

# Routine Clinical Practice Effectiveness of the Glidescope in Difficult Airway Management

## *An Analysis of 2,004 Glidescope Intubations, Complications, and Failures from Two Institutions*

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### ABSTRACT

**Introduction:** The Glidescope video laryngoscope has been shown to be a useful tool to improve laryngeal view. However, its role in the daily routine of airway management remains poorly characterized.

**Methods:** This investigation evaluated the use of the Glidescope at two academic medical centers. Electronic records from 71,570 intubations were reviewed, and 2,004 cases were identified where the Glidescope was used for airway management. We analyzed the success rate of Glidescope intubation in various intubation scenarios. In addition, the incidence and character of complications associated with Glidescope use were recorded. Predictors of Glidescope intubation failure were determined using a logistic regression analysis.

**Results:** Overall success for Glidescope intubation was 97% (1,944 of 2,004). As a primary technique, success was 98% (1,712 of 1,755), whereas success in patients with predictors of difficult direct laryngoscopy was 96% (1,377 of 1,428). Success for Glidescope intubation after failed direct laryngoscopy was 94% (224 of 239). Complications were noticed in

### What We Already Know about This Topic

- The Glidescope video laryngoscope may improve laryngeal view compared with direct laryngoscopy.

### What This Article Tells Us That Is New

- In a retrospective review, primary intubation with the Glidescope was successful in 98% of 1,755 cases and rescued failed direct laryngoscopy in 94% of 239 cases.
- Altered neck anatomy with presence of a surgical scar, radiation changes, or mass was the strongest predictor of Glidescope failure.

1% (21 of 2,004) of patients and mostly involved minor soft tissue injuries, but major complications, such as dental, pharyngeal, tracheal, or laryngeal injury, occurred in 0.3% (6 of 2,004) of patients. The strongest predictor of Glidescope failure was altered neck anatomy with presence of a surgical scar, radiation changes, or mass.

**Conclusion:** These data demonstrate a high success rate of Glidescope intubation in both primary airway management and rescue-failed direct laryngoscopy. However, Glidescope intubation is not always successful and certain predictors of failure can be identified. Providers should maintain their competency with alternate methods of intubation, especially for patients with neck pathology.

**T**HE Glidescope video laryngoscope (GVL; Verathon Inc., Bothell, WA), a type of rigid indirect video laryngoscope, has been advocated as an effective tool for difficult airway management.<sup>1</sup> Small, controlled studies have established that GVL often improves laryngeal views compared with direct laryngoscopy.<sup>2,3</sup> Other studies document im-

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◆ This article is accompanied by two Editorial Views. Please see: Schmidt U, Eikermann M: Organizational aspects of difficult airway management: Think globally, act locally. ANESTHESIOLOGY 2011; 114:3-6; Isono S, Ishikawa T: Oxygenation, not intubation, does matter. ANESTHESIOLOGY 2011; 114:7-9.

proved intubation success in novices with GVL compared with direct laryngoscopy.<sup>4</sup>

Despite the efficacy of GVL when used by experienced providers, “real-world” effectiveness data regarding the use of GVL in daily routines involving difficult intubation situations is lacking. Studies on manikins simulating difficult airway scenarios and small patient studies pertaining to difficult airways have been published.<sup>1,5,6</sup> In predicted difficult direct laryngoscopy airways, GVL improves intubation difficulty scale scores, but it has not been shown to improve intubation success rates compared with direct laryngoscopy.<sup>7</sup> For patients with cervical spine immobilization, GVL offers favorable laryngeal views, but no improvements in intubation success rates compared with direct laryngoscopy are notable.<sup>6,8</sup> Beyond patient reports, no studies have evaluated the use of GVL as a rescue device for failed direct laryngoscopy.<sup>1</sup> Although complications with GVL use are described, they are limited to lip and pharyngeal injury and do not give a measure of incidence.<sup>9–16</sup> Studies have evaluated GVL intubation difficulty in terms of increased laryngoscopy time, increased intubation difficulty, or increased attempts, but no data exist to predict GVL intubation failure.<sup>17,18</sup>

The purpose of this study is to evaluate the performance of GVL in the real-world environment of large-scale clinical practice. The analysis aims to determine the success of GVL intubation in airways predicted to be easy or difficult, the success after failed direct laryngoscopy, the predictors of failed GVL intubation, and complications associated with GVL intubation. We hypothesize that this real-world environment demonstrates a high intubation success rate with GVL but lower than that reported in controlled studies.<sup>2,3,7,8,19</sup>

## Materials and Methods

Institutional Review Board (Oregon Health and Science University [OHSU], Portland, Oregon, and University of Michigan Medical School, Ann Arbor, Michigan [UMHS]) approval was obtained for evaluation of all existing GVL intubation records at two large tertiary care academic medical centers.

