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Original Contributions

THE UTILITY OF THE C-MAC AS A DIRECT LARYNGOSCOPE FOR INTUBATION IN THE EMERGENCY DEPARTMENT

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☐ **Abstract—Background: Although the C-MAC (Karl Storz, Tuttlingen, Germany) is a video laryngoscope (VL), it can also be used as a direct laryngoscope (DL). Objective: The goal of this study was to evaluate the utility of the C-MAC as a DL for intubations in the emergency department (ED). Methods: This was an analysis of prospectively collected continuous quality-improvement data during the 6-year period from February 1, 2009 to January 31, 2015, when both the C-MAC and Macintosh DL (Mac DL) were clinically available in our ED. This analysis included adult patients who underwent rapid sequence intubation by an emergency medicine resident in the ED with a C-MAC initially used as a DL or a Mac DL. The primary outcome measure was the first pass success (FPS). Results: When the C-MAC was used as a DL, the initial DL attempt was successful in 199 of 346 (57.6%) cases. When the attempt could not be completed using the C-MAC as a DL, the operator utilized the video monitor and successfully completed the intubation using VL in 104 of 134 (77.6%) cases, thus achieving an overall FPS of 303 of 346 (87.6%). When the Mac DL was used, the FPS was 505 of 671 (75.3%). Conclusions: The C-MAC is a useful device for DL because in the event of a failed DL attempt, operators have the option of switching to the video monitor to successfully complete the intubation using VL without having to make a second attempt.** © 2016 Elsevier Inc. All rights reserved.

☐ **Keywords—C-MAC; direct laryngoscopy; EM resident intubations**

Dr. Sakles currently serves on the Verathon Scientific Advisory Committee (Verathon is the manufacturer of the GlideScope).

INTRODUCTION

Airway management in the emergency department (ED) frequently involves intubation of the trachea. Historically, this has been most commonly accomplished with a direct laryngoscope (DL). However, there has been a surge recently in the use of video laryngoscopes (VL) for emergent intubation (1). There have been numerous studies comparing VLs to DLs, yet great controversy exists over the appropriate primary device for intubation (2–20). Some authors believe that VL should be used routinely as the primary intubation device because of evidence that has demonstrated improved laryngeal views, higher first pass success (FPS), and fewer complications (2,8,9,13–15,21–25). Others have voiced concern that by using VL exclusively operators will lose their DL skills, which is believed by many to be an important skill in emergency medicine (2–4,26). The C-MAC (Karl Storz, Tuttlingen, Germany) is a VL that incorporates a microvideocamera on a standard Macintosh blade and therefore it can be used as a DL or

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a VL (27,28). This is advanta-geous because it allows operators to perform direct laryngoscopy and, if this method of intubation proves difficult or unsuccessful, allows for easy transition to the video monitor to accomplish the intubation with video laryngoscopy. The ability to easily switch from DL to VL can be useful clinically, as it can help decrease the number of intubation attempts, which has been shown in multiple studies to be strongly associated with an increase in adverse events (29–31). The purpose of this investigation is to evaluate the clinical utility of the C-MAC as a DL and to determine its impact on FPS compared to a conventional Macintosh DL (Mac DL).

MATERIALS AND METHODS

Study Design and Setting

This is a single-center prospective observational study of ED intubations performed during the 6-year period from February 1, 2009 to January 31, 2015 based on data recorded into a continuous quality improvement database. 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 of approximately 70,000 visits. This institution has an Accreditation Council for Graduate Medical Education–accredited 3-year emergency medicine (EM) residency program, as well as a 5-year combined EM/pediatrics residency program. Intubations in this ED are performed primarily by EM residents under direct supervision of an EM attending. All residents receive training in DL and VL use. Device selection for intubation is at the discretion of the EM resident and the attending.

Selection of Participants

The C-MAC was introduced into our ED on February 1, 2009. Only adult patients who were intubated using the C-MAC initially as a DL or a Mac DL as the initial device, from February 1, 2009 until January 31, 2015, when both devices were available in the ED, were included in this study. Patients who did not undergo rapid sequence intubation (RSI) or were not intubated by an EM resident were excluded. See Figure 1 for details of the study group.

