



# The Impact of Airway Technique on Anesthesia Control Time

Matthew J. Rowland<sup>1</sup> · Richard D. Urman<sup>1</sup> · Xinling Xu<sup>2</sup> · Jesse M. Ehrenfeld<sup>3</sup> · David A. Preiss<sup>1</sup> · Joshua C. Vacanti<sup>1</sup>

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## Abstract

Few studies have examined the impact of video laryngoscopy (VL) on operating room efficiency. We hypothesized that VL reduces anesthesia control time (ACT), a metric of anesthesia efficiency, compared with fiberoptic intubation (FOI) in potentially difficult airways, but that direct laryngoscopy (DL) remains more efficient in routine cases. We performed a multi-institutional, retrospective chart review of anesthetic cases from 2015 to 2016. Cases were compared based on choice of airway technique (laryngeal mask airway [LMA], DL, VL or FOI) and ACT. Generalized linear models with gamma distribution and log link were then used to model the data to control for variables including ASA physical status (PS), Mallampati (MP) score, body mass index, and presence of a trainee. ACT was analyzed for 32,542 cases. LMA insertion was associated with a median ACT of 10 min (CI 8–14 min), DL 14 min (CI 11–18 min), VL 17 min (CI 13–21 min) and FOI 20 min (CI 14.5–26 min). Modeling confirmed these results when controlling for variables expected to increase the ACT. However, modeling also revealed that presence of a trainee minimizes the increase in ACT for cases using VL or FOI. Use of VL in patients with a high MP score may improve anesthesia efficiency in the operating room. ASA PS, MP score, and presence of a trainee are all associated with an increased ACT. Trainee presence with both FOI and VL was associated with reduced increases in ACT for these devices.

**Keywords** Anesthesia control time · Videolaryngoscopy · Laryngoscopy · Operating room · Efficiency · Fiberoptic · Intubation

## Abbreviations

ACT	Anesthesia Control Time
FOI	Fiberoptic intubation
VL	Video laryngoscopy
DL	Direct laryngoscopy
BMI	Body mass index
LMA	Laryngeal mask airway
MP	Mallampati class
CI	Confidence interval
T1	In room to induction complete
T2	Induction start to induction complete

T3	Induction start to intubation
T4	In room to intubation
CRNA	Certified Registered Nurse Anesthetist
SRNA	Student Registered Nurse Anesthetist

## Introduction

The prevalence and availability of video laryngoscopes has increased dramatically over the past 20 years [1] with the introduction of videolaryngoscopes such as the Glidescope® (Verathon Inc., Seattle) in 2001, the C-MAC® (Karl Storz, Tuttlingen) in 2009, the McGrath® (Medtronic, Minneapolis) in 2010, and several other devices. Video laryngoscopes are increasingly being employed in both routine and difficult airway management [1]. There is clear evidence that video laryngoscopy (VL) has a role in anticipated difficult airways as well as known difficult airways [2]. VL has repeatedly been shown to decrease the number of airway attempts and improve laryngeal view [3–7]. While it has been shown that VL is associated with a faster intubation time in the difficult airway [8], the results are mixed for routine use. Some studies have shown that the C-MAC was associated with shorter time to intubation in the general population [9], yet other studies have

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✉ Richard D. Urman  
rurman@bwh.harvard.edu

- <sup>1</sup> Department of Anesthesiology, Perioperative and Pain Medicine, Brigham and Women's Hospital, Harvard Medical School, 75 Francis St., Boston, MA 02115, USA
- <sup>2</sup> Department of Anesthesia, Beth Israel Deaconess Hospital, Harvard Medical School, Boston, MA 02115, USA
- <sup>3</sup> Department of Anesthesiology, Vanderbilt University Medical Center, Nashville, TN 37232, USA

suggested a slightly longer time to intubation with VL [7]. A recent Cochrane review suggested that there was no evidence to indicate that VL increases time to intubation [10].

Despite the increasing popularity of video laryngoscopy and the clear impact it has had on patient safety, it remains unclear how the choice of airway management technique affects operating room (OR) efficiency. Anesthesia control time (ACT) is considered an important metric for efficiency in cases requiring anesthesia [11–14], and is being increasingly scrutinized, together with other OR metrics as hospitals aim to reduce operating costs and increase OR productivity. The relationship between video laryngoscopy use and ACT has yet to be examined, particularly with respect to routine, elective cases.

The goal of this study was to examine the association between airway management choice and ACT, along with other time metrics including in room time to intubation. We hypothesized that VL improves anesthesia efficiency and reduces ACT in patients with potentially difficult airways compared with fiberoptic intubation (FOI) as well as direct laryngoscopy (DL). We also hypothesized that DL would be more efficient in routine cases compared to VL based on previous studies and anticipated set-up time required.

The secondary goal of this study was to determine variables that contributed to increases in ACT. It has previously been reportedly by Luedi et al. that higher ages and American Society of Anesthesiologists (ASA) physical status (PS) patients lead to increases in turnover time which in this study included ACT as part of turnover time. Our goal was to specifically analyze ASA-PS related to the specific time periods measured in our study including ACT while also looking at other variables including body mass index (BMI), trainee presence, and Mallampati (MP) score [15].

