Video-guided Versus Direct Laryngoscopy: Considerations For Using Simulation To Teach Inexperienced Medical Students

Hannes Prescher¹, David E. Biffar², Laura E. Meinke³, John E. Jarred², Aubrey J. Brooks⁴, Allan J. Hamilton¹²

¹Department of Surgery, University of Arizona, Tucson, Arizona, ²Arizona Simulation Technology & Education Center, University of Arizona, Tucson, Arizona, ³Department of Medicine, University of Arizona, Tucson Arizona, ⁴Department of Psychology, University of Arizona, Tucson, Arizona

hprescher@email.arizona.edu, dbiffar@surgery.arizona.edu, lmeinke@deptofmed.arizona.edu, jjarred@surgery.arizona.edu, brooksaj@email.arizona.edu, allan@surgery.arizona.edu

Keywords airway management training, autonomous learning, direct laryngoscopy, endotracheal intubation, video-guided laryngoscopy

Abstract
The goal of this study was to determine whether video laryngoscopy (VL) provides any advantage over direct laryngoscopy (DL) in first-attempt intubations. This was a controlled, randomized study of 120 medical students. Students were randomly assigned to either of 2 intubation groups, which used (1) DL (n=64) or (2) VL (n=56) with the Karl Storz C-MAC® video laryngoscope. Each student attempted 1 endotracheal intubation on a Laerdal® Airway Management Trainer. The primary outcome measure was the time for successful endotracheal intubation. Secondary outcome measures included the incidence of esophageal intubation (EI), excess application of pressure on the maxillary incisor teeth (EMP), and first-time success rate. Mean time for endotracheal intubation was significantly faster in the VL group than in the DL group (101 ± 83 seconds vs. 180 ± 102.5 seconds; P˂0.001). In the VL group, 3.6% of the students committed an EI versus 56.3% in the DL group (P˂0.001). No significant difference was found in the incidence of EMP: 51.8% in the VL group versus 57.8% in the DL group (P=0.508). For medical students with little or no endotracheal intubation experience, VL facilitates success and decreases the number of EIs, at least in a simulated environment.

1. INTRODUCTION
Intubation with an endotracheal tube (ETT) is the standard procedure used to secure the airway and ensure ventilation in advanced airway management. Complications associated with endotracheal intubation, however, remain a leading cause of anesthetic morbidity and mortality [1-3].

Direct laryngoscopy (DL), the traditional standard for intubation, poses a number of challenges to the practitioner performing the procedure. In particular, it requires direct line-of-sight (LOS) visualization and alignment of the oral pharyngeal and laryngeal structures to visualize the vocal cords, which can be obstructed by anatomic obstacles [4]. Direct LOS is important in DL to prevent tissue trauma and inadvertent esophageal intubation, which can delay the delivery of necessary medical care. But given the position of the glottic structures, DL intubation requires extended training, practice, and experience to master. Further, the challenge of obtaining direct visualization can make it a difficult technique to teach to novice medical trainees.

Video-guided laryngoscopy (VL) is an alternative intubation method that facilitates visualization of the vocal cords [4-8]. With VL, a fiberoptic camera is placed on the distal undersurface of the blade along with the light source and projects the image onto a video screen, enabling easy viewing of the glottic inlet and better validation of the correct placement of the ETT. Several studies have shown that VL provides a superior view of the larynx [4-8], yet it has not consistently been associated with faster intubation times or with enhanced overall intubation success rates [4, 6-9].

Previous studies comparing DL and VL have primarily been conducted with experienced practitioners in a clinical environment [5-9]. But the clinical environment introduces confounding variables, such as a considerable training effect of practitioners and variable patient anatomy. Few
studies have used inexperienced medical trainees to determine the effectiveness of VL and DL as training tools.

In our study, we created a more rigidly objective way to compare the C-MAC® (Karl Storz Endoscopy-America, Inc., El Segundo, CA) video laryngoscope with the traditional Macintosh laryngoscope. Our purpose was to identify which aspect of the intubation procedure posed the greatest challenge to medical students with little or no intubation experience, and to determine whether or not VL provides any advantage over DL in first intubation attempts.

2. MATERIALS AND METHODS

2.1 Study Design
This was a randomized, controlled study of 120 medical students. This project was conducted under the supervision of, and in compliance with the regulations of the University of Arizona Institutional Review Board.