Methods and Measurements

After each intubation, the operator completed a paper data-collection form that captures patient, operator, and intubation characteristics. This includes patient demographics, operator postgraduate year (PGY), indication for intubation, method of intubation, neuromuscular blocking agent (NMBA), sedative agent, device(s) used, reason for device selection, presence of certain difficult airway characteristics (DACs), number of attempts at intubation, the outcome of each attempt, and adverse events. 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. FPS was defined as successful tracheal intubation on a single laryngoscope insertion. DACs documented on the data form include blood or vomit 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. Multiple adverse events were tracked and have been described previously (31). Hypoxemia was defined as any oxygen saturation falling below 90% during the intubation. Information was collected on how the C-MAC was used during the intubation. Options for C-MAC use included the following: used as a DL only, used as a VL only, used as a DL initially then switched to VL, or used as a VL initially then switched to DL. Only patients in whom the C-MAC was initially used as a DL were included in this study (DL only and DL to VL switch).

The primary investigator reviewed all data forms. Any incomplete forms or forms with contradictory data were discussed with the operator for completion or clarification. To ensure compliance, data forms were cross-referenced with the electronic medical record and the hospital admission log. Compliance was 100%. Data from the paper forms were entered into Excel for Windows 2013 (Microsoft, Redmond, WA) and then transferred and coded into STATA 13 (StataCorp, College Station, TX) for statistical analysis.

Outcome Measures

The primary outcome measure was FPS. The secondary outcome measures included the Cormack-Lehane (CL) laryngeal view and incidence of hypoxemia.

Primary Data Analysis

Patients were categorized into two groups: those that were intubated with a C-MAC used initially as a DL and those using a Mac DL as the initial device. Summary statistics were calculated for patient, intubation, and operator characteristics. Continuous normally distributed variables were reported as means with standard deviations. Patient age was the only continuous variable in the dataset. Categorical variables were reported as percentages. A multivariate logistic regression analysis was performed to evaluate the association between device (C-MAC vs. Mac DL) used and FPS. Confounders considered to be pertinent based on clinical expertise