## Methods

To test our hypothesis, we conducted a multi-institutional, retrospective chart review of electronic health records at two academic hospitals and two community hospitals, examining ACT and type of airway technique used over a 14-month period, from September 2015 to October 2016 at one academic center, May 2016 to October 2016 at the other academic center and the community hospitals (different study time frames correspond to implementation of a new electronic medical record system at various times at each institution). Inductions were performed in the same OR as the case was to be performed and none of the sites utilized induction rooms. The academic centers were both large institutions that included combinations of solo attendings, residents, CRNAs and SRNAs. The community sites utilized a combination of solo attendings and CRNAs. Monitored anesthesia care cases were excluded as there was no airway instrumentation documented.

ACT was defined as the time the patient entered the room to the time of induction complete [11–13]. Airway techniques included DL with both Miller and Macintosh blades, VL with both Glidescope and C-MAC devices, and FOI, both awake and asleep. This study was approved by Partners Healthcare Institutional Review Board and the study was exempted from consent requirement given its retrospective nature.

We excluded all cases with known variables that delay ACT such as arterial line placement, central line placement, cardiac or thoracic cases, peripheral nerve block placement or neuraxial anesthesia, and emergency cases and cases with ASA-PS 5 [11]. Although many of these cases may have had quickly performed airway techniques, the possibility of a delay in achieving the induction complete time due to performing additional procedures or tasks caused us to exclude these cases. The primary outcome was anesthesia control time (T1), which is measured from the time the patient entered the OR to induction complete. However, several other time variables were analyzed including induction start to induction complete (T2), induction start to intubation (T3), and in-room time to intubation (T4). Further exclusions were made based on the completeness of the data. Cases where time points were missing were excluded separately and the analytical sample was restricted to patients with  $T1 > 0$ ,  $T2 > 0$ ,  $T3 \geq 0$  and  $T4 > 0$ . Thus, cases with inaccurate charting (e.g. intubation charted prior to in-room time) were automatically excluded. Cases without documented ASA PS scores or MP scores were excluded as were cases with the BMI less than 10 or greater than 70. Furthermore, cases with an anesthesia control time  $> 120$  min were excluded. Lastly, cases with multiple airway devices used were excluded as it was impossible to tell which device had been used first in our electronic anesthesia record.

Categorical variables were summarized with frequencies and percentages, while continuous variables were summarized with median and interquartile. Chi-square test and Kruskal-Wallis test were used to analyze whether there were differences in patient characteristics among the four groups.

Generalized linear models with gamma distribution and log link were then used to model the right-skewed responses. Modeling was performed to further control for variables that were suspected to increase anesthesia control time (MP scores, ASA PS, presence of a trainee [16], BMI). The reference point for all analyses with modeling was an ASA PS 1 patient with a MP 1 score who underwent a DL airway technique. Since MP scores was suspected to be an effect modifier for airway technique used, we initially included an interaction term of MP scores and airway technique in all four models. Later this term was removed in the models for T3 and T4 due to non-significance. Then, further sub-group analysis was performed between various airway techniques using Wilcoxon rank-sum test. The significance level was set to be 0.05. All tests were two-sided and all statistical analyses were performed with SAS software version 9.4 (SAS Institute Inc. Cary, NC).

## Results

Our search identified 84,022 completed cases, of which 33,861 records met our inclusion criteria (see Fig. 1). We analyzed 32,542 cases for ACT (T1, in room time to induction complete time), 31,697 cases for T2 (induction start to induction complete), 32,595 cases for T3 (induction start to intubation) and 32,819 cases for T4 (in room to intubation time). The characteristics of the T1 group are displayed in Table 1, the T3 group characteristics are in Table 3, and the T4 group characteristics are in Table 4.

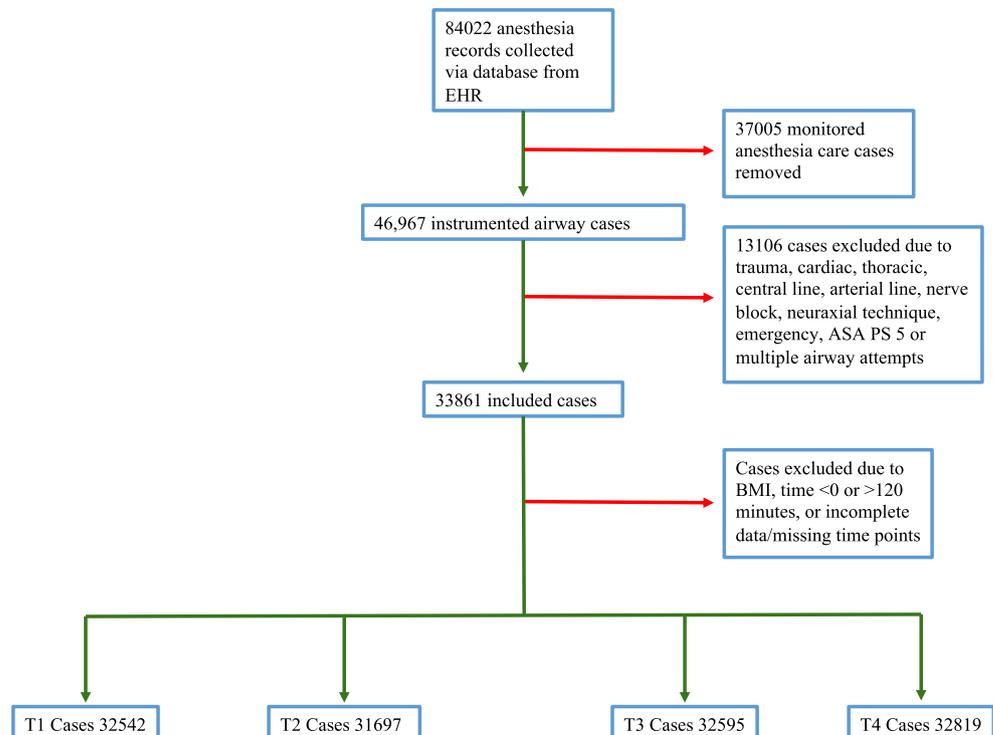
The characteristics for the group T2 were similar to T1, T3, and T4 and are displayed in Table 2. For each airway technique group, the populations were similar with respect to age (Laryngeal Mask Airway [LMA] 54 years old, DL 54 years old, VL 59 years old, and FOI 55.5 years old) and BMI (LMA 26.8 m<sup>2</sup>/kg, DL 27.1 m<sup>2</sup>/kg, VL 29.6 m<sup>2</sup>/kg, and FOI 25.9 m<sup>2</sup>/kg). However, the VL and FOI airway groups were more likely to be associated with the presence of a trainee (VL 37.8%, FOI 57.2%) compared to LMA and DL (LMA 27.1%, DL 30.9%). This difference was statistically significant with a *p* value of <0.0001. This difference was also noted for higher ASA PS and MP scores. For instance, ASA PS 3 patients were 47% of the VL group and 35.7% of the FOI population compared to 20.2% of the LMA population and 26.2% of the DL population. Similar trends are noted for the other time periods analyzed (T2-T4).