2.2 Study Setting and Population
This study was conducted in an isolated room designated for research at the Arizona Simulation Technology and Education Center at the University of Arizona, College of Medicine. The simulation center is used by the College of Medicine to teach clinical skills to medical students in preparation for third year clerkships. Medical students receive their first formal airway management training, which includes a stepwise demonstration and practice of endotracheal intubation with both DL and VL, during the third year internal medicine clerkship.

All 1st, 2nd and 3rd-year medical students (115 MS1; 115 MS2), and 3rd-year medical students who had not yet received the formal airway management training, qualified for inclusion in this study. A convenience sample of 120 medical students was selected (Table 1). Of these, 15 reported having performed an intubation procedure on a mannequin previously but without formal training and none in the last 6 months. The majority (88%) of students had performed none.

This level of inexperience was a prerequisite for participation.

2.3 Study Protocol
To evaluate the difference in efficacy between DL and VL, we randomly assigned 120 medical students to either of 2 intubation groups, which used (1) DL (n=64) or (2) VL (n=56).

Each participant watched a 5-minute instructional video on DL and VL that included an introduction to the equipment and demonstrated both a misplacement of the ETT in the esophagus and the correct placement in the trachea. Then, the students were each oriented on the Laerdal® Airway Demonstration Model so that they could visualize the correct anatomic landmarks and the ideal insertion path of the ETT. Finally, they were each oriented on the Laerdal® Airway Management Trainer. The orientation was given by an expert simulation technician with extensive clinical intubation experience. It was entirely didactic and did not include any trial runs by the participants.

After the training, each of the students attempted 1 endotracheal intubation on the Laerdal® Airway Management Trainer. They were timed from initiation of hand placement on the laryngoscope to successful intubation with a 7.0 ETT, as evidenced by visible lung excursion. If students performed an esophageal intubation, as indicated by inflation of the stomach pouch, this was counted as 1 EI and students were prompted to start again. We recorded only the first EI and not repeat EIs. A maximum time limit of 300 seconds (5 minutes) was set for all students. The trial was complete when the student either 1) successfully passed the ETT into the trachea or 2) the 300 second time limit was reached. Failure to achieve endotracheal intubation by that point was defined as an “unsuccessful” intubation trial.

The Laerdal® Airway Management Trainer gives an audible indication intended to signal tooth damage when pressure on the upper incisors exceeds a validated value. This clicking sound was recorded to indicate excess maxillary pressure by the laryngoscope blade. We recorded only the first EMP and not repeat errors.

To avoid introducing contaminating factors, our study had a research assistant help prepare the ETT and the stylet, inflate the ETT cuff after intubation, and begin mechanical ventilation with an Ambu® bag valve mask. This was to ensure that the intubation time reflected only the participant’s ability to obtain proper visualization and to pass the ETT, the two pivotal steps of the intubation procedure [4]. The research assistant was a simulation technician who was specifically trained to perform these tasks and in no other way interfered with the performance of the

Table 1 Student Characteristics

<table>
<thead>
<tr>
<th></th>
<th>DL</th>
<th>VL</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS1</td>
<td>21</td>
<td>16</td>
<td>37</td>
</tr>
<tr>
<td>MS2</td>
<td>39</td>
<td>35</td>
<td>74</td>
</tr>
<tr>
<td>MS3</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>64</td>
<td>56</td>
<td>120</td>
</tr>
</tbody>
</table>

DL: direct laryngoscopy; VL: C-MAC video-guided laryngoscopy
MS1, 1st-year medical students; MS2, 2nd-year medical students
MS3, 3rd-year medical students
subject. No faculty was used in order to eliminate evaluator bias.

2.4 Key Outcome Measures
To assess our primary objective, instrument efficacy, we measured the time for successful endotracheal intubation. Our secondary outcome measures evaluated the quality of the intubation procedure and included the number of students who committed at least 1 esophageal intubation, and the number of students who applied excess pressure on the maxillary incisor teeth. We also determined the overall endotracheal intubation success rate of the 2 groups.

2.5 Data Analysis
We conducted chi-square analyses using SAS software to determine whether students in the DL group or the VL group were more likely to exceed the 300-second time limit (i.e., to time out). A non-paired t-test was conducted to compare the two methods on the total time to complete the procedure (in seconds). For the purpose of mean time calculations, students that failed to complete the intubation by the time limit were recorded with an intubation time of 300 seconds. Chi-square analyses were also conducted to calculate the likelihood of an esophageal intubation and of excess maxillary pressure application in the two groups. Significance was set as $P<0.001$.