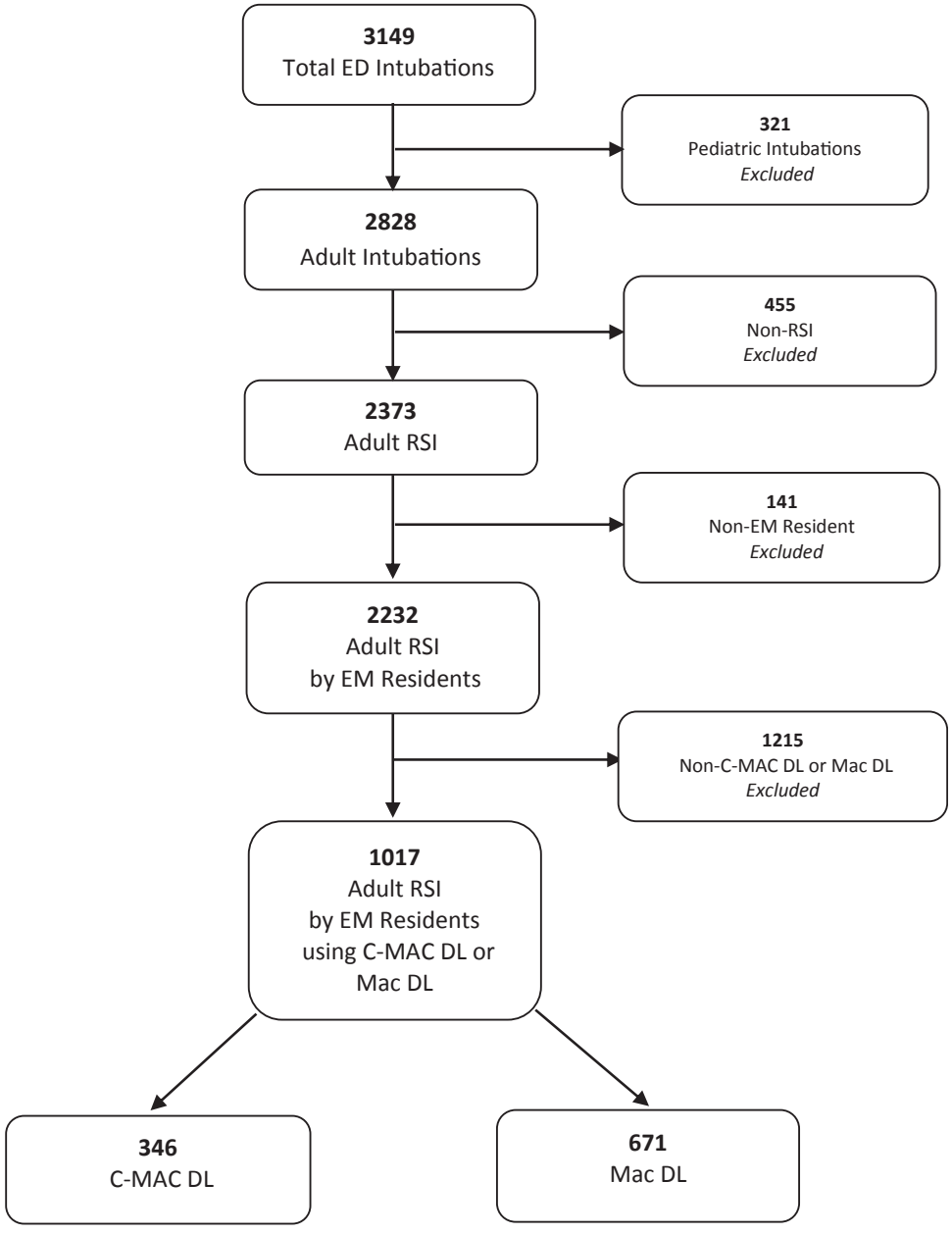

Figure 1. Flow diagram of patients in the study. ED = emergency department; RSI = rapid sequence intubation; EM = emergency medicine.

of the investigators were NMBA, sedative, number of difficult airway characteristics, reason for device selection, operator PGY, and whether the patient was a medical or trauma patient. The intent was not to develop a parsimonious model, thus all potential confounders were included in the model. There was no theoretical basis to consider any model interactions. Model discrimination was evaluated by generating a received operating characteristics curve. The goodness-of-fit of the model was checked by the Hosmer-Lemeshow test. All analyses were conducted in STATA 13.

RESULTS

Characteristics of Study Subjects

A total of 3,149 intubations were performed in the ED during the 6-year study period. There were 1,017 patients left for analysis after excluding intubations performed on patients that were younger than 18 years of age, those that did not undergo RSI by an EM resident, and those in which an initial device other than the C-MAC as a DL or a Mac DL was used. Of these, the C-MAC as a DL