Based on the analysis applied above, LMA insertion was the quickest form of airway technique based on the anesthesia con-

trol time with an average time of 10 min (CI 8–14 min), then DL 14 min (CI 11–18 min), then VL 17 min (CI 13–21 min) and lastly FOI 20 min (CI 14.5–26 min). All of these results were statistically significant. Results are displayed in Table 1. A similar trend was noted for induction start to induction complete times (T3). LMA was 2.0 min (CI 1–4 min), DL was 4 min (CI 2–6 min), VL was 5 min (CI 3–7 min), and FOI was 6 min (CI 4–11 min). All results had a *p* value of <0.0001. Results for the T3 time period are shown in Table 3. This trend was again seen with the in-room to intubation time. LMA was 8 min (CI 7–11 min), DL was 11 min (CI 9–15 min), VL was 13 min (CI 10–17 min) and FOI was 15 min (CI 11–20 min). All results had a *p* value of <0.0001 and are displayed in Table 4.

The generalized linear model with gamma distribution and log link is displayed in Table 5 for all time points. Higher ASA PS was associated with increased duration for all four time periods measured (T1-4). Anesthesia control time was increased by 2.78% (CI 1.15–4.43%) for ASA PS 2 patients, 16.52% (CI 14.37–18.72%) for ASA PS 3 patients, and 42.96% (CI 34.47–52.14%) for ASA PS 4 patients. The BMI increased anesthesia control time by a small but significant factor (0.2%) when controlling for other variables. VL use was associated with increased control time in the modeling (17.68% CI 13.77–21.76%) compared to DL given that the patient was MP 1 and after controlling for other variables, as was FOI (38.29%, CI 26.28–51.71%) compared to MP 1 with DL. These were both statistically significant. These trends were also true and significant for the other time metrics analyzed and are displayed in Table 5.

**Fig. 1** Selection process for records identified in specific time period (September 2015–October 2016). EHR, electronic health record; ASA PS, American Society of Anesthesiologists Physical Status; BMI, body mass index; T1, anesthesia control time; T2, induction start to induction complete; T3, induction start to intubation; T4, in-room time to intubation



**Table 1** Characteristics by Airway Technique Groups, in-room time to induction complete time

	Total	LMA	Direct laryngoscopy	Video laryngoscope	Fiberoptic intubation	<i>P</i> value
Number of patients	<i>N</i> = 32,519	5435 (16.7)	22,251 (68.4)	4321 (13.3)	512 (1.6)	
In-room time to induction complete time in minutes	14.0 (10.0–18.0)	10.0 (8.0–14.0)	14.0 (11.0–18.0)	17.0 (13.0–21.0)	20.0 (14.5–26.0)	<0.0001
Age in years	54.0 (41.0–66.0)	54.0 (39.0–66.0)	54.0 (40.0–65.0)	59.0 (48.0–68.0)	55.5 (39.0–65.0)	<0.0001
ASA PS						
1	3654 (11.2)	899 (16.5)	2545 (11.4)	156 (3.6)	54 (10.55)	<0.0001
2	19,358 (60.1)	3415 (62.8)	13,772 (61.9)	2080 (48.1)	271 (52.9)	
3	9134 (28.1)	1099 (20.2)	5823 (26.2)	2029 (47.0)	183 (35.7)	
4	193 (0.6)	22 (0.4)	111 (0.5)	56 (1.3)	4 (0.8)	
MP score						
I	10,525 (32.4)	1821 (33.5)	7863 (35.3)	728 (16.9)	113 (22.1)	<0.0001
II	17,258 (53.1)	3067 (56.4)	11,938 (53.7)	2018 (46.7)	235 (45.9)	
III	4320 (13.3)	518 (9.5)	2335 (10.5)	1358 (31.4)	109 (21.3)	
IV	416 (1.3)	29 (0.5)	115 (0.5)	217 (5.0)	55 (10.7)	
BMI	27.4 (23.7–31.8)	26.8 (23.5–30.7)	27.1 (23.6–31.5)	29.6 (25.3–35.0)	25.9 (22.3–30.8)	<0.0001
Presence of a trainee						
No	22,246 (68.4)	3964 (72.9)	15,377 (69.1)	2686 (62.2)	219 (42.8)	<0.0001
Yes	10,273 (31.6)	1471 (27.1)	6874 (30.9)	1635 (37.8)	293 (57.2)	

