Original contribution

Comparison of direct and video-assisted views of the larynx during routine intubation

Marshal B. Kaplan MDa, Carin A. Hagberg MD∗b, *, Denham S. Ward MD, PhDc, Ansgar Brambrink MDb, Ashwani K. Chhibber MDb, Thomas Heidegger MDe, Leonardo Lozada MDf, Andranik Ovassapian MDg, David Parsons MDh, James Ramsay MDi, Wolfram Wilhelm MDj, Bernhard Zwissler MDk, Haus J. Gerig MDc, Christian Hofstetter MDk, Suzanne Karan MDb, Nevin Kreisler MDi, Robert M. Pousman MDi, Andreas Thierbach MDb, Marc Wrobel MDj, George Berci MDm

aDepartment of Anesthesiology, UCLA and Cedars-Sinai Medical Center, Los Angeles, CA 90095, USA
bDepartment of Anesthesiology, The University of Texas at Houston Medical School, Houston, TX 77030, USA
cDepartment of Anesthesiology, University of Rochester School of Medicine and Dentistry, Rochester, NY 14642, USA
dDepartment of Anesthesiology and Peri-Operative Medication, Oregon Health & Science University, Portland, OR 97239, USA
eDepartment of Anesthesiology, Cantonal Hospital, St Gallen, Switzerland
fDepartment of Anesthesia, Eastern Maine Medical Center, Bangor, ME 04401, USA
gDepartment of Anesthesia and Critical Care, University of Chicago Medical Center, Chicago, IL 60637, USA
hDepartment of Anesthesiology, Vancouver General Hospital, Vancouver, BC, Canada
iDepartment of Anesthesiology, Emory University Hospital, Atlanta, GA, USA
jDepartment of Anesthesiology and Intensive Care Medicine, University of Saarland, Hamburg, Germany
kDepartment of Anesthesiology, Johann-Wolfgang-Goethe Universitat, Frankfurt, Germany
lDepartment of Anesthesiology, UCLA, Los Angeles, CA 90095, USA
mDepartment of Surgery, University of Southern California and Cedars-Sinai Medical Center, Los Angeles, CA 90048, USA

Received 17 May 2004; accepted 11 January 2006

Abstract

Objective: To compare the direct and indirect (video monitor) views of the glottic opening using a new Macintosh blade that is modified to provide a video image of airway structures during laryngoscopy.

Design: Prospective multicenter trial.

Setting: 11 university-affiliated hospitals.

Patients: 867 adults undergoing elective surgery requiring general anesthesia and tracheal intubation.

Interventions: Patients received general anesthesia and were paralyzed. Direct laryngoscopy was supervised by one of the investigators at each institution. The best possible view was obtained with a...
Macintosh video laryngoscope during direct vision using standard techniques such as external laryngeal manipulation and backward, upward, and rightward pressure, if necessary. The laryngoscopist then looked at the video monitor and performed any necessary maneuvers to obtain the best view on the video monitor. Thus, 2 assessments were made during the same laryngoscopy (direct naked-eye view vs video monitor view). Tracheal intubation was then performed using the monitor view. Glottic views were rated according to the Cormack-Lehane scoring system, as modified by Yentis and Lee. A questionnaire was completed for each patient.

**Measurments and Main Results:** Data from 865 patients were suitable for analysis. Visualization was considered easy (Cormack-Lehane score < 3) in 737 patients and difficult (Cormack-Lehane score = 3 or 4) in 21 for both direct and video-assisted views. In 7 patients, the view was considered easy during direct visualization yet difficult on the video monitor view. On the other hand, the view was considered difficult in 100 patients during direct visualization yet easy on the video monitor view ($P < 0.001$).

**Conclusions:** Video-assisted laryngoscopy provides an improved view of the larynx, as compared with direct visualization. This technique may be useful for cases of difficult intubation and reintubation as well as for teaching laryngoscopy and intubation.

© 2006 Elsevier Inc. All rights reserved.

1. Introduction

In 1895, Kirstein modified an esophagoscope to directly view the vocal cords and called it an autooscope [1]. Once anesthesiologists adopted tracheal intubation, many variations of the laryngoscope followed, including the Macintosh and Miller laryngoscope blades, resulting in claims of improved views of the glottis, thus facilitating tracheal intubation [2]. More specialized designs such as indirect rigid laryngoscopes have been introduced into clinical practice [3-6] because patients continue to present with difficult airways and even relatively minor changes in the design of the blade may improve glottic visualization [7].

Laryngoscopes are traditionally powered by a battery in the handle and include an electric bulb at the distal portion of the blade. Recent designs to improve reliability and increase illumination place the bulb in the handle, with illumination transmitted to the distal blade tip via a fiberoptic light guide [2]. Generally, power is supplied from batteries located in the laryngoscope handle, although use of a separate power supply has been described [8]. Studies have shown that, in general, better illumination is supplied by distal bulbs, not fiberoptic blades [9,10]. Bulbs on blades also tend to supply a larger area of illumination; however, illumination supplied by different manufacturers’ versions of the same blade varies over a wide range [9]. Thus, anesthesiologists continue to experience poor visibility during laryngoscopy and intubation.