Table 1. Characteristics of Patients in the Study

Characteristic	C-MAC (n = 346)	Mac DL (n = 671)	Difference (95% CI)
Age (y), mean ± SD	52.0 ± 18.7	50.9 ± 19.7	1.1 (−3.5 to 1.5)
Sex (male), n (%)	204 (59.0)	433 (64.5)	−5.5 (−11.9 to 0.7)
Trauma, n (%)	95 (27.5)	193 (28.8)	−1.3 (−7.1 to 4.5)
Specific difficult airway characteristics, n (%)			
Cervical immobility	61 (17.6)	136 (20.3)	−2.7 (−7.7 to 2.4)
Facial/neck trauma	31 (9.0)	50 (7.5)	1.5 (−2.1 to 5.1)
Airway edema	11 (3.2)	11 (1.6)	1.6 (−0.5 to 3.6)
Small mandible	12 (3.5)	30 (4.5)	−1 (−3.5 to 1.5)
Obesity	66 (19.1)	139 (20.7)	−1.6 (−6.8 to 3.5)
Large tongue	36 (10.4)	59 (8.8)	1.6 (−2.3 to 5.5)
Short neck	37 (10.7)	66 (9.8)	0.9 (−3.1 to 4.8)
Restricted mouth opening	4 (1.2)	1 (0.1)	1 (−0.1 to 2.2)
Blood in airway	58 (16.8)	121 (18.0)	−1.3 (−6.2 to 3.6)
Vomit in airway	43 (12.4)	76 (11.3)	1.1 (−3.1 to 5.3)
No. of difficult airway characteristics, n (%)			
None	157 (45.4)	282 (42.0)	3.3 (−3.1 to 9.8)
1	92 (26.7)	207 (30.8)	−4.3 (−10.1 to 1.6)
2	45 (13.3)	99 (14.8)	−1.5 (−6.2 to 2.7)
≥3	52 (15.0)	83 (12.4)	2.7 (−1.9 to 7.2)
Reason for device selection			
Standard device	177 (51.2)	618 (92.1)	−40.9 (−46.6 to −35.3)
Difficult airway	87 (25.1)	16 (2.4)	22.8 (18.0 to 27.5)
Educational purposes	82 (23.7)	37 (5.5)	18.2 (13.4 to 23.0)
Stylet, standard	293 (84.7)	574 (85.5)	−0.9 (−5.5 to 3.8)
NMBA used, succinylcholine	169 (48.8)	340 (50.7)	−1.8 (−8.3 to 4.7)
Sedative agent used, etomidate	303 (87.6)	625 (93.1)	−5.6 (−9.5 to −1.6)
PGY level of operator			
1	98 (28.3)	151 (22.6)	5.8 (0.1 to 11.5)
2	160 (46.2)	240 (35.8)	10.5 (4.1 to 16.9)
3, 4, 5	88 (25.4)	280 (41.7)	−16.3 (−22.2 to 10.4)

NMBA = neuromuscular blocking agent; PGY = postgraduate year; SD = standard deviation; CI = confidence interval.

was used on 346 patients and the Mac DL was used on 671 patients. See Figure 1 for details.

The clinical characteristics of the C-MAC and Mac DL groups are summarized in Table 1. The mean patient age was 52 ± 18.7 years in the C-MAC group and 50.9 ± 19.7 years in the Mac DL group; 27.5% of the patients in the C-MAC group were trauma patients and 28.8% of patients in the Mac DL group were trauma patients. The C-MAC was chosen as the initial device in 25.1% of patients for a suspected difficult airway, while the Mac DL was chosen in 2.4% for a suspected difficult airway. In the C-MAC group, 25.4% of the operators were senior residents (PGY3, 4, or 5), while in the Mac DL group 41.7% were senior residents.

Main Results

When the C-MAC was used as a DL, the intubation was successful, with DL in 199 of 346 (57.6%; 95% confidence interval [CI] 52.1–62.8%) cases. When the intubation could not be completed using the C-MAC as a DL, the operator utilized the video monitor and successfully completed the intubation using VL in 104 of 134 (77.6%; 95% CI 69.6–84.4%) cases. Thus, when using the C-MAC initially as a DL, an overall FPS of 303 of 346 (87.6%; 95% CI 83.6–90.9%) was achieved. When the Mac DL was used, the FPS was 505 of 671 (75.3%; 95% CI 71.8–78.5%). See Figure 2 for details. In the multivariate regression analysis, use of a C-MAC was associated with an increase in FPS as compared to the Mac DL (adjusted OR = 2.9; 95% CI 1.9–4.6) (Table 2). The area under the receiver operating characteristics curve was 0.67. According to the Hosmer-Lemeshow goodness-of-fit test, the model fit the data well ($p = 0.262$).

In the C-MAC group, success by the second attempt was 327 of 346 (94.5%; 95% CI 91.6–96.7%) when using the C-MAC again. The ultimate success using the C-MAC was 343 of 346 (99.1%; 95% CI 97.5–99.8%). In the Mac DL group, success by the second attempt was 542 of 671 (80.8%; 95% CI 77.6–83.7%) when using the Mac DL again. The ultimate success using the Mac DL was 554 of 671 (82.6%; 95% CI 79.5–85.4%).

