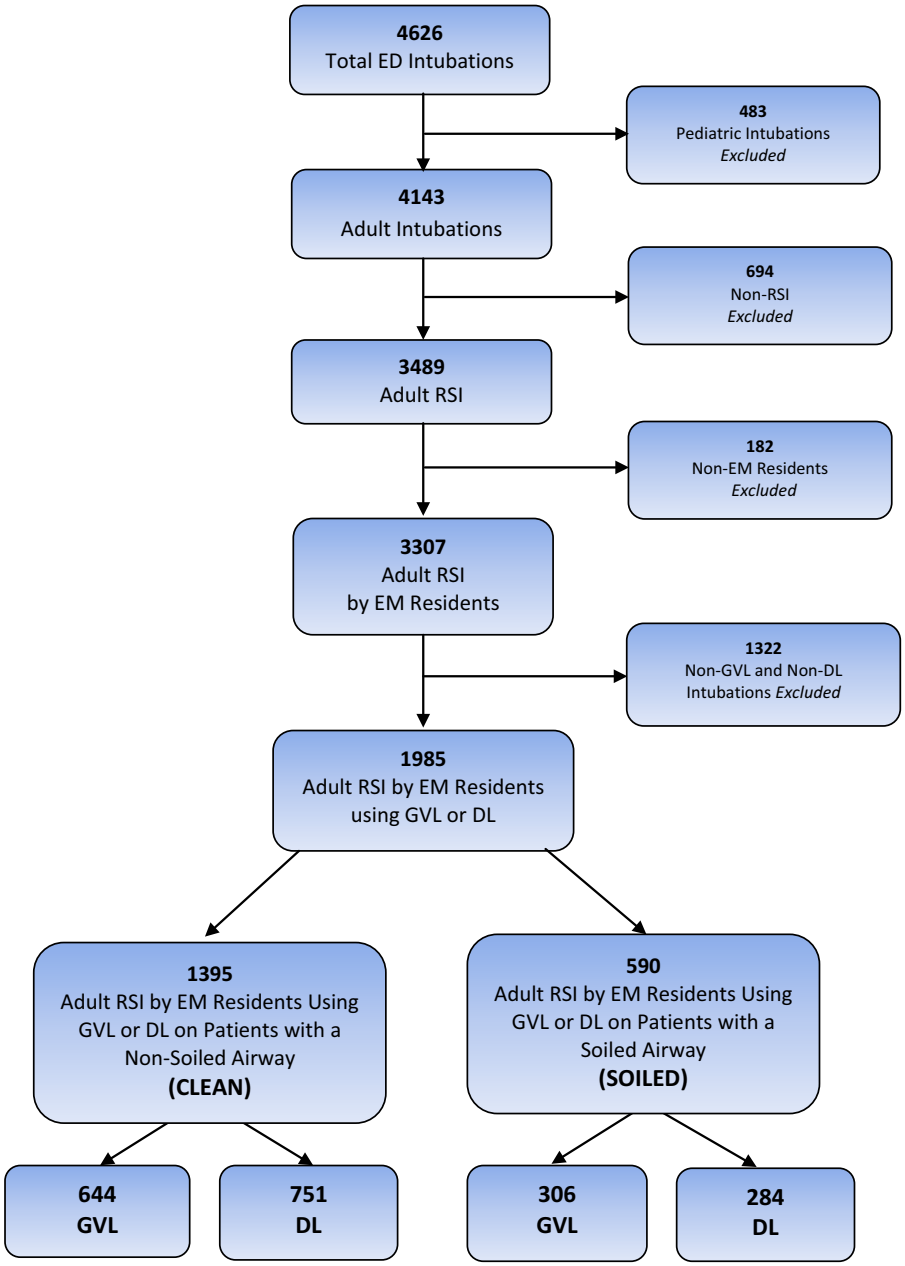

Figure 1. Flow diagram of patients in the study. DL = direct laryngoscope; GVL = GlideScope video laryngoscope; RSI = rapid sequence intubation. [Color figure can be viewed at wileyonlinelibrary.com]