Note: Continuous variables were summarized using median and interquartiles. Categorical variables were summarized using frequencies and percentages. *LMA* laryngeal mask airway, *ASA PS* American Society of Anesthesiologists Physical Status, *MP* Mallampati score, *BMI* body mass index

Trainee presence increased anesthesia control time by 17.42% (CI 16.02–18.85, *p* value <0.0001) during DL cases after controlling for other covariates, yet the presence of trainees had a smaller impact during VL airways

as it only increased ACT by 9.66% (CI 6.85–12.53). The presence of a trainee during a FOI had no impact on ACT (*P* value 0.6244) after controlling for other covariates.

**Table 2** Characteristics by Airway Technique Groups, induction to induction complete time

	Total	LMA	Direct laryngoscopy	Video laryngoscope	Fiberoptic	<i>P</i> value
Number of patients	<i>N</i> = 31,681	5272 (16.6)	21,656 (68.4)	4246 (13.4)	507 (1.6)	
Induction to induction complete time in minutes	7.0 (4.0–10.0)	4.0 (3.0–7.0)	7.0 (5.0–10.0)	8.0 (6.0–12.0)	11.0 (7.0–17.0)	<0.0001
Age in years	55.0 (41.0–66.0)	54.0 (39.0–66.0)	54.0 (40.0–65.0)	59.0 (48.0–68.0)	56.0 (39.0–65.0)	<0.0001
ASA PS						
1	3504 (11.1)	861 (16.3)	2440 (11.3)	151 (3.6)	52 (10.3)	<0.0001
2	19,000 (60.0)	3322 (63.0)	13,369 (61.7)	2039 (48.0)	270 (53.3)	
3	8987 (28.4)	1070 (20.3)	5738 (26.5)	1998 (47.1)	181 (35.7)	
4	190 (0.6)	19 (0.4)	109 (0.5)	58 (1.4)	4 (0.8)	
MP score						
I	10,250 (32.4)	1758 (33.4)	7660 (35.4)	720 (17.0)	112 (22.1)	<0.0001
II	16,810 (53.1)	2980 (56.5)	11,619 (53.7)	1979 (46.6)	232 (45.8)	
III	4216 (13.3)	506 (9.6)	2266 (10.5)	1336 (31.4)	108 (21.3)	
IV	405 (1.3)	28 (0.5)	111 (0.5)	211 (5.0)	55 (10.9)	
BMI	27.4 (23.7–31.8)	26.9 (23.5–30.8)	27.1 (23.6–31.5)	29.6 (25.2–35.0)	25.8 (22.2–30.8)	<0.0001
Presence of a trainee						
No	21,550 (68.0)	3833 (72.7)	14,867 (68.7)	2633 (62.0)	217 (42.8)	<0.0001
Yes	10,131 (32.0)	1439 (27.3)	6789 (31.3)	1613 (38.0)	290 (57.2)	

Note: Continuous variables were summarized using median and interquartiles. Categorical variables were summarized using frequencies and percentages. *LMA* laryngeal mask airway, *ASA PS* American Society of Anesthesiologists Physical Status, *MP* Mallampati score, *BMI* body mass index

**Table 3** Characteristics by Airway Technique Groups, induction to intubation time

	Total	LMA	Direct laryngoscopy	Video laryngoscope	Fiberoptic	P value
Number of patients	<i>N</i> = 32,587	2717 (8.3)	24,264 (74.5)	5070 (15.6)	536 (1.6)	
Induction to intubation time in minutes	4.0 (2.0–6.0)	2.0 (1.0–4.0)	4.0 (2.0–6.0)	5.0 (3.0–7.0)	6.0 (4.0–11.0)	<0.0001
Age in years	55.0 (41.0–66.0)	54.0 (40.0–66.0)	54.0 (40.0–65.0)	59.0 (48.0–68.0)	55.0 (38.5–65.0)	<0.0001
ASA PS						
1	3643 (11.2)	411 (15.1)	2976 (12.3)	199 (3.9)	57 (10.6)	<0.0001
2	19,729 (60.5)	1776 (65.4)	15,075 (62.1)	2589 (51.1)	289 (53.9)	
3	9025 (27.7)	522 (19.2)	6096 (25.1)	2221 (43.8)	186 (34.7)	
4	190 (0.6)	8 (0.3)	117 (0.5)	61 (1.2)	4 (0.8)	
MP score						
I	10,461 (32.1)	890 (32.8)	8614 (35.5)	832 (16.4)	125 (23.3)	<0.0001
II	16,893 (51.8)	1554 (57.2)	12,812 (52.8)	2288 (45.1)	239 (44.6)	
III	4760 (14.6)	257 (9.5)	2705 (11.2)	1683 (33.2)	115 (21.5)	
IV	473 (1.5)	16 (0.6)	133 (0.6)	267 (5.3)	57 (10.6)	
BMI	27.4 (23.7–32.0)	27.1 (23.8–30.9)	27.1 (23.6–31.5)	29.8 (25.4–35.0)	25.8 (22.2–30.6)	<0.0001
Presence of a trainee						
No	22,984 (70.5)	2188 (80.5)	17,178 (70.8)	3394 (66.9)	224 (41.8)	<0.0001
Yes	9603 (29.5)	529 (19.5)	7086 (29.2)	1676 (33.1)	312 (58.2)	