CL view data were available in 328 C-MAC cases. When using the C-MAC as a DL a CL view of I or II was obtained in 247 of 328 (75.3%; 95% CI 70.3–79.9%) cases. When using a Mac DL, a CL view of I or II was obtained in 547 of 671 (81.5%; 95% CI 78.4–84.4%) cases. See Table 3 for details. Complete CL data were available for 106 cases in which the C-MAC was used and the operator made a switch from DL to VL. When a CL view of III

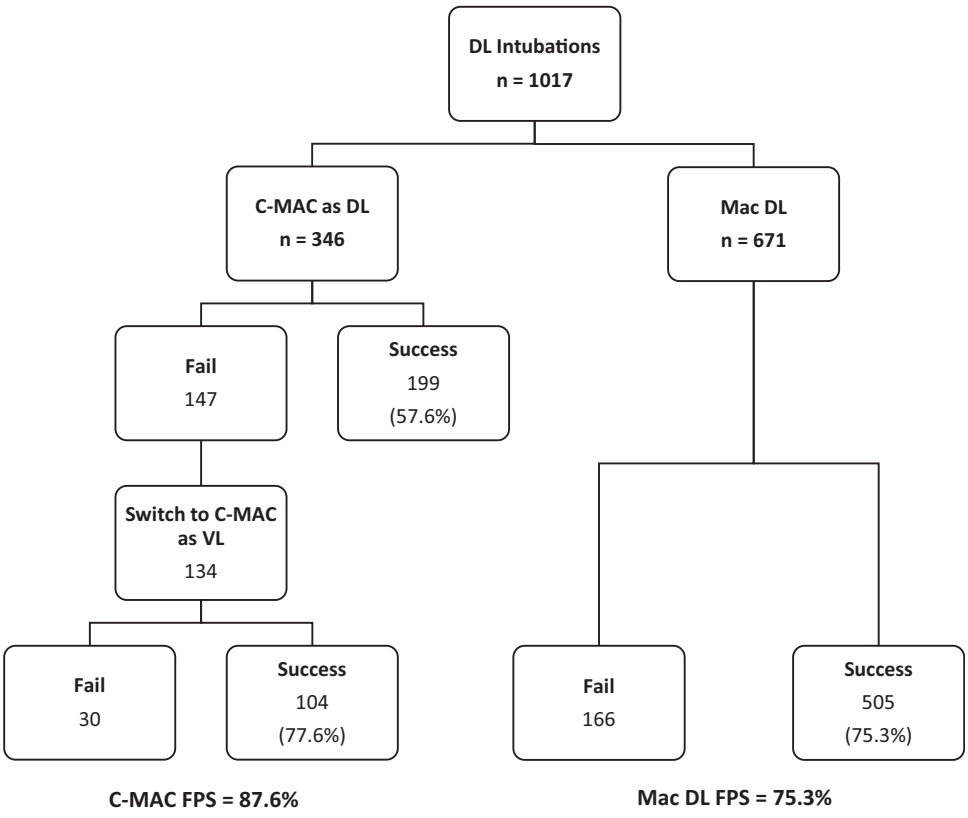

Figure 2. First attempt outcomes of C-MAC DL and Mac DL intubations. DL = direct laryngoscope; VL = video laryngoscope.

or IV was obtained using the C-MAC as a DL, the CL view obtained on the external video monitor for the C-MAC improved to a CL view of I or II in 71 of 76 (93.4%; 95% CI 85.3–97.8%) cases. See Figure 3 for details.

In the C-MAC group, the incidence of hypoxemia in the FPS cohort was 28 of 303 (9.2%; 95% CI 6.2–13.1%) and in the Mac DL group was 48 of 505 (9.5%; 95% CI 7.1–12.4%). The overall incidence of hypoxemia in the patients in which the C-MAC was used initially as a DL was 48 of 346 (13.9%; 95% CI 10.4–18.0%) and in the Mac DL group was 111 of 671 (16.5%; 95% CI 13.8–19.6%).