cohort (aOR = 0.6; 95% CI = 0.5–0.8; Table 2). No interactions were identified in either model and the models fit the data well according to the Hosmer-Lemeshow goodness-of-fit test. When both cohorts were combined, there was no significant interaction between presence of a soiled airway and device type ($p = 0.272$). Thus, the effect of a soiled airway does not depend on the type of device used. There were four potentially influential observations in the direct laryngoscope group and three potentially influential observations in the GlideScope group. After these patients were excluded, the results were unchanged. The assumption of linearity in the logit appeared to be violated at high age (i.e., >80 years). When we dichotomized age at this cutoff value, it did not change our results. There were 40 patients (2% of the overall cohort) who were intubated on more than one admission during the study time frame. Since this potentially violates the assumption of independence between subjects, we accounted for this clustering (i.e., cluster option in STATA) and it did not change our results.

Ultimate Success and Rescue Devices

In the GlideScope cohort, the GlideScope was ultimately successful in 287 patients (93.8%) in the SOILED group and 627 patients (97.4%) in the

Table 1
Patient, Operator, and Intubation Characteristics

	GlideScope, *n* = 950		Direct Laryngoscope, *n* = 1,035	
	CLEAN, *n* = 644	SOILED, *n* = 306	CLEAN, *n* = 751	SOILED, *n* = 284
Age (y)	50.6 ± 20.1	45.2 ± 18.5	51.8 ± 20.0	46.9 ± 19.7
Sex				
Male	402 (62.4)	227 (74.2)	462 (61.5)	210 (73.9)
Medical/trauma				
Trauma	274 (42.5)	215 (70.3)	197 (26.2)	135 (47.5)
Reason for intubation				
Airway protection/patient control	479 (74.4)	275 (89.9)	557 (74.4)	248 (87.3)
Respiratory failure (type I and II)	150 (23.3)	23 (7.5)	177 (23.6)	30 (10.6)
Post-arrest	15 (2.3)	8 (2.3)	17 (2.3)	6 (2.1)
Reason for device selection				
Difficult airway	260 (40.4)	205 (67.0)	13 (1.7)	10 (3.5)
Difficult airway characteristics				
0	195 (30.3)	0	417 (55.5)	0
1	208 (32.3)	48 (15.7)	214 (28.5)	106 (37.3)
2	134 (20.8)	71 (23.2)	69 (9.2)	80 (28.2)
≥3	107 (16.6)	187 (61.1)	51 (6.8)	98 (34.5)
Neuromuscular blocking agent				
Succinylcholine	332 (51.6)	179 (58.5)	362 (48.2)	151 (53.2)
Rocuronium/vecuronium	312 (48.4)	127 (41.5)	389 (51.8)	133 (46.8)
Induction agent				
Etomidate	579 (89.9)	277 (90.5)	711 (94.7)	265 (93.3)
Ketamine	37 (5.8)	7 (2.3)	21 (2.8)	5 (1.8)
Propofol	16 (2.5)	6 (2.0)	6 (0.8)	2 (0.7)
Midazolam	4 (0.6)	1 (0.3)	5 (0.7)	2 (0.7)
Other/none	8 (1.2)	15 (4.9)	8 (1.1)	10 (3.5)
PGY operator				
PGY-1	127 (19.7)	54 (17.6)	173 (23.0)	47 (16.6)
PGY-2	249 (38.7)	120 (39.2)	267 (35.6)	112 (39.4)
PGY-3, -4, -5	268 (41.6)	132 (43.1)	311 (41.4)	125 (44.0)

Data are reported as mean ± SD or number (%).
PGY = postgraduate year.

CLEAN group. In the direct laryngoscope cohort, the direct laryngoscope was ultimately successful in 227 patients (79.9%) in the SOILED group and 634 patients (84.4%) in the CLEAN group. The ultimate success of the initial device and rescue devices utilized are listed in Table 3. In the SOILED group, the GlideScope rescued the direct laryngoscope in 15.1% of the patients and the direct laryngoscope rescued the GlideScope in 4.9% of the patients.

Lens Contamination

The incidence of severe lens contamination when the GlideScope was used was 0.5% in the CLEAN cohort and 1.3% in the SOILED cohort (Table 4).