Note: Continuous variables were summarized using median and interquartiles. Categorical variables were summarized using frequencies and percentages. *LMA* laryngeal mask airway, *ASA PS* American Society of Anesthesiologists Physical Status, *MP* Mallampati score, *BMI* body mass index

Modeling shows that MP 3 and 4 scores were associated with longer ACTs compared to MP 1 score group. MP 3 scores had an increase by 3.21% (95% CI 1.19–5.27%) and MP 4 scores had an increase by 14.84% (95% CI 6.37–24.22%) for DL group, after adjusting for other covariates. However, for a MP 4 patient, the increase in ACT when using VL was not statistically significant (*P* value = 0.8997), when controlling for other variables. Similarly, using FOI in an MP

**Table 4** Characteristics by Airway Technique Groups, in-room time to intubation time

	Total	LMA	Direct laryngoscopy	Video laryngoscope	Fiberoptic	P value
Number of patients	<i>N</i> = 32,810	2723 (8.3)	24,456 (74.5)	5087 (15.5)	544 (1.7)	
In-room time to intubation time in minutes	11.0 (9.0–15.0)	8.0 (7.0–11.0)	11.0 (9.0–15.0)	13.0 (10.0–17.0)	15.0 (11.0–20.0)	<0.0001
Age in years	55.0 (41.0–66.0)	54.0 (40.0–66.0)	54.0 (40.0–65.0)	59.0 (48.0–68.0)	55.0 (39.0–65.5)	<0.0001
ASA PS						
1	3676 (11.2)	413 (15.2)	3005 (12.3)	202 (4.0)	56 (10.3)	<0.0001
2	19,861 (60.5)	1780 (65.4)	15,198 (62.1)	2592 (50.9)	291 (53.5)	
3	9081 (27.7)	522 (19.2)	6132 (25.1)	2234 (43.9)	193 (35.5)	
4	192 (0.6)	8 (0.3)	121 (0.5)	59 (1.2)	4 (0.7)	
MP score						
I	10,534 (32.1)	897 (32.9)	8678 (35.5)	835 (16.4)	124 (22.8)	<0.0001
II	17,008 (51.8)	1554 (57.1)	12,913 (52.8)	2298 (45.2)	243 (44.7)	
III	4793 (14.6)	257 (9.4)	2729 (11.2)	1688 (33.2)	119 (21.9)	
IV	475 (1.4)	15 (0.6)	136 (0.6)	266 (5.2)	58 (10.7)	
BMI	27.4 (23.7–32.0)	27.0 (23.7–30.9)	27.1 (23.5–31.5)	29.7 (25.4–35.0)	25.8 (22.3–30.7)	<0.0001
Presence of a trainee						
No	23,153 (70.6)	2192 (80.5)	17,330 (70.9)	3402 (66.9)	229 (42.1)	<0.0001
Yes	9657 (29.4)	531 (19.5)	7126 (29.1)	1685 (33.1)	315 (57.9)	

Note: Continuous variables were summarized using median and interquartiles. Categorical variables were summarized using frequencies and percentages. *LMA* laryngeal mask airway, *ASA PS* American Society of Anesthesiologists Physical Status, *MP* Mallampati score, *BMI* body mass index

**Table 5** Modeling results from generalized linear models with gamma distribution and log link, for four times separately