3. RESULTS
Statistically significant differences existed between the DL and VL groups for 3 out of the 4 outcomes measured: time to intubation, incidence of EI, and success rate. Data are reported as mean ± STDEV.

3.1 Time for Complete Intubation
Students in the VL group intubated significantly faster, with a mean time of 101 ± 83 seconds, than students in the DL group, whose mean time was 180 ± 102.5 seconds ($t(117.3) = 4.47; P<0.001$) (Fig. 1).

3.2 Quality of Intubation
A significantly lower incidence of esophageal intubations (EI) occurred in the VL group (3.6%) than in the DL group (56.3%) ($\chi^2(1) = 38.3; P<0.001$) (Fig. 2). Of the 38 EIs, 36 (94.7%) occurred in the DL group. But we found no significant difference in the application of excess maxillary pressure (EMP): 51.8% in the VL group versus 57.8% in the DL group ($\chi^2(1) = 0.44; P=0.508$) (Fig. 2). Our overall comparison of the 2 types of intubation errors revealed a lower prevalence of EI (32%) than of EMP (55%).

3.3 Intubation Success Rate
In the VL group, 91.1% of students successfully completed their intubation within the set time limit of 300 seconds versus only 65.6% of students in the DL group ($\chi^2(1) = 11.09; P<0.001$). Of those students in the VL group who failed to complete their intubation, 20% committed at least 1 esophageal intubation but a full 100% applied excess maxillary pressure (Table 2). Comparatively, in the DL group, of those students who failed, 54.5% committed at least 1 esophageal intubation and 90.9% applied excess maxillary pressure.
Table 2 Intubation Success Rate, by Time and Errors

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Successful</th>
<th>Unsuccessful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>118 ± 67 s</td>
<td>300 s</td>
</tr>
<tr>
<td>EI</td>
<td>57%</td>
<td>54.5%</td>
</tr>
<tr>
<td>EMP</td>
<td>41%</td>
<td>90.9%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Successful</th>
<th>Unsuccessful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>81.9 ± 57.1 s</td>
<td>300 s</td>
</tr>
<tr>
<td>EI</td>
<td>1.9%</td>
<td>20%</td>
</tr>
<tr>
<td>EMP</td>
<td>47%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Notes:**
- DL: direct laryngoscopy; EI: esophageal intubation
- EMP: excess maxillary pressure; s: seconds;
- VL-CMAC: C-MAC video-guided laryngoscopy
- Data are mean ± STDEV

4. DISCUSSION

The findings of our study suggest that VL facilitates successful endotracheal intubation with inexperienced trainees. The higher success rate (91.1%, VL; 65.6%, DL) and shorter mean intubation time (101 ± 83 seconds, VL; 180 ± 102.5 seconds, DL) both support this conclusion.

Previous studies have shown that VL generally facilitates laryngeal exposure but does not necessarily improve delivery and advancement of the ETT. DL makes visualization more difficult, yet has proven to be more effective in ETT advancement once direct LOS is obtained. Platts-Mills et al. [9] showed, in a study of experienced practitioners, that completing an intubation with VL requires significantly more time.

However, in our study of inexperienced medical students, we found that the improved view of the laryngeal structures afforded by the camera feature of the C-MAC makes it a better tool in initial performance of the procedure, especially with respect to advancing the ETT. The incidence of esophageal intubations (EIs) in our study supports this finding: 94% of them occurred in the DL group. Note that we recorded only the first EI and not repeat EIs.

Using experienced anesthesiologists, Lee et al. demonstrate that significantly less force is applied to maxillary incisor teeth with VL compared with a standard DL Macintosh blade [10]. We did not find this to be the case with novice medical students. Both our DL and VL groups experienced substantial difficulties with handling the laryngoscope blade. The prevalence of the EMP error (51.8%, VL-C-MAC; 57.8%, DL) confirms this technical difficulty. However, VL reduces the need for reinsertion or for repeated manipulations, due to faster visualization of the relevant anatomy and successful passing of the ETT on the first attempt [5, 8].