All adult patients (18 yr or older) given general anesthesia using tracheal intubation from May 2007 to December 2009 were included. For each anesthetic, a detailed anesthesia history and physical was documented by an anesthesiology resident, a certified registered nurse anesthetist, or an attending anesthesiologist using a point-of-care perioperative clinical information system (Centricity; General Electric Healthcare, Waukesha, WI). The patient’s history and physical examination included discrete data elements regarding patient anthropomorphic details, history, and physical examination (appendix). A detailed airway examination, including cervical spine mobility, dentition, neck anatomy, thyromental distance, mouth opening, and modified Mallampati classification,<sup>20</sup> was documented for each patient. For the individual elements of the airway examination, data entry was facil-

itated by standardized predefined pick lists. Alternatively, the provider had the option to enter free text if the choices did not adequately describe the patient characteristics.

The intraoperative anesthetic record was documented using the same perioperative clinical information system. Providers used predefined pick lists to document the number of intubation attempts, Cormack-Lehane view achieved, intubation device(s), direct laryngoscopy blade type, and any adjuncts used (appendix). All intubations, including the term “Glidescope,” were included in the analysis. In addition, all electronic intraoperative records were screened using a free-text search, including the terms “Glidescope” or “gs.”

The perioperative clinical information system databases were also queried to determine provider and institutional characteristics. Provider information was recorded as the attending anesthesiologist signed into the patient case at the time of induction of anesthesia. In addition, the total number of endotracheal intubations performed using any device during the study period was determined. Patients were identified as potentially difficult to intubate by direct laryngoscopy if any of the following validated measures were documented: Mallampati III/IV; thyromental (TM) distance less than 6 cm; mouth opening less than 3 cm; neck pathology from mass, surgical scar, or radiation; obese neck; or reduced cervical motion.<sup>21–23</sup> The electronic record captured the first GVL intubation ever performed at UMHS, but the electronic record was commenced at OHSU after GVL had already been established in the clinical routine.

Both institutions adhered to the principles of the American Society of Anesthesiologists difficult airway algorithm with an aim to restore ventilation, identify alternate laryngoscopy devices, and employ experienced assistance.<sup>24</sup> No specified rescue techniques were advocated more than others in either institution. There was no formalized training for GVL intubations at either site. Patients were placed in the sniffing position unless contraindicated by cervical spine precautions. Obese patients were placed into a “ramped” position. For patients at risk of aspiration, cricoid pressure was maintained, and external laryngeal manipulation was used to improve glottic view when appropriate. Endotracheal tubes were shaped with a preformed flexible or rigid stylet for GVL intubations.

## Quantification of Intubation Success

Identified records were reviewed by two of the authors (Aziz and Healy) and placed into a category describing the outcome of GVL intubation when used as either primary device or rescue. When the category was not apparent from the database query, the patient record was manually examined to further elucidate all of the details of the intubation scenario. Patients were included for further analysis when GVL was attempted for airway management or excluded if GVL was mentioned in the record but not used during airway management.

The primary outcome was “intubation success” as defined by confirmed endotracheal tube placement using GVL. Secondary outcomes included “success of tracheal intubation when

**Table 1.** Patient Preoperative Demographics and Anesthetic Technique of Successful and Failed Glidescope Intubations

Parameter	Success (n = 1944)	Failure (n = 60)	P Value	Data Complete, %
Age, yr (mean ± SD)	53 ± 15	52 ± 15	.2128	100.0
Sex, male	1,108 (57)	32 (53)	.8382	100.0
BMI (mean ± SD)	32 ± 11	33 ± 13	.6841	98.8
Mallampati III/IV	646 (33)	29 (48)	.0247	90.6
Mouth opening < 3 cm	249 (13)	13 (22)	.1452*	95.2
TM distance < 6 cm	276 (14)	19 (32)	.0020*	96.41
Neck anatomy abnormal	656 (34)	32 (53)	<.0001*	97.21
Cervical motion reduced	596 (31)	26 (43)	.1336*	94.4
Institution, UMHS	851 (44)	38 (63)	.0027	100.0
Anesthetic technique				
Without neuromuscular blockade	34 (2)	3 (5)	.097*	100

Unless otherwise noted, values are n (%).

\* P values were calculated based on Fisher exact test.

BMI = body mass index; TM = thyromental distance; UMHS = University of Michigan Health System.

GVL was used as the first (primary) device,” “success in patients with predictors of difficult direct laryngoscopy,” and “success of rescue-failed direct or flexible fiberoptic laryngoscopy.”