	T1			T2			T3			T4		
	Exp (estimate)	95% CI	P value	Exp (estimate)	95% CI	P value	Exp (estimate)	95% CI	P value	Exp (estimate)	95% CI	P value
ASA PS = 1 (ref)	1			1			1			1		
ASA PS = 2	1.0278	(1.0115, 1.0443)	0.0008	1.0028	(0.9800, 1.0260)	0.8117	1.0758	(1.0417, 1.1109)	<0.0001	1.0588	(1.0417, 1.0761)	<0.0001
ASA PS = 3	1.1652	(1.1437, 1.1872)	<0.0001	1.1174	(1.0880, 1.1475)	<0.0001	1.2355	(1.1899, 1.2827)	<0.0001	1.2160	(1.1933, 1.2394)	<0.0001
ASA PS = 4	1.4296	(1.3447, 1.5214)	<0.0001	1.2432	(1.1404, 1.3583)	<0.0001	1.4588	(1.2872, 1.6532)	<0.0001	1.5693	(1.4734, 1.6713)	<0.0001
Direct laryngoscopy (MAC/Miller) ref	1			1			1			1		
Video laryngoscopy (C-MAC/Glidescope)	1.1768	(1.1377, 1.2176)	<0.0001	1.2310	(1.1735, 1.2920)	<0.0001	1.1313	(1.0953, 1.1685)	<0.0001	1.0992	(1.0813, 1.1173)	<0.0001
Fiberoptic	1.3829	(1.2628, 1.5171)	<0.0001	1.5493	(1.3662, 1.7635)	<0.0001	1.7706	(1.5823, 1.9814)	<0.0001	1.4198	(1.3422, 1.5020)	<0.0001
LMA	0.7711	(0.7536, 0.7890)	<0.0001	0.6547	(0.6336, 0.6767)	<0.0001	0.6148	(0.5920, 0.6385)	<0.0001	0.7847	(0.7699, 0.7999)	<0.0001
Trainee present	1.1742	(1.1602, 1.1885)	<0.0001	1.2801	(1.2585, 1.3021)	<0.0001	1.3312	(1.3003, 1.3630)	<0.0001	1.1633	(1.1496, 1.1773)	<0.0001
Trainee present and video laryngoscopy	0.9339	(0.9076, 0.9609)	<0.0001	0.8951	(0.8597, 0.9320)	<0.0001	0.9731	(0.9211, 1.0280)	0.3293	0.9862	(0.9593, 1.0140)	0.3270
Trainee present and fiberoptic	0.8675	(0.8048, 0.9349)	0.0002	0.8560	(0.7700, 0.9510)	0.0039	0.7840	(0.6764, 0.9086)	0.0012	0.8492	(0.7886, 0.9143)	<0.0001
Trainee present and LMA	1.0743	(1.0449, 1.1047)	<0.0001	1.1929	(1.1466, 1.2412)	<0.0001	1.3944	(1.2822, 1.5165)	<0.0001	1.1709	(1.1224, 1.2216)	<0.0001
BMI	1.0020	(1.0013, 1.0027)	<0.0001	0.9998	(0.9987, 1.0008)	0.6571	0.9983	(0.9968, 0.9997)	0.0192	1.0020	(1.0013, 1.0028)	<0.0001
Age	1.0015	(1.0012, 1.0018)	<0.0001	1.0004	(1.0000, 1.0009)	0.0430	0.9994	(0.9988, 1.0000)	0.0346	1.0013	(1.0010, 1.0016)	<0.0001
MP score = I (ref)	1			1			1			1		
MP score = II	0.9985	(0.9864, 1.0107)	0.8045	0.9904	(0.9735, 1.0077)	0.2780	1.0157	(0.9943, 1.0376)	0.1511	1.0068	(0.9943, 1.0177)	0.2152
MP score = III	1.0321	(1.0119, 1.0527)	0.0018	1.0250	(0.9965, 1.0544)	0.0866	0.9910	(0.9608, 1.0221)	0.5676	1.0127	(0.9970, 1.0286)	0.1124
MP score = IV	1.1484	(1.0637, 1.2422)	0.0005	1.2247	(1.0983, 1.3709)	0.0003	1.0605	(0.9787, 1.1489)	0.1512	1.0485	(1.0070, 1.0917)	0.0215
MP score = II and video laryngoscopy	1.0021	(0.9650, 1.0405)	0.9111	1.0150	(0.9622, 1.0704)	0.5826	—	—	—	—	—	—
MP score = III and video laryngoscopy	0.9703	(0.9298, 1.0125)	0.1656	0.9883	(0.9303, 1.0496)	0.7011	—	—	—	—	—	—
MP score = IV and video laryngoscopy	0.8550	(0.7731, 0.9449)	0.0022	0.7976	(0.6906, 0.9195)	0.0019	—	—	—	—	—	—
	1.0910		0.0731	1.1320		0.0705	—	—	—	—	—	—

**Table 5** (continued)

	T1			T2			T3			T4		
	Exp (estimate)	95% CI	P value	Exp (estimate)	95% CI	P value	Exp (estimate)	95% CI	P value	Exp (estimate)	95% CI	P value
MP score = II and fiberoptic	1.0762	(0.913, 1.1994)	0.2021	1.0642	(0.9887, 1.2934)	0.4425	—	—	—	—	—	—
MP score = III and fiberoptic	0.9734	(0.8328, 1.2047)	0.7353	0.9775	(0.7845, 1.2473)	0.8398	—	—	—	—	—	—
MP score = IV and fiberoptic	0.9759	(0.9497, 1.1389)	0.0780	0.9810	(0.9436, 1.2205)	0.3322	—	—	—	—	—	—
MP score = III and LMA	1.0194	(0.9742, 1.0027)	0.4080	1.0340	(0.9695, 1.1033)	0.3116	—	—	—	—	—	—
MP score = IV and LMA	1.0644	(0.8981, 1.2687)	0.4789	1.0668	(0.8382, 1.3738)	0.6074	—	—	—	—	—	—

Modeling results for each time group (T1-T4). Modeling using generalized linear models with gamma distribution and log link. All times compared to a reference number of 1 for a ASA PS 1, MP 1, no trainee present patient intubated with DL. Exp (estimate) exponentiated estimate, LMA laryngeal mask airway, ASA PS American Society of Anesthesiologists Physical Status, MP Mallampati score, BMI body mass index

1 patient would increase the control time by 34.61% (95% CI 16.99–54.87%). With higher MP class, airway technique impacted efficiency more. Given that the patient had a MP 3 score and no trainee presence, using VL would increase the control time by 14.18% (95% CI 10.8–17.67%), while using FOI would increase the control time by 48.82% (95% CI 36.07–62.76%), compared to using DL and after adjusting for other covariates. This trend was also noted for the other time variables analyzed.