Our study may have important implications for airway management training. Several studies have shown that VL can facilitate the training of novice students [11-14]. Low et al., in a study of novice learners, demonstrate that training with a video laryngoscope improves intubation performance and increases confidence compared to a standard Macintosh laryngoscope under simulated difficult airway conditions [15]. Our study confirms these results even under normal airway conditions. Even though VL has gained popularity as an educational tool in medical education programs, DL remains the preferred and initial intubation tool introduced to novice trainees. This may not be the most efficient use of students' training time.

Ti et al. demonstrate that experiential learning, in which trainees work independently through trial and error, improves skill acquisition of endotracheal intubation in a simulated environment [16]. Our results seem to support this conclusion and suggest that VL can facilitate experiential learning compared to DL. The students in our study received only a brief instructional video on intubation and were unguided during the procedure. Despite this, in the VL group, only 1.9% of students committed an EI and students had a success rate of 91.1% on first-attempt intubations. In contrast, in the DL group 56.3% of students committed an EI with a success rate of only 65.6. Plummer and Owen [17] show that first-time success has an important impact on learning. Using novice trainees on an airway mannequin, they were able to demonstrate that a novice trainee learns as much from 1 successful endotracheal intubation as from 12 failed trials.

Therefore, initial intubation training should be conducted using video laryngoscopy. When used with instructor guidance, the C-MAC provides a clear visual field to both the trainee and the instructor similar to the direct LOS visualization obtained by an experienced practitioner [18]. It enables the instructor to facilitate proper and timely identification of the anatomy, to guide the trainee toward the trachea, and to reduce the time needed for a successful intubation [4, 6]. In a large class of medical students, this could help the instructor provide individual guidance before allowing students to practice on their own.

It appears that starting an airway management training program with an introduction to VL might shorten the learning curve for mastering this fundamental skill [12, 19, 20]. Mulcaster et al. [21] defined the learning curve with DL and discovered that 47 attempts are required to achieve a 90% probability of a "good intubation." Further research is needed to determine the comparative learning curve with VL. Several studies have suggested that the improved coordination between the instructor and the
trainee afforded by the video monitor of the C-MAC shortens the learning curve [22, 23].

A particular benefit of the C-MAC tested in our study is that it uses the same Macintosh blade that DL uses [24]. This similarity suggests that skills acquired from VL could be transferrable to DL. However, it remains to be seen whether the initial favorable intubation success rate with VL translates into faster mastery of DL.

4.1 Limitations

There is an inherent limitation in using an airway mannequin in this study. Schebesta et al. report that the anatomy of airway trainers does not reflect the upper airway anatomy of actual patients and therefore undermines teaching of proper technique [24]. While some studies have shown that intubation skills learned on a simulator do not transfer to the clinical setting [25], Stratton et al. demonstrate that these skills do translate into successful endotracheal intubations in patients [26]. For the purpose of this study, the mannequin provided a standard platform allowed us to objectively compare the two instruments and to assess the initial intubation experience of novice learners. For patient safety reasons, this would not have been possible in a clinical setting.

In this study, we set a 300 second time limit for the endotracheal intubation attempt. This time was used for our mean time calculations. Given the high percentage of unsuccessful intubation attempts in the DL group (34.4%), the mean time would have been higher had we allowed each student to continue until a successful intubation had been completed. Nonetheless, we were able to demonstrate statistical significance in the mean time difference between the DL and VL groups. In addition, counting repeat errors of EMP may have demonstrated a statistically significant difference between the groups. In the future, doing a prospective cross-over study with DL and VL including learner perspective with preference feedback and self-perceived skill levels on each tool could provide further insight into the efficacy of both instruments as educational tools.

5. CONCLUSIONS

In conclusion, the higher success rate and lower incidence of intubation errors with C-MAC-guided video laryngoscopy in first-time intubation attempts with inexperienced medical students may warrant an increased allocation of resources toward VL as an educational tool. Moreover, it may be easier for trainees to learn the DL intubation after they are initially introduced to VL.

ACKNOWLEDGMENT

This work was sponsored by an unrestricted educational grant by Karl Storz Endoscopy America Inc. to the University of Arizona and was completed at the Arizona Simulation Technology and Education Center (ASTEC), University of Arizona, Tucson, AZ, USA.

References


Intubation in the Emergency Department,” Academic Emergency Medicine, 16, no.9, 866-871.