DISCUSSION

Airway management in the ED typically requires laryngoscopy and tracheal intubation with a cuffed tube. Patients requiring intubation in the ED frequently have blood or vomitus in their airway and this can potentially impede visualization of the airway, thereby reducing the likelihood of first pass success. Achieving firstpass success is important during emergency intubation as studies have demonstrated a significant increase in adverse events even after a single failed intubation attempt.[17–19] Historically the direct laryngoscope has been the primary device to perform intubation in the ED, but recent data from the National Emergency Airway Registry indicate that video laryngoscopes are being used with increased frequency.[2] Both direct laryngoscopes and video laryngoscopes have been shown to have very high success rates when used for intubation of patients in the ED.[9,20–27] The GlideScope has been shown to be a very effective device for emergency intubation, even in patients with predicted difficult airways.[23,28] However, the performance of video laryngoscopes can potentially be negatively impacted by blood or vomitus in the airway as the video camera on the distal portion of the blade can be contaminated from even small amounts of material. In this study we sought to determine the impact of an airway contaminated with blood or vomitus on the firstpass success during emergency intubation. We found that the presence of a soiled airway was associated with a reduction in firstpass success.

Table 2
Multivariate Regression Analyses for GlideScope and Direct Laryngoscope Cohorts

Variable	GlideScope,* n = 950	Direct Laryngoscope,† n = 1,035
Device		
CLEAN	[Reference]	[Reference]
SOILED	0.4 (0.3–0.7)	0.6 (0.5–0.8)
Age	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Sex		
Female	[Reference]	[Reference]
Male	1.2 (0.8–1.9)	0.7 (0.5–0.9)
Medical/trauma		
Medical	[Reference]	[Reference]
Trauma	0.7 (0.5–1.2)	1.0 (0.7–1.4)
Reason for intubation		
Non-airway protection/patient control	[Reference]	[Reference]
Airway protection/patient control	1.6 (0.9–2.7)	0.8 (0.6–1.2)
Reason for device selection		
Non-difficult airway	[Reference]	[Reference]
Difficult airway	1.1 (0.7–1.7)	0.3 (0.1–0.8)
Neuromuscular blocking agent		
Rocuronium/vecuronium	[Reference]	[Reference]
Succinylcholine	1.0 (0.6–1.4)	1.3 (0.9–1.7)
Induction agent		
Non-etomidate	[Reference]	[Reference]
Etomidate	1.2 (0.7–2.3)	0.6 (0.3–1.2)
PGY operator		
PGY-1	[Reference]	[Reference]
PGY-2	1.5 (0.9–2.6)	1.4 (0.9–2.0)
PGY-3, -4, -5	2.2 (1.3–3.8)	1.4 (1.0–2.1)

Data are reported as adjusted OR (95% CI).
*Hosmer-Lemeshow goodness of fit (p = 0.108).
†Hosmer-Lemeshow goodness of fit (p = 0.438).
PGY = postgraduate year.

Table 3
Ultimate Success and Rescue Devices in CLEAN and SOILED Cohorts

	GlideScope, Initial Device, n = 950		Direct Laryngoscope, Initial Device, n = 1,035	
Final Device	CLEAN, n = 644	SOILED, n = 306	CLEAN,* n = 751	SOILED, n = 284
GlideScope	627 (97.4)	287 (93.8)	91 (12.1)	43 (15.1)
C-MAC	0	0	21 (2.8)	11 (3.9)
DL	16 (2.5)	15 (4.9)	634 (84.4)	227 (79.9)
Intubating-LMA	0	1 (0.3)	4 (0.5)	2 (0.7)
Cricothyrotomy	1 (0.2)	3 (1.0)	0	1 (0.4)

Data are reported as number (%).
*One patient is this group rescued with the Pentax Airway Scope.
direct laryngoscope

Interestingly, the reduction in firstpass success was similar in both the GlideScope and the direct laryngoscope cohorts (9.6% vs. 10.3%). This suggests that the reduction in firstpass success was likely due to contamination of the airway resulting in impaired recognition of the relevant airway anatomy and was independent of whether the airway was visualized directly or indirectly the video laryngoscope. The presence of blood or vomitus in the airway appeared to have little impact on the optical performance of the GlideScope, as demonstrated by the very low incidence of severe lens contamination (1.3%) reported by the operators.