### Predictors of Glidescope Failure

Patient anthropometric data were recorded and analyzed using descriptive statistics in relation to success and failure. In addition, intraoperative factors, such as the use of neuromuscular blockade, were described. Univariate comparison of patient characteristics between “GVL intubation failure” and “GVL intubation success” were analyzed using a two-sided *t* test for continuous variables and a chi-square or a Fisher exact test for categorical variables. Variables tested as possible predictors for failed GVL intubation included age, gender, body mass index, cervical spine motion, neck anatomy, Mallampati score, and TM distance. A logistic regression full model fit was used to identify predictors for failure of GVL intubation while controlling for sites. To evaluate a potential learning curve with the use of GVL, failures were evaluated for each site by time as a continuous variable.

Absent records or notations of “unable to assess” were noted as null records and included in the analysis of multivariable logistic regression as a separate category for each predictor to preclude the problem of missing data. A receiver operating characteristic curve was constructed from the logistic regression model along with the calculated area under the curve to assess the discriminative ability of identifying intubation failure of the logistic model. The goodness-of-fit of the logistic regression model was assessed using Hosmer-Lemeshow test. All analyses were performed using SAS 9.1.3 (SAS Institute Inc., Cary, NC).

### Incidence and Characteristics of Glidescope Complications

All medical records that documented GVL intubation were queried for notation of traumatic intubation by searching for the following words: “trauma,” “lip,” “nick,” “laceration,” “dental,” “injury,” “dislodgement,” or “perforation.” The

records identified with these words were then manually reviewed to determine the precise nature of the injury.