Further subgroup analysis was performed within the ACT group (T1) to examine the differences between direct laryngoscopy techniques and differences between video laryngoscopy techniques (Table 6). Miller blade direct laryngoscopy (13 min, CI 11–18) was shown to reduce ACT by 1 min compared to a MAC blade (14 min, CI 10–17,  $p < 0.0001$ ). It was also noted that Glidescope video laryngoscopy intubations (15 min, CI 12–20) were significantly faster than CMAC intubations (18 min, CI 14–22). The  $p$  value for this comparison was significant ( $p < 0.0001$ ). Interestingly, both the Miller ( $n = 2150$ ) and Glidescope ( $n = 1743$ ) techniques were less commonly used at these four institutions compared to Macintosh ( $n = 20,101$ ) and CMAC ( $n = 2578$ ) techniques, as shown in Table 6. Results were similar when looking at the time point T3 (induction to intubation time) except for the Macintosh vs. Miller category, which showed no statistically significant difference between airway device used and duration of time from induction to intubation time.

### Discussion

In this retrospective chart analysis of 32,542 cases we found that LMA insertion was associated with the shortest ACT. This seems logical since endotracheal intubation often requires use of paralytic agents and longer bag-mask ventilation in the case of non-depolarizing muscle relaxants and therefore, more time elapses while waiting for medications to exert their effect. This study also showed that direct laryngoscopy was associated with shorter ACTs compared to video laryngoscopy, contrary to some previous reports. Despite the increased use of VL, this study suggests that for maximum efficiency in routine cases, direct laryngoscopy should continue to be used. This further supports the important role of direct laryngoscopy for all anesthesia providers and the importance of continuing to teach this technique to trainees [17]. Additionally, the study showed a statistically significant difference in ACT based on type of DL or VL used (e.g. ACTs were shorter with the Miller blade than with Macintosh, with the Glidescope than the CMAC). This difference is not explained by increased familiarity with these techniques since they were actually less commonly used during this time period but may instead suggest an intrinsic value in these airway devices. For instance, one reason an intubation with a Glidescope may be quicker is that

**Table 6** Subgroups in Direct Laryngoscope, Video Laryngoscope, and Fiberoptic. In-room time to induction complete time

	Direct laryngoscopy (N = 22,251)		Video laryngoscope (N = 4321)		Fiberoptic (N = 512)	
	MAC (N = 20,101)	Miller (N = 2150)	CMAC (N = 2578)	Glidescope (N = 1743)	Awake (N = 59)	Asleep (N = 453)
In-room time to induction complete time T1 in minutes, median (Q1–Q3)	14.0 (11.0–18.0)	13.0 (10.0–17.0)	18.0 (14.0–22.0)	15.0 (12.0–20.0)	25.0 (21.0–31.0)	19.0 (14.0, 25.0)
Age in years, median (Q1–Q3)	54.0 (40.0–65.0)	53.0 (40.0–64.0)	59.0 (48.0–68.0)	60.0 (49.0–69.0)	60.0 (50.0–69.0)	54.0 (39.0–64.0)
ASA PS, N (%)						
1	2286 (11.4)	259 (12.0)	70 (2.7)	86 (4.9)	0 (0.0)	54 (11.9)
2	12,354 (61.5)	1418 (66.0)	1066 (41.4)	1014 (58.2)	11 (18.6)	260 (57.4)
3	5358 (26.6)	465 (21.6)	1405 (54.5)	624 (35.8)	47 (79.7)	136 (30.0)
4	103 (0.5)	8 (0.4)	37 (1.4)	19 (1.1)	1 (1.7)	3 (0.7)
MP score, N (%)						
I	7058 (35.1)	805 (37.4)	439 (17.0)	289 (16.6)	5 (8.5)	108 (23.8)
II	10,792 (53.7)	1146 (53.3)	1222 (47.4)	796 (45.7)	20 (33.9)	215 (47.5)
III	2143 (10.7)	192 (8.9)	809 (31.4)	549 (31.5)	18 (30.5)	91 (20.1)
IV	108 (0.5)	7 (0.3)	108 (4.2)	109 (6.3)	16 (27.1)	39 (8.6)
BMI, N (%)	27.3 (23.6–31.6)	26.5 (23.3–30.6)	30.0 (25.8–35.6)	29.1 (24.7–34.4)	28.2 (22.2–38.0)	25.7 (22.3–30.2)
Presence of a trainee, N (%)						
No	13,637 (67.8)	1740 (80.9)	1450 (56.3)	1236 (70.9)	36 (61.0)	183 (40.0)
Yes	6464 (32.2)	410 (19.1)	1128 (43.7)	507 (29.1)	23 (39.0)	270 (59.6)

Using Wilcoxon rank-sum test, we compared the in-room time to induction complete time between MAC versus Miller, CMAC versus Glidescope, and Fiberoptic awake versus Fiberoptic asleep. The unadjusted  $p$ -values are  $p < 0.0001$ ,  $p < 0.0001$ , and  $p < 0.0001$ . After adjusting for multiple comparisons, the three  $p$ -values are  $p < 0.0001$ ,  $p < 0.0001$ , and  $p < 0.0001$ . Hence, the in-room time to induction complete time was significantly different between MAC and Miller groups, between CMAC and Glidescope groups, and between Fiberoptic awake and Fiberoptic asleep groups. ASA PS American Society of Anesthesiologists Physical Status, MP Mallampati, BMI body mass index.

there is no ability to perform direct laryngoscopy, thus speeding up the process, unlike the CMAC which can allow both direct and indirect laryngoscopy.