Table 2. Multivariate Regression Analysis for First Pass Success

Variable	Odds Ratio	95% CI	*p* Value
Device			
Mac DL	(Reference)		
C-MAC	2.9	1.9–4.6	<0.001
NMBA			
Rocuronium or vecuronium	(Reference)		
Succinylcholine	1.2	0.8–1.6	0.398
Sedative			
Non-etomidate	(Reference)		
Etomidate	0.8	0.4–1.4	0.379
No. of anatomic DACs	0.7	0.6–0.8	<0.001
Medical/trauma			
Medical	(Reference)		
Trauma	1.2	0.8–1.7	0.395
Reason for device			
Standard	(Reference)		
Difficult	0.7	0.4–1.3	0.267
Education	0.9	0.5–1.5	0.576
Operator PGY			
1	(Reference)		
2	1.5	1.0–2.2	0.045
3 or more	1.9	1.3–2.9	0.003

CI = confidence interval; DAC = difficult airway characteristic; DL = direct laryngoscope; PGY = postgraduate year; NMBA = neuromuscular blocking agent.

DISCUSSION

Although DL is the most common method of airway control in the ED, VL use is rapidly increasing (1). The

Table 3. Cormack-Lehane View in the C-MAC and Mac DL Groups

CL View as DL	C-MAC as DL, n (%) (n = 328)	Mac DL, n (%) (n = 671)	% Difference (95% CI)
CL I	149 (45.4)	316 (47.1)	−1.7 (−8.2 to 4.9)
CL II	98 (29.9)	231 (34.4)	−4.5 (−10.7 to 1.6)
CL III	66 (20.1)	100 (14.9)	5.2 (0.1 to 10.3)
CL IV	15 (4.6)	24 (3.6)	1.0 (−1.7 to 3.7)

CL = Cormack-Lehane; DL = direct laryngoscope.

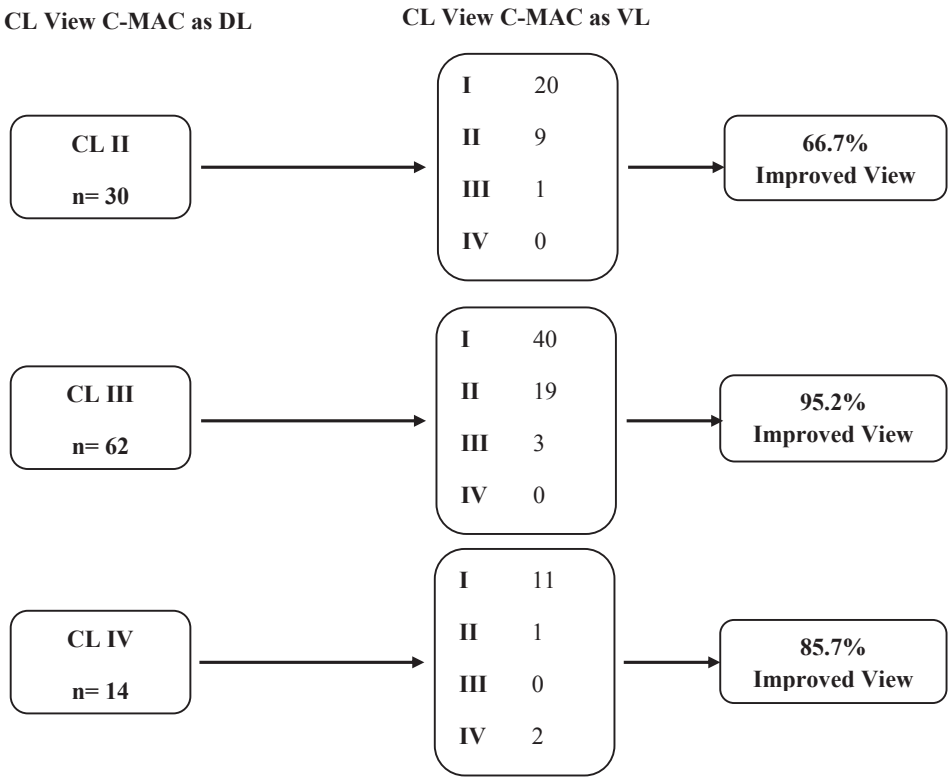

Figure 3. Cormack-Lehane (CL) view changes in the C-MAC DL to VL switch group. DL = direct laryngoscope; VL = video laryngoscope.

appropriate primary device for intubation remains a controversial topic. Some authors have encouraged movement toward VL as the primary intubation device due to their demonstrated superior performance, while others have expressed concern that this approach may result in the erosion of operators' DL skills (2,4,8,9,15,21–23,26). Because the C-MAC is a combination DL/VL device, it is perfectly positioned to address this dilemma. Operators can use the C-MAC as a DL initially and, if unsuccessful, can easily transition to VL by utilizing the video monitor.