## Results

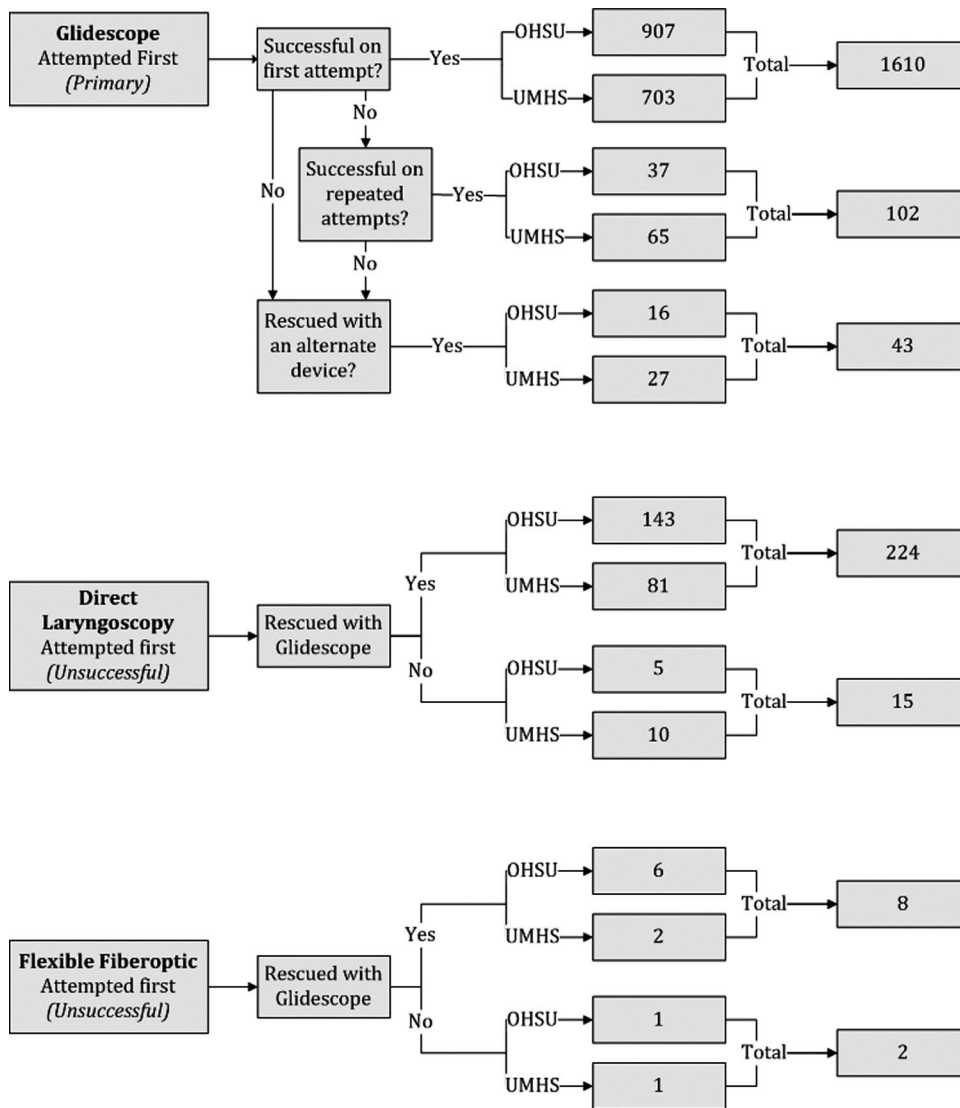
### Patient Population

During the study period, 71,570 patients underwent tracheal intubation. A total of 2,048 intubations included documentation of the terms “Glidescope” or “gs.” Of these, 44 were excluded from further analysis, because upon review, GVL was not used during airway management. Rather, the notations were only mentions of availability of a GVL, recommendations for its future use, or GVL used to exchange endotracheal tubes *in situ*. The final analysis described GVL-guided endotracheal intubations in 2,004 (2.8%) patient records. Patient anthropometric data in relation to success and failure are described in table 1. The majority of GVL-guided intubations (81%; 1,616 of 2,004), were performed on patients with preoperative predictors of difficult direct laryngoscopy or obesity (body mass index more than 30). There were 142 attending anesthesiologist providers involved in these intubations using a total of 7 individual, identical GVL devices (six at

**Table 2.** Summary of Patient Sample Preoperative Predictors

Predictor	Distribution of the Study Population
Age, yr (mean ± SD)	54.48 ± 15.4
Sex, male (%)	56
BMI (mean ± SD)	31.99 ± 10.89
Mallampati III/IV (%)	33.68
Mouth opening < 3 cm (%)	13.07
TM distance < 6 cm (%)	14.72
Neck anatomy obese (%)	29.14
Neck anatomy radiation/surgical scar/mass (%)	5.19
Cervical motion limited (%)	31.04

BMI = body mass index; TM = thyromental.



**Fig. 1.** Flow chart describing the intubation characteristic categories of the Glidescope at each institution. OHSU = Oregon Health and Science University; UMHS = University of Michigan Health System.

OHSU and one at UMHS). At OHSU, 51 providers performed GVL intubation with a greater frequency (mean 21.7, median 19) than 91 providers at UMHS (mean 9.9, median 6, *P* less than 0.001). The studied population’s anthropometric and clinical data are summarized in table 2.

**Glidescope Video Laryngoscope Success**

The categorization of success and failure are seen in figure 1. A total of 1,944 (97%) patients were successfully intubated using GVL, and 60 patients could not be intubated using GVL. When used as the initial intubation device, the success was 92% (1,610 of 1,755) on first attempt and 98% (1,712/1,755) for any number of attempts. GVL was used 576 times (24%) in patients without objective predictors of difficult direct laryngoscopy. The success rate for this group was 98% for any number of attempts. For patients with at least one of the potential predictors of difficult direct laryngoscopy (1,428), the success rate was 96%. When used as a rescue

device, the success rate was decreased. GVL rescued 94% (224 of 239) failed direct laryngoscopies. GVL rescued failed flexible fiberoptic intubation in 8 of 10 patients.

GVL intubations were facilitated by neuromuscular blockade in 98% of patients. Five patients were intubated with an “awake” sedation or topicalization technique among 7 attempts, and 29 patients were anesthetized without muscle relaxation but with general anesthesia. Intubation was facilitated with a gum elastic bougie in 2.5% (48 patients). A modified Cormack-Lehane grade 1 or 2 view was achieved in 98% of the successful laryngoscopies.

**Glidescope Video Laryngoscope Failure**

In 60 patients, GVL failed as a primary or rescue technique, and this subgroup was further analyzed. It is noteworthy that tracheal intubation after failed GVL attempts was most frequently achieved using direct laryngoscopy (47%, n = 28) or flexible fiberoptic intubation (32%, n = 19). Less common

techniques were use of a supraglottic airway (5%,  $n = 3$ ), wake up with airway management at a later time (5%,  $n = 3$ ), surgical airway (3%,  $n = 2$ ), blind endotracheal tube passage (3%,  $n = 2$ ), Bullard video laryngoscopy (2%,  $n = 1$ ), or use of a lightwand (2%,  $n = 1$ ). The rescue was poorly documented in one patient (2%). GVL laryngeal view was recorded as a modified Cormack-Lehane grade 1 or 2 view in 35% of failures ( $n = 21$ ). The remaining 65% of failures involved inadequate GVL laryngeal views ( $n = 39$ ). Two of those failures were a result of electrical failure of the GVL video system (no video output) and one was because of excessive fogging. Three of the failures did not receive neuromuscular blockade before or during airway management. Two of these three failures were awake attempts with sedation and topicalization. There was not a significant increased rate of failure in those attempts without muscle relaxation ( $P = 0.097$ ).