This study does show that expected factors including ASA PS, MP score, presence of a trainee and BMI are associated with increased ACTs. Interestingly, BMI had a very minimal impact on ACT compared to the other variables. ASA PS likely increases ACT due to slower inductions for more medically complex patients. MP score likely contributes to both airway time and possibly a slower induction. It has previously been shown that trainees have a shorter intubation time with VL than DL [18]. Interestingly, having a trainee present did not impact the time for FOI and had less impact than would be expected for VL compared to DL. This may be because these techniques are faster with additional, skilled personnel available to assist with instrumentation.

Perhaps the most interesting results of the study are that in the anticipated difficult airway (which we categorized as MP 4 patients), VL minimizes the increase in ACT compared to DL with these cases; however this was not seen with the MP 3 patients. This suggests that in particular situations, VL may be the most efficient technique in addition to being the safest technique [1], similar to previous reports [8].

DL is likely more efficient compared to VL or FOI due to decreased set-up time and ease of use of equipment. Our findings are discrepant with some previous studies evaluating time to intubation between DL and VL. However, we used the ACT as the primary outcome measure instead of time to intubation as this better captures time required for each airway technique, including setup and utilization. Interestingly, our data also showed this difference between VL and DL for all other time periods (T2-4), suggesting an intrinsic difference in the airway technique itself. Furthermore, a unique aspect of our study is that it looks at the influence of airway management technique in the general population instead of focusing on difficult airway populations.

As this study was performed at both academic and community hospital settings and included a robust sample size, its results are generalizable. However, none of the sites utilized induction rooms to start cases. Induction rooms may improve overall OR efficiency, but their use should not alter the in room time to intubation time, another metric that was analyzed in this dataset, showing similar trends to ACT. It is limited by its retrospective nature, and the fact that the VL and FOI populations involved patients with statistically higher MP scores and higher ASA PS scores. Furthermore, the data are based on charted time points in the electronic anesthesia record which likely have variable accuracy based on provider entry. The time points are charted to the closest minute, not second, further limiting accuracy. Statistical modeling helps to control for variables associated with longer ACT, and still shows an increase in ACT with VL and FOI compared to DL. Other possible limitations include the exclusion of cases

where multiple airway devices were used. For instance, cases where a difficult airway may have been predicted (MP 3 or 4) and DL was initially attempted with inability to secure the airway but later rescued by VL or FOI, were excluded. These cases may have increased the ACT for DL cases. Our database is unable to capture successful first attempts, and evidence of fewer attempts with VL has already been reported in several prior analyses [2–10].

There is little debate that video laryngoscopes have improved patient safety during induction of anesthesia and airway instrumentation [1, 6, 7, 10, 18], but our novel study suggests that their use does have an impact on OR efficiency. In some cases, VL can decrease efficiency (routine cases, not anticipated difficult airway) and in others (especially patients with a higher MP score) it can have minimal impact or possibly increase efficiency. Reduction of time spent in the operating suite is potentially valuable; estimates of cost per minute in individual ORs range from 15 to 62 U.S. dollars per minute [19–22]. Administrators often extrapolate these time reductions to savings at the end of the workday through prevention of over-utilized time, although this association may be overstated. These theoretical time savings must be balanced against the expensive nature of these devices, which range from \$500 to \$60,000 depending on set-up and device. We must also acknowledge that because of the sheer number of variables associated with airway techniques, the relationship between reduction in OR time and savings is not always clear. However, the results from our data are promising and support the notion that video laryngoscopy may improve efficiency in patients with specific traits associated with a more challenging intubation, such as higher ASA PS and MP score. This, combined with possible improvements in patient safety and outcomes likely justify the high cost of this equipment.

In conclusion, we found that laryngeal mask insertion is associated with the shortest ACT. Furthermore, despite previous reports, our data suggests that DL is associated with a shorter ACT than VL, even when controlling for other variables. The statistical modeling also shows that ACT is increased with factors such as presence of a trainee, higher BMI, ASA PS and MP score. Knowing that these variables impact ACT may allow for more accurate time management for selected cases. The increased time for ACT with trainee presence likely reflects a component of teaching, incomplete skill development and change in routine OR teams, which has previously been shown to impact turnover times which includes the ACT [23].

Further research in this area may include a randomized control trial between DL and VL, such as the ongoing EMMA trial evaluating McGrath Mac vs Macintosh laryngoscopy. Results from the EMMA [24] trial will likely help further our understanding of the risks and benefits of VL compared to DL, while also evaluating the efficiency associated with each procedure.

Regardless of the results of the EMMA trial, our study shows that in appropriately selected patients, an LMA device is the most efficient airway management technique currently available. Furthermore, it suggests that in certain patient populations, VL may not only be more ideal from a patient safety standpoint (better first attempt success [3–7]) but also improve efficiency. Some previous studies have advocated for the utilization of VL for most patients. Our study does not support this idea from an efficiency standpoint in a patient with a routine airway.

### Compliance with ethical standards

**Conflict of interest** None of the authors have any conflicts of interest relevant to this work.

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