Video technology (a system based on an optical relay coupled to a small but efficient television camera) has had enormous impact on endoscopic surgery. Many surgical procedures require assistance and coordinated movements; in addition, by viewing these procedures on a video monitor, coordination among several individuals may be achieved.

We have previously reported on the use of such a system in the instruction of intubation [11] because this technology may provide an improved view of the glottic structures and permit others to visualize the intubation. This multicenter prospective study seeks to determine if coupling video technology to a conventional laryngoscope will improve an experienced laryngoscopist’s view of the glottis during routine intubation. Subsets of these data have been previously reported [12,13].

2. Materials and methods

The Macintosh video laryngoscope (MVL) was developed and manufactured by Karl Storz Endoscopy by modifying a conventional laryngoscope handle to house a small color video camera (Micro Video Module, MVM, Karl Storz Endoscopy, Culver City, Calif) [11]. A short fiber image/light bundle exits from this handle and is inserted into a guide tube, recessed 40 mm from the tip of a Macintosh blade (Fig. 1), to avoid interference during advancement of the endotracheal tube (ET). A fiber light cord and a television cable exit the other end of the handle and are connected to a light source and the camera control unit. Digital signal processing is used in the control unit to enhance the image. The blade is interchangeable and autoclavable; the handle with the fiber bundle can be immersed or gas sterilized. In this study, MVL 3 or 4 blade (equivalent to a conventional Macintosh 3 and 4) was used for all intubations.

All investigators were experienced in the performance of conventional direct laryngoscopy and trained in the use of the MVL by a representative of Karl Storz Endoscopy in a table-top mannequin and performed 5 to 10 intubations in patients before the inception of this study. Investigators at the 11 participating medical centers secured institutional review board approval from their local ethics committee, and written informed consent was obtained from all patients. This study included 867 adult patients undergoing elective surgery in whom tracheal intubation was indicated. All patients received general anesthesia and were paralyzed.
The participating centers were allowed latitude in the anesthetic induction method and choice of muscle relaxant to accommodate the typical practice at a variety of institutions in the United States and Europe. Patients were placed in a sniffing position and laryngoscopy was attempted once there were 0 twitches on a train of 4 using a peripheral nerve stimulator or when clinically indicated. Patients who met enrollment criteria were those aged 18 years or older scheduled to receive general anesthesia for an elective surgical procedure. Exclusion criteria included the following: being younger than 18 years; emergency surgery; major pathology of the neck, upper respiratory or alimentary tracts; or risk of pulmonary aspiration of gastric contents. Patient enrollment was not randomized and several centers specifically selected patients who had a higher likelihood of a difficult laryngoscopy (eg, Mallampati class 2 or 3) for inclusion into the study. A data sheet in the form of a questionnaire was provided for the uniform recording of data at each center.

The view of the glottis was rated using 5 grades according to the Cormack-Lehane [14] scoring system as modified by Yentis and Lee [15]: 1 = full view of the glottis; 2a = partial view of the glottis; 2b = arytenoids or posterior portion of cords only visible; 3 = only the epiglottis visible; 4 = neither epiglottis nor glottis visible. Direct laryngoscopy was performed with the naked eye (direct view), and the best view obtained (with optimal laryngeal manipulation, if necessary) was graded by the laryngoscopist without looking at the video monitor. The view on the video monitor, located in front of the intubator and to the right of the patient, was then immediately graded. There was no standardization regarding the nature of the manipulations required to improve the views. Subjective assessments regarding the views obtained with the MVL were made, comparing these views with the traditional Macintosh laryngoscope blade views (better, same, or worse). These included such factors as fogging or obstruction of the video monitor with secretions or blood. Difficult laryngoscopy was defined as the inability to visualize the vocal cords, which included grades 3 and 4.

All data were collected on standardized forms. Statistical analysis was performed using the STATA statistical package (STATA Corporation, College Station, Tex). A P value <0.05 was considered significant. The specific statistical tests used are discussed in the following section.

3. Results

In total, 867 patients with American Society of Anesthesiologists physical status I, II, III, or IV (51% were men) who ranged in age as: younger than 40 (23%) years, between 40 and 60 (41%) years, and older than 60 (35%) years were enrolled in this study at the 11 participating hospitals, averaging 79 patients per hospital (range = 25–144). Two case patients were excluded because they did not meet enrollment criteria; 865 cases were used in the analysis. Unanticipated difficulties in intubation were reported in 5% of the study population.

Our goal was to compare the best view obtainable of the glottis under direct vision with the view obtained on the video monitor when using the MVL (Table 1). The view using the MVL was at least one grade better for 359 (41.5%) patients, was worse for 23 (2.7%) patients, and remained the same in 56% of the patients. The difference between the 2 distributions was significant (P < 0.001) as determined by the Stewart-Maxwell test for marginal homogeneity.