Four preoperative predictors, including neck anatomy ( $P = 0.002$ ), TM distance ( $P = 0.003$ ), cervical motion ( $P = 0.046$ ), and institution ( $P = 0.004$ ), were found to be significantly associated with failed GVL intubation. Regarding neck pathology, patients with scar, radiation, or mass were more likely to have a failed GVL intubation compared with patients with normal neck anatomy (odds ratio: 4.39; 95% CI: 2.04, 9.46) and patients with thick neck (OR: 3.21; 95% CI: 1.37, 7.48). Patients with a shorter TM distance (less than 6 cm) were more likely to have a failed GVL intubation (OR: 2.53; 95% CI: 1.38, 4.64) compared with patients with a TM distance of more than 6 cm. In addition, patients with limited cervical motion (OR: 1.76; 95% CI: 1.01, 3.06) and those from UMHS (OR: 2.28; 95% CI: 1.30, 4.01) were also more likely to have a failed GVL intubation. The other tested variables—age, gender, body mass index, Mallampati score, and mouth opening—were not significantly associated with failed GVL intubation. For the above model, the area under the receiver operating characteristic curve was 0.73, indicating “acceptable” discriminative ability of identifying intubation failure. Results from the Hosmer-Lemeshow test indicated that the model has a good fit ( $P = 0.910$ ). Although the failures decreased slightly with time, the trend was not significant for either institution or for the entire sample from both institutions ( $P = 0.109$ ).

### Glidescope Video Laryngoscope Complications

There were 21 (1% of the GVL sample) documented traumatic laryngoscopies. Minor complications included lip or gum lacerations ( $n = 13$ ). Of these, four cases involved GVL rescue of failed direct laryngoscopy. More serious complications ( $n = 6$ ) included one vocal cord trauma, one tracheal injury, one trauma to the hypopharynx, one tonsillar perforation, and two dental injuries, all of which occurred during GVL use only. Of note, one of the dental injuries was a dislodged tooth that was localized using the GVL. The other dental injury was a chipped tooth. Two records did not indicate the nature of the intubation trauma but did note a “traumatic intubation.”

## Discussion

We observed 2,004 GVL intubations involving 142 attending anesthesiologist providers at two tertiary care institutions and noted an overall success rate of 97%, a success rate of 96% in the predicted difficult airway, and a success rate of 94% for failed direct laryngoscopy. This is the largest series of GVL intubations analyzed, and the first to determine the performance of GVL as a technique to rescue failed direct laryngoscopy. In addition, this is the first study that identifies risk factors for failure of GVL intubation. These data demonstrate high success rates of GVL intubation in normal airways, in those predicted to be difficult, and after failed direct laryngoscopy. Abnormal neck anatomy because of previous surgery, a local tissue mass, or radiation was found to be the strongest predictor of GVL failure. Major complications, such as dental, pharyngeal, tracheal, or laryngeal injury, occurred in 0.3% of patients.

These data represent the real-world operating room environment of a large anesthesia practice because providers were diverse, and these data originate from two different institutions. Because these 2,004 intubations occurred in a small fraction of the total number of intubations performed at both institutions (2.8%), it is apparent that GVL was not routinely used in primary airway management but rather when providers thought it would potentially be more helpful than direct laryngoscopy. In fact, only 24% of GVL laryngoscopies were performed in airways without objective predictors of difficulty.

The overall success rate of 97% is similar to that reported in other smaller series or randomized trials of 96–100%.<sup>2,3,25,26</sup> These published success rates are in a select group of experienced providers' hands and with a general operative population. Our GVL studies include a much broader provider sample in a more challenging patient population and better reflect routine clinical use of GVL. For airways predicted to be difficult, a meta-analysis describes a first attempt Glidescope success rate of 92%, but only 36 patients are included for analysis.<sup>19</sup> Our success rate for both predicted difficult airways and encountered difficult airways was higher.

The capacity of an airway device to rescue failed direct laryngoscopy is highly relevant. Difficult airway algorithms call for the use of an alternate device when direct laryngoscopy has failed, but there is currently no mention of the role of rigid video laryngoscopy.<sup>24</sup> The supraglottic airway has been described as a useful device to rescue ventilation during failed direct laryngoscopy.<sup>27</sup> In contrast, increased laryngoscopy attempts are associated with morbidity and mortality.<sup>28,29</sup> The high success rate of rescue laryngoscopy found in this study may provide some encouragement for early use of GVL after failed direct laryngoscopy. The early use of a technique with a high rescue success rate for a definitive, secure airway may prevent further deterioration of the airway that is initially difficult to ventilate and intubate to the potentially catastrophic cannot intubate–cannot ventilate scenario.