Table 4
Operator Assessment of Lens Contamination When Using the GlideScope

Lens Contamination	CLEAN, n = 644 (%)	SOILED, n = 306 (%)
None	595 (92.4)	258 (84.3)
Mild	44 (6.8)	38 (12.4)
Moderate	2 (0.3)	6 (2.0)
Severe	3 (0.5)	4 (1.3)

Data are reported as number (%).

We also found that in patients with a soiled airway the GlideScope was associated with a higher overall success (93.8%) than the direct laryngoscope (79.9%), indicating that the GlideScope performed remarkably well in the presence of blood or vomitus. After a failed attempt in a soiled airway, the GlideScope successfully rescued the direct laryngoscope much more frequently (15.1%) than the direct laryngoscope rescued the GlideScope (4.9%), providing further evidence that the GlideScope functions very well and is quite successful even in the presence of a soiled airway.

Despite the abundance of literature on emergency intubation of the critically ill, there is a paucity of clinical data on the efficacy of various laryngoscopes in the presence of a soiled airway. The only ED-based study on this topic was published by Carlson and colleagues.[29] They performed a subgroup analysis of 325 patients in the National Emergency Airway Registry who were intubated for gastrointestinal bleeding and were presumed to have a potentially bloody airway. They found a similar firstpass success in those intubated with a video laryngoscope and a direct laryngoscope. A prehospital study by Naito and colleagues[13] evaluated the factors associated with intubation success with the C-MAC in a helicopter emergency medical service. Retrospective analysis of video footage demonstrated that body fluids (blood, vomitus, or secretions) obstructing the view of the airway was negatively associated (OR = 0.29; p = 0.01) with C-MAC intubation success. In another prehospital study, Hossfeld and

colleagues[30] evaluated the use of the C-MAC as a first-line device in 228 patients intubated by helicopter emergency medical service physicians. Similar to our findings, they noted a high incidence of patients with a blood or vomitus contaminated airway (29.4%), but despite this a very low incidence of lens contamination (0.9%). Their overall C-MAC success of 99.6% attests to the excellent performance of this video laryngoscope even in the face of moderate to severe airway contamination. The C-Mac, however, is different from the GlideScope in that it has a conventional Macintosh blade shape and thus can also be used to perform direct laryngoscopy.[31,32] In three patients the operators had to switch from a video view to a direct view to successfully accomplish the intubation. This highlights an important advantage of conventional Macintosh-shape video laryngoscope designs. In the event of severe lens contamination impairing the video view of the airway the operator can easily transition to direct laryngoscopy on the same attempt to complete the intubation. This obviously is not possible with the hyperangulated GlideScope blade we evaluated in our study. Fortunately, however, the incidence of severe lens contamination of the GlideScope was so low that operators were able to achieve very high intubation success rates.

LIMITATIONS

There were several important limitations in this study. As this was an observational study, the patients in which the GlideScope and direct laryngoscope were used were not randomly assigned, and thus there may be other characteristics in the groups that may have impacted the firstpass success. For example, the degree of airway soiling with blood or vomitus may be different in the GlideScope and the direct laryngoscope cohorts. Operators may have preferentially selected the direct laryngoscope when there was heavy soiling of the airway. However, the number of patients in the SOILED group who were intubated with a GlideScope or a direct laryngoscope were similar (306 vs. 284), suggesting that GlideScope use was not avoided in patients with blood or vomitus in the airway. We also performed a subset analysis of patients likely to have extensive bleeding. This included patients with facial trauma and patients with gastrointestinal hemorrhage. Even in this subset of patients at risk for heavy soiling the GlideScope still outperformed the direct laryngoscope. To account for the nonrandomized nature of this study we performed a multivariate logistic regression analysis to control for potential confounders such as indication for intubation, reason for device selection, drugs used for intubation, and operator level of training. However, there may be unknown confounders that could have impacted the results. Another limitation is that all data collected in the study were documented by the operator performing the intubation. The self-reporting of airway data is subject to reporting error by the operators, which has been well documented using video review of emergency intubations.[33] We have no reason, however, to believe that this would be different between the two cohorts. Another limitation is that determination of a contaminated airway was made by a subjective assessment by the operator and the amount of blood or vomitus was not quantified and could be quite variable. Additionally, the presence of active bleeding or regurgitation was not documented, which can obviously impact the performance of a laryngoscope more than just the simple presence of pooled blood or vomitus in the airway. The only video laryngoscope evaluated in this study was the GlideScope, and thus these results may not be applicable to other video laryngoscopes. Previous studies have demonstrated that video laryngoscopes have very variable design features and function quite differently under difficult airway scenarios.[34,35] We chose to limit this evaluation to only the GlideScope and direct laryngoscope as these were the only two devices that were continuously available during the 9-year study period and were used for the majority of intubations. Finally, all the intubations in this study were by performed by emergency medicine residents, who although have overall limited airway experience, have extensive training with video laryngoscopes, so these results may not be generalizable to other operators or other clinical settings.