In this study, we found that when the C-MAC was used initially as a DL it was successful 58% of the time, whereas the conventional Mac DL was successful 75% of the time. Although the FPS using C-MAC as a DL is somewhat lower than that of the Mac DL, when operators experienced difficulty they were able to make a mid-intubation switch to VL, enabling them to achieve a higher overall FPS (88%) than when using the Mac DL. This improvement in FPS was seen even though the C-MAC was more commonly used in patients with suspected difficult airways and by operators with less training. To account for these confounders, we performed a multivariate regression analysis that demonstrated that use of the C-MAC was associated with an almost 3-fold increase in the likelihood of FPS compared to the Mac DL. This improvement in FPS is important, as previous studies have demonstrated a significant increase in adverse events, after even a single failed first attempt during emergent intubation (31).

It is interesting to note that the CL view achieved when using the C-MAC as a DL was fairly similar to that of the Mac DL. Thus it appears that despite comparable CL views, the success of the C-MAC as a DL was still lower than that of the Mac DL. The most likely explanation for this is that operators using the C-MAC as a DL had a very low threshold for switching to VL if any difficulties were encountered during the DL attempt, even if the CL view was good. It is also possible that even though the C-MAC provided good CL views, the presence of the videocamera on the undersurface of the C-MAC blade might have made tube delivery more difficult compared to a conventional Mac DL. It is also notable that when a poor CL view (CL III or IV) was obtained using the C-MAC as a DL, operators who switched to using the C-MAC as a VL obtained a good CL view (CL I or II) in the vast majority of patients (93%).

The improvement in CL view that we observed when converting from C-MAC as a DL to C-MAC as a VL is

consistent with results from previous studies on the C-MAC. Piepho et al. studied the change in CL views when switching to a C-MAC for patients in the operating room with unexpected CL III or IV views using a Mac DL (32). The use of a C-MAC as a VL resulted in an improvement of the CL view in 94% of patients and the majority of patients (32 of 49) improved by two full grades. A study by Brown et al. in the ED evaluated the change in CL views when using the V-MAC (a precursor to the C-MAC) as a DL device vs. a VL device (33). In this study, 78% of patients that had a CL III or IV view by direct vision had an improved view with video laryngoscopy. Finally, a prehospital study by Hossfeld et al. compared the CL views when the C-MAC PM (Pocket Monitor) was used as a DL and as a VL (34). In patients with a CL view of III or IV using the C-MAC PM as a DL, 94% improved by at least one grade when the C-MAC PM was used as a VL. These studies, which have similar findings to ours, demonstrate that when a poor CL view is achieved by direct vision, switching to an indirect view by using a video monitor results in an improved view in the vast majority of patients.

Previous literature has also shown that the C-MAC is a very effective rescue device after a failed DL attempt. In a study by Kilicaslan et al., 42 patients with an unexpected failed DL attempt in the operating room underwent the next intubation attempt with the C-MAC (35). The C-MAC was successful on the first rescue attempt in 36 of 42 (86%) cases and ultimately successful in 100% of cases. In a study by Sakles et al., the C-MAC was compared to a conventional Mac DL for the rescue of failed first intubation attempts in the ED (36). When the C-MAC was used for the second attempt after a failed DL attempt it was successful in 78% of cases. Thus, given the C-MACs proven success as a rescue device for failed DL intubations, it seems that the C-MAC is an ideal primary device for DL intubation in that it allows operators to perform DL with the added safety of VL backup.