This is the first study to identify risk factors to predict failure of GVL intubation. Difficult or failed GVL intuba-

tion, despite an adequate laryngeal view, is currently discussed among practitioners and experts, but it has never been formally investigated.<sup>30,31</sup> In this study, the strongest predictor of failed GVL intubation was the presence of airway pathology from previous surgery, a local mass, or radiation. Combined with existing data demonstrating that radiation changes are also the strongest predictor for impossible face-mask ventilation, this finding indicates the need for a carefully crafted plan for airway management in the context of providing anesthesia in patients with neck radiation changes.<sup>32</sup> The patient with reduced cervical spine motion is at higher risk of failed GVL intubation, despite previous suggestions that improved laryngeal view with GVL can overcome intubation difficulty in this patient population.<sup>33</sup>

The predictors for failure of GVL are different from those predicting failure of direct laryngoscopy. Although combined high Mallampati score and reduced TM distance is the strongest predictor of failure of direct laryngoscopy, according to the most recent meta-analysis,<sup>23</sup> Mallampati score did not predict GVL failure in our study. However, some predictors are similar between direct laryngoscopy and GVL. Patients with neck pathology are identified as having increased risk of failed direct laryngoscopy.<sup>21</sup> This study likewise demonstrated that patients with neck pathology are also at increased risk of failed GVL. Therefore, these data speak to the need to retain access and skill with alternative techniques, such as flexible fiberoptic intubation, for patients with head and neck pathology.

The GVL failure rates were significantly different between the two institutions in this study. Although the patient and surgical populations were apparently similar, the GVL was used more frequently at one (OHSU) *versus* the other (UMHS) institution, and institutional incorporation of GVL occurred at OHSU before electronic data capture was started. Furthermore, providers at OHSU used GVL with greater frequency than at UMHS. Despite evidence and perception of easy adaptability of GVL into clinical practice, our data suggest that GVL intubation success improves with practice and experience.<sup>3,4</sup>

Nearly half the GVL intubations occurred in obese patients. Although obesity *per se* has not been consistently identified as an independent predictor for failed direct laryngoscopy, the consequence of failure to secure the airway is more severe in these patients who have increased risk of rapid arterial oxygen desaturation, difficult bag-mask ventilation, and aspiration. Obesity, determined by body mass index, did not predict failed GVL intubation in this study.

The analysis of failures revealed some interesting trends. Whereas other studies have reported that most GVL failures involve an adequate laryngeal view, the majority of GVL failures in this study involved a poor laryngeal view.<sup>3</sup> Regarding the use of muscle relaxation, only 37 of 2,004 laryngoscopies were attempted without muscle relaxation, whereas seven were awake attempts. Although a greater proportion of failures occurred without muscle relaxation and in the awake

patient, this sample is too small to demonstrate a significant difference associated with muscle relaxation. Although it appears that muscle relaxation may facilitate GVL intubation, future investigations are needed to answer this question.

Although complications occurred in 1% of patients, there were only a few major complications. Tonsillar perforation and pharyngeal injury, as identified in this study, have been described previously in individual case reports, but this study uniquely provides a measure of incidence.<sup>9–12,14–16</sup> Tonsillar and pharyngeal injuries are thought to be particularly associated with the use of rigid video laryngoscopy, especially when rigid stylets are used and if the providers inappropriately move their attention from the patient exclusively to the video screen during advancement of the endotracheal tube into and through the oropharynx.<sup>34</sup> Although proper GVL intubation technique describes direct visualization of the tube entering the pharynx, providers do not always notice the traumatic forces that they are applying to the pharyngeal portion of the airway as they view the video screen.<sup>35,36</sup> Dental trauma and laryngeal or tracheal injuries have not been described in the literature before. The localization of the dislodged tooth using GVL has been described with other airway foreign body retrievals.<sup>37</sup>

This study had several limitations. These data rely on accurate recording of the users' experience to appropriately document success, failure, and preoperative predictors. Specifically, complications may have been unnoticed or underreported. The patients to be managed with GVL were selected by providers based on their clinical judgment and not predetermined by the study. Although the selection criterion by the individual patient remains undetermined, it is clear that the majority of the study sample had predictors of difficult direct laryngoscopy. However, experts agree that the predictive value of preoperative airway assessment is generally poor.<sup>38,39</sup> Interpretation of GVL performance is limited because this study offers no comparative data to the performance of other laryngoscopy devices. The high success rate in patients with objective predictors of difficult direct laryngoscopy, as well as the high rescue success rate after failed direct laryngoscopy, suggests that GVL has high effectiveness when a difficult airway is encountered expectedly or unexpectedly. Because these data originated from large academic centers, the intubations were most often attempted by certified registered nurse anesthetists and anesthesiology residents with variable exposure to video laryngoscopy and under the medical direction of an attending anesthesiologist. However, this diverse mixture of providers and patients should give a reasonable reflection of the use of this device to a broad user population in such an environment. All these data were derived from surgical patients in the operating room, so these data may not extrapolate well to other intubation scenarios, such as critical care or emergency medicine.

In summary, this study demonstrates the use of the Glidescope in the predicted difficult airway, as well as the unexpected difficult airway, after direct laryngoscopy has failed.