CONCLUSIONS

In summary, we found that a soiled airway contaminated with blood or vomitus was a risk factor for afailed first intubation attempt. The reduction in firstpass success was similar with both the GlideScope and the direct laryngoscope, suggesting that the cause is impaired recognition of the airway anatomy and is independent of how the anatomy is viewed. The GlideScope appears to be a viable option for emergency intubation even in patients with a soiled airway.

References

1. Sakles JC, Laurin EG, Rantapaa AA, Panacek EA. Airway management in the emergency department: a one-year study of 610 tracheal intubations. Ann Emerg Med 1998;31:325–32.
2. Brown CA 3rd, Bair AE, Pallin DJ, Walls RM. Techniques, success, and adverse events of emergency department adult intubations. Ann Emerg Med 2015;65:363–70.
3. Stevenson AG, Graham CA, Hall R, Korsah P, McGuffie AC. Tracheal intubation in the emergency department: the Scottish district hospital perspective. Emerg Med J 2007;24:394–7.
4. Kerslake D, Oglesby AJ, Di Rollo N, James E, McKeown DW, Ray DC. Tracheal intubation in an urban emergency department in Scotland: a prospective, observational study of 3738 intubations. Resuscitation 2015;89:20–4.
5. Reid C, Chan L, Tweeddale M. The who, where, and what of rapid sequence intubation: prospective observational study of emergency RSI outside the operating theatre. Emerg Med J 2004;21:296–301.
6. Kovacs G, Law JA, Ross J, et al. Acute airway management in the emergency department by non-anesthesiologists. Can J Anaesth 2004;51:174–80.
7. Hasegawa K, Hagiwara Y, Chiba T, et al. Emergency airway management in Japan: interim analysis of a multi-center prospective observational study. Resuscitation 2012;83:428–33.
8. Sagarin MJ, Barton ED, Chng YM, Walls RM. Airway management by US and Canadian emergency medicine residents: a multicenter analysis of more than 6,000 endotracheal intubation attempts. Ann Emerg Med 2005;46:328–36.
9. Fogg T, Alkhouri H, Vassiliadis J. The Royal North Shore Hospital Emergency Department airway registry: closing the audit loop. Emerg Med Australas 2016;28:27–33.
10. Lockey DJ, Healey B, Crewdson K, Chalk G, Weaver AE, Davies GE. Advanced airway management is necessary in prehospital trauma patients. Br J Anaesth 2015;114:657–62.
11. Lockey DJ, Coats T, Parr MJ. Aspiration in severe trauma: a prospective study. Anaesthesia 1999;54:1097–8.
12. Lockey DJ, Avery P, Harris T, Davies GE, Lossius HM. A prospective study of physician pre-hospital anaesthesia in trauma patients: oesophageal intubation, gross airway contamination and the 'quick look' airway assessment. BMC Anesthesiol 2013;13:21.
13. Naito H, Guyette FX, Martin-Gill C, Callaway CW. Video laryngoscopic techniques associated with intubation success in a helicopter emergency medical service system. Prehosp Emerg Care 2016;20:333–42.
14. Wong E, Ng YY. The difficult airway in the emergency department. Int J Emerg Med 2008;1:107–11.
15. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Ann Intern Med 2007;147:573–7.
16. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. J Clin Epidemiol 1996;49:1373–9.
17. Sakles JC, Chiu S, Mosier J, Walker C, Stolz U. The importance of first pass success when performing orotracheal intubation in the emergency department. Acad Emerg Med 2013;20:71–8.
18. Hasegawa K, Shigemitsu K, Hagiwara Y, et al. Association between repeated intubation attempts and adverse events in emergency departments: an analysis of a multicenter prospective observational study. Ann Emerg Med 2012;60:749–54.
19. Mort TC. Emergency tracheal intubation: complications associated with repeated laryngoscopic attempts. Anesth Analg 2004;99:607–613.
20. Platts-Mills TF, Campagne D, Chinnock B, Snowden B, Glickman LT, Hendey GW. A comparison of GlideScope video laryngoscopy versus direct laryngoscopy intubation in the emergency department. Acad Emerg Med 2009;16:866–71.
21. Sakles JC, Mosier JM, Chiu S, Keim SM. Tracheal intubation in the emergency department: a comparison of GlideScope(R) video laryngoscopy to direct laryngoscopy in 822 intubations. J Emerg Med 2012;42:400–5.
22. Sakles JC, Mosier J, Chiu S, Cosentino M, Kalin L. A comparison of the C-MAC video laryngoscope to the Macintosh direct laryngoscope for intubation in the emergency department. Ann Emerg Med 2012;60:739–48.
23. Mosier JM, Stolz U, Chiu S, Sakles JC. Difficult airway management in the emergency department: GlideScope videolaryngoscopy compared to direct laryngoscopy. J Emerg Med 2012;42:629–34.
24. Driver BE, Prekker ME, Moore JC, Schick AL, Reardon RF, Miner JR. Direct versus video laryngoscopy using the C-MAC for tracheal intubation in the emergency department, a randomized controlled trial. Acad Emerg Med 2016;23:433–9.
25. Yeatts DJ, Dutton RP, Hu PF, et al. Effect of video laryngoscopy on trauma patient survival: a randomized controlled trial. J Trauma Acute Care Surg 2013;75:212–9.
26. Vassiliadis J, Tzannes A, Hitos K, Brimble J, Fogg T. Comparison of the C-MAC video laryngoscope with direct Macintosh laryngoscopy in the emergency department. Emerg Med Australas 2015;27:119–25.
27. Sulser S, Ubmann D, Schlaepfer M, et al. C-MAC videolaryngoscope compared with direct laryngoscopy for rapid sequence intubation in an emergency department: a randomised clinical trial. Eur J Anaesthesiol 2016;33:943–8.