It can be argued that one should use a conventional Mac DL for routine airways and only consider using a C-MAC as a DL for potentially difficult airways when they are more likely to need VL backup. However, previous studies have demonstrated that our ability to predict a difficult airway in the clinical setting is very poor. In a study of > 180,000 intubations by anesthesiologists in the operating room, Norskov et al. found that of 3,391 difficult intubations, 93% were unanticipated (37). Furthermore, studies have shown that the ability to perform a difficult airway assessment on critically ill patients is very limited and, in the vast majority of patients, cannot even be performed (38,39). Thus, given the difficulty in being able to accurately predict a difficult airway, it seems that the most prudent strategy would be to use the C-MAC as a primary device for DL intubation so that VL backup is readily available in the event that an unanticipated difficult airway is encountered.

A legitimate concern for using the C-MAC as a DL is that there may be an unexpectedly high incidence of hypoxemia during the attempt, as the operator may be taking "two attempts" on a single pass, one as a DL and one as a VL. Consequently, one may have an improved FPS at the expense of an increased incidence of hypoxemia. Based on our results, this did not appear to be the case, as the incidence of hypoxemia in the C-MAC and Mac DL groups was very similar (C-MAC 9.2% vs. Mac DL 9.5%). This is likely due to the fact that when the operators attempted DL with the C-MAC and were not immediately successful, they rapidly switched to using the C-MAC as a VL. We believe that this is the appropriate and safest course of action for the patient, as opposed to persisting with a failing DL attempt and risking the development of hypoxemia.

Limitations

This was a single-institution study at an academic medical center and thus the results may not generalize to other institutions. In particular, this institution has been using video laryngoscopy for over 15 years and the majority of intubations in the ED are now performed with a VL. Therefore, these results may not be applicable to institutions that are not as experienced with VL. Although the data were prospectively collected after the intubation, it is based on the recall and accuracy of the operator performing the intubation and is, therefore, potentially subject to error. Also, the patients in the C-MAC as a DL and the Mac DL groups were not randomized and thus there exists the potential for selection bias. However, to account for this, we performed a multivariate regression analysis that incorporated many of the likely confounders, such as DACs and PGY level of the operator. Nonetheless, there may be unidentified confounders that can impact the results. Finally, because we only studied the C-MAC, the generalizability of these findings may not be applicable to other Macintosh-style VLs, such as the McGRATH MAC (Covidien, Minneapolis, MN) and the GlideScope Titanium MAC (Verathon, Bothell, WA).

CONCLUSIONS

In summary, the results of this study indicate the C-MAC is a useful device for direct laryngoscopy in the ED. It provides operators with DL experience, but has the added benefit of allowing quick and easy transition to VL if the DL attempt proves difficult or impossible. The improvement in first pass success when using the C-MAC can potentially improve patient care by minimizing

the number of intubation attempts, thereby reducing the occurrence of adverse events. We recommend using the C-MAC as a DL preferentially over a conventional Macintosh direct laryngoscope for ED intubations.

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ARTICLE SUMMARY

1. Why is this topic important?

The ability to easily switch from direct laryngoscope (DL) to video laryngoscope (VL) may be useful clinically, as it can help to decrease the number of intubation attempts, which has been shown in multiple studies to be strongly associated with an increase in adverse events.

2. What does this study attempt to show?

This study attempts to show that the use of a video-enabled device, such as the C-MAC, for direct laryngoscopy increases patient safety by improving first pass success, while still providing operators with valuable DL experience.

3. What are the key findings?

When using the C-MAC initially as a DL an overall first pass success (FPS) of 303 of 346 (87.6%; 95% confidence interval [CI] 83.6–90.9%) was achieved. When the Mac DL was used the FPS was 505 of 671 (75.3%; 95% CI 71.8–78.5%). In the multivariate regression analysis, the use of a C-MAC was associated with an increase in FPS compared to the Mac DL (adjusted OR = 2.9; 95% CI 1.9–4.6).

4. How is patient care impacted?

The C-MAC provides operators with DL experience but has the added benefit of allowing quick and easy transition to VL if the DL attempt proves difficult or impossible. The improvement in FPS when using the C-MAC can potentially improve patient care by minimizing the number of intubation attempts, thereby reducing the occurrence of adverse events.