Based on these presented data, the incidence of failed Glidescope intubation can now be quantified, and failure can be predicted by objective criteria. In addition, the incidence of Glidescope complications can now be predicted based on a very large sample size. Future studies should focus on comparative effectiveness to determine how the Glidescope compares with other flexible and rigid video laryngoscopes in regard to safety and efficacy, as well as efficiency, to determine whether the added costs of video laryngoscopy actually alter patient outcomes.

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## References

- Cooper RM: Use of a new videolaryngoscope (GlideScope) in the management of a difficult airway. *Can J Anaesth* 2003; 50:611-3
- Sun DA, Warriner CB, Parsons DG, Klein R, Umedaly HS, Moulton M: The GlideScope Video Laryngoscope: Randomized clinical trial in 200 patients. *Br J Anaesth* 2005; 94:381-4
- Cooper RM, Pacey JA, Bishop MJ, McCluskey SA: Early clinical experience with a new videolaryngoscope (GlideScope) in 728 patients. *Can J Anaesth* 2005; 52:191-8
- Nouruzi-Sedeh P, Schumann M, Groeben H: Laryngoscopy via Macintosh blade *versus* GlideScope: Success rate and time for endotracheal intubation in untrained medical personnel. *ANESTHESIOLOGY* 2009; 110:32-7
- Benjamin FJ, Boon D, French RA: An evaluation of the GlideScope, a new video laryngoscope for difficult airways: A manikin study. *Eur J Anaesthesiol* 2006; 23:517-21
- Lai HY, Chen IH, Chen A, Hwang FY, Lee Y: The use of the GlideScope for tracheal intubation in patients with ankylosing spondylitis. *Br J Anaesth* 2006; 97:419-22
- Malik MA, Subramaniam R, Maharaj CH, Harte BH, Laffey JG: Randomized controlled trial of the Pentax AWS, Glidescope, and Macintosh laryngoscopes in predicted difficult intubation. *Br J Anaesth* 2009; 103:761-8
- Robitaille A, Williams SR, Tremblay MH, Guilbert F, Thériault M, Drolet P: Cervical spine motion during tracheal intubation with manual in-line stabilization: Direct laryngoscopy *versus* GlideScope videolaryngoscopy. *Anesth Analg* 2008; 106:935-41
- Cooper RM: Complications associated with the use of the GlideScope videolaryngoscope. *Can J Anaesth* 2007; 54:54-7
- Choo MK, Yeo VS, See JJ: Another complication associated with videolaryngoscopy. *Can J Anaesth* 2007; 54:322-4
- Cross P, Cytryn J, Cheng KK: Perforation of the soft palate using the GlideScope videolaryngoscope. *Can J Anaesth* 2007; 54:588-9
- Chin KJ, Arango MF, Paez AF, Turkstra TP: Palatal injury associated with the GlideScope. *Anaesth Intensive Care* 2007; 35:449-50
- Hsu WT, Hsu SC, Lee YL, Huang JS, Chen CL: Penetrating injury of the soft palate during GlideScope intubation. *Anesth Analg* 2007; 104:1609-10
- Malik AM, Frogel JK: Anterior tonsillar pillar perforation during GlideScope video laryngoscopy. *Anesth Analg* 2007; 104:1610-1
- Leong WL, Lim Y, Sia AT: Palatopharyngeal wall perforation during Glidescope intubation. *Anaesth Intensive Care* 2008; 36:870-4
- Vincent RD Jr, Wimberly MP, Brockwell RC, Magnuson JS: Soft palate perforation during orotracheal intubation facilitated by the GlideScope videolaryngoscope. *J Clin Anesth* 2007; 19:619-21
- Cortellazzi P, Minati L, Falcone C, Lamperti M, Caldiroli D: Predictive value of the El-Ganzouri multivariate risk index for difficult tracheal intubation: A comparison of Glidescope videolaryngoscopy and conventional Macintosh laryngoscopy. *Br J Anaesth* 2007; 99:906-11
- Tremblay MH, Williams S, Robitaille A, Drolet P: Poor visualization during direct laryngoscopy and high upper lip bite test score are predictors of difficult intubation with the GlideScope videolaryngoscope. *Anesth Analg* 2008; 106:1495-500
- Mihai R, Blair E, Kay H, Cook TM: A quantitative review and meta-analysis of performance of non-standard laryngoscopes and rigid fiberoptic intubation aids. *Anaesthesia* 2008; 63:745-60
- Samsoun GL, Young JR: Difficult tracheal intubation: A retrospective study. *Anaesthesia* 1987; 42:487-90
- Arné J, Descoins P, Fusciardi J, Ingrand P, Ferrier B, Boudigues D, Ariès J: Preoperative assessment for difficult intubation in general and ENT surgery: Predictive value of a clinical multivariate risk index. *Br J Anaesth* 1998; 80:140-6
- Brodsky JB, Lemmens HJ, Brock-Utne JG, Vierra M, Saidman LJ: Morbid obesity and tracheal intubation. *Anesth Analg* 2002; 94:732-6
- Shiga T, Wajima Z, Inoue T, Sakamoto A: Predicting difficult intubation in apparently normal patients: A meta-analysis of bedside screening test performance. *ANESTHESIOLOGY* 2005; 103:429-37
- American Society of Anesthesiologists Task Force on Management of the Difficult Airway: Practice guidelines for management of the difficult airway: An updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. *ANESTHESIOLOGY* 2003; 98:1269-77
- Hsiao WT, Lin YH, Wu HS, Chen CL: Does a new videolaryngoscope (glidescope) provide better glottic exposure? *Acta Anaesthesiol Taiwan* 2005; 43:147-51
- Rai MR, Dering A, Verghese C: The Glidescope system: A clinical assessment of performance. *Anaesthesia* 2005; 60:60-4
- Parmet JL, Colonna-Romano P, Horrow JC, Miller F, Gonzales J, Rosenberg H: The laryngeal mask airway reliably provides rescue ventilation in cases of unanticipated difficult tracheal intubation along with difficult mask ventilation. *Anesth Analg* 1998; 87:661-5
- Mort TC: Emergency tracheal intubation: Complications associated with repeated laryngoscopic attempts. *Anesth Analg* 2004; 99:607-13
- Peterson GN, Domino KB, Caplan RA, Posner KL, Lee LA, Cheney FW: Management of the difficult airway: A closed claims analysis. *ANESTHESIOLOGY* 2005; 103:33-9
- Cuchillo JV, Rodriguez MA: Considerations aimed at facilitating the use of the new GlideScope videolaryngoscope. *Can J Anaesth* 2005; 52:661; author reply 661-2
- Doyle DJ: The GlideScope video laryngoscope. *Anaesthesia* 2005; 60:414-5
- Kheterpal S, Martin L, Shanks AM, Tremper KK: Prediction and outcomes of impossible mask ventilation: A review of 50,000 anesthetics. *ANESTHESIOLOGY* 2009; 110:891-7
- Malik MA, Maharaj CH, Harte BH, Laffey JG: Comparison of Macintosh, Truview EVO2, Glidescope, and Airwayscope laryngoscope use in patients with cervical spine immobilization. *Br J Anaesth* 2008; 101:723-30
- Dupanovic M: Maneuvers to prevent oropharyngeal injury during orotracheal intubation with the GlideScope video laryngoscope. *J Clin Anesth* 2010; 22:152-4
- Turkstra TP, Harle CC, Armstrong KP, Armstrong PM, Cherry RA, Hoogstra J, Jones PM: The GlideScope-specific rigid stylet and standard malleable stylet are equally effective for GlideScope use. *Can J Anaesth* 2007; 54:891-6