28. Sakles JC, Patanwala AE, Mosier JM, Dicken JM. Comparison of video laryngoscopy to direct laryngoscopy for intubation of patients with difficult airway characteristics in the emergency department. Intern Emerg Med 2014;9:93–8.
29. Carlson JN, Crofts J, Walls RM, Brown CA 3rd. Direct versus video laryngoscopy for intubating adult patients with gastrointestinal bleeding. West J Emerg Med 2015;16:1052–6.
30. Hossfeld B, Frey K, Doerges V, Lampl L, Helm M. Improvement in glottic visualisation by using the C-MAC PM video laryngoscope as a first-line device for out-of-hospital emergency tracheal intubation: an observational study. Eur J Anaesthesiol 2015;32:425–31.
31. Cavus E, Kieckhaefer J, Doerges V, Moeller T, Thee C, Wagner K. The C-MAC videolaryngoscope: first experiences with a new device for videolaryngoscopy-guided intubation. Anesth Analg 2010;110:473–77.
32. Sakles JC, Mosier JM, Patanwala AE, Arcaris B, Dicken JM. The utility of the C-MAC as a direct laryngoscope for intubation in the emergency department. J Emerg Med 2016;51:349–57.
33. Kerrey BT, Rinderknecht AS, Geis GL, Nigrovic LE, Mittiga MR. Rapid sequence intubation for pediatric emergency patients: higher frequency of failed attempts and adverse effects found by video review. Ann Emerg Med 2012;60:251–9.
34. Kleine-Brueggeney M, Greif R, Schoettker P, Savoldelli GL, Nabecker S, Theiler LG. Evaluation of six videolaryngoscopes in 720 patients with a simulated difficult airway: a multicentre randomized controlled trial. Br J Anaesth 2016;116:670–9.
35. Mihara R, Komasawa N, Matsunami S, Minami T. Comparison of direct and indirect laryngoscopes in vomitus and hematemesis settings: a randomized simulation trial. Biomed Res Int 2015;2015:806243.