36. Maassen R, Lee R, Hermans B, Marcus M, van Zundert A: A comparison of three videolaryngoscopes: The Macintosh laryngoscope blade reduces, but does not replace, routine stylet use for intubation in morbidly obese patients. *Anesth Analg* 2009; 109:1560-5
37. Morris LM, Wax MK, Weber SM: Removal of hypopharyngeal foreign bodies with the GlideScope video laryngoscope. *Otolaryngol Head Neck Surg* 2009; 141:416-7
38. Bainton CR: Difficult intubation-what's the best test? *Can J Anaesth* 1996; 43:541-3
39. Wilson ME: Predicting difficult intubation. *Br J Anaesth* 1993; 71:333-4

**Appendix.** Preoperative and Intraoperative Selection Fields

Preoperative Selection Field						
Mallampati	I	II	III	IV	Unable to assess	
Thyromental distance	>6 cm	<6 cm	Unable to assess			
Mouth opening	>3 cm	<3 cm	Unable to assess			
Neck anatomy	Normal	Mass	Previous surgery or scar	Radiation changes	Thick/obese	Unable to assess
Cervical motion	Normal	Limited flexion	Limited extension	Limited flexion and extension	Possibly unstable (cervical precautions)	Known unstable
Airway comments	Free text					
Intraoperative Selection Fields						
Intubation blade type	Macintosh	Miller	Wisconsin	Other		
Intubation method	Oral		Nasal			
Intubation attempts	1st	2nd	3rd	4th	>4th	
Video	Flexible fiberoptic	Glidescope	CMAC	Bullard	Shikani	
Cormack-Lehane laryngeal view	I	2	3	4		
Adjuncts used	Bougie	LMA	Wedge	Exchange catheter		
Intubation comments	Free text					

CMAC = C-MAC® video laryngoscope; LMA = laryngeal mask airway.