Views of the glottis were divided into easy (grades 1, 2a, or 2b) and difficult (grades 3 or 4), as indicated in Table 2. The difference between the 2 techniques was significant (P < 0.001) as determined by the McNemar exact test for symmetry (a test of paired proportions). A histogram of the difference (the difference between 2a and 2b was taken as one unit) between the 2 grades of view (direct vs video) monitor is shown in Fig. 1; positive numbers indicate an improved view.

Table 1 Comparison of modified Cormack-Lehane score between direct vision laryngoscopy and video-assisted laryngoscopy

<table>
<thead>
<tr>
<th>Video-assisted laryngoscopy</th>
<th>Direct vision laryngoscopy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2a</td>
</tr>
<tr>
<td>1</td>
<td>285</td>
<td>117</td>
</tr>
<tr>
<td>2a</td>
<td>11</td>
<td>133</td>
</tr>
<tr>
<td>2b</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>299</td>
<td>256</td>
</tr>
</tbody>
</table>

The difference between the 2 techniques is significant at P < 0.001.
with video-assisted laryngoscopy. The distribution of the histogram is highly asymmetrical, demonstrating an improved view with the video monitor. Although the 2 views remained the same in 56% of the patients, many of these patients (59%) had a grade 1 view and no further improvement was possible. One of the specific questions asked on the questionnaire, taking into account all factors, was whether the laryngoscopist’s view was better, the same, or worse with the video monitor. Respondents stated that 51% of the views were better, 46% were the same, and 3% were worse (most commonly a result of the lens fogging) in centers where a lens defogging solution was not used.

Logistic regression (robust estimation, clustered by patient) was used for the view (easy or difficult) to further investigate factors that could contribute to the differences between the 2 techniques, as compared with the method (direct or video assisted), American Society of Anesthesiologists physical status classification, age, sex, and hospital as independent factors. We determined that only the method was significant, with the odds ratio of an easy view being 4.8 (95% confidence interval = 3.4–7.0) with the MVL.

### Table 2: Comparison of easy (Cormack-Lehane score < 3) and difficult (Cormack-Lehane score = 3 or 4) views of the glottis between direct vision laryngoscopy and video-assisted laryngoscopy

<table>
<thead>
<tr>
<th>Video-assisted laryngoscopy</th>
<th>Direct vision laryngoscopy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Easy</td>
<td>Difficult</td>
</tr>
<tr>
<td>Easy</td>
<td>735</td>
<td>101</td>
</tr>
<tr>
<td>Difficult</td>
<td>7</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>742 (85.8)</td>
<td>123 (14.2)</td>
</tr>
</tbody>
</table>

The difference between the 2 techniques is significant at \( P < 0.001 \). Values in parentheses are expressed in percentage.

4. Discussion

Securing the airway and ensuring ventilation are the priorities in every case involving general anesthesia. When performing laryngoscopy, the first step is to determine whether visualization of the glottis is possible. If it is not, additional attempts should be made to improve the view. Although a large selection of laryngoscope blades is available, each offers a somewhat restricted view because of the width and profile of the blade. The fact that there are so many laryngoscope blade designs indicates that there is no single satisfactory design that provides optimal exposure of the glottis.

Commonly, the laryngoscopic view is grouped into easy (grades 1, 2a, and 2b) and difficult (grades 3 and 4), as in Table 2 [16]. Difficult laryngoscopy has been defined as the inability to visualize the vocal cords or as grades 3 and 4 using the modified Cormack-Lehane scoring system [14-18]. The reported incidence of difficult laryngoscopy in unselected patients is 3% to 13% [14,19-21]. In our study, the view of the glottis with direct laryngoscopy was graded as 3 or 4 in a higher percentage (14%), most likely because patients with potential for difficult laryngoscopy were preferentially entered into the study. In 83.5% of the patients in whom a difficult laryngoscopic view was obtained by direct vision, the monitor view provided better visualization and a grade 3 or 4 view was seen in only 28 (3.2%) patients.

The introduction of video techniques (well established in surgical endoscopic procedures) provides a magnified and wide-angle view as compared with direct vision [11,22-24]. The video monitor provides a better view of the glottic structures and the sometimes interfering glottic anomalies, all in one single viewing field. If external laryngeal manipulation is required, as seen in Fig. 2, then an assistant who also has a view of the glottis may be able to provide assistance more accurately.

Improved views of the glottis have also been achieved with another video laryngoscope, the Glidescope (Saturn Biomedical Systems, Burnaby, BC, Canada), which projects an image on an LCD screen [22,23,33]. Previously, the Glidescope was limited to a black-and-white monitor. Unlike the MVL, which has the same dimensions, curvature, and material as the traditional Macintosh laryngoscope, the Glidescope has a plastic blade that has been modified with a 60° bend at the midline. This can prevent anesthesiologists from being able to directly view the anatomical structures. In addition, the Glidescope has a camera lens embedded with an antifogging mechanism, whereas the MVL requires the application of a defogging solution. In addition, the MVL is an integral part of the DCI Video Intubation System, which is interchangeable with two straight blades (Miller 1 and 3), the Bonfils Retromolar Intubation Fiberscope and Flexible Fiberoptic (3 sizes), all manufactured by Karl Storz Endoscopy.

There are several possible reasons for the improved view with the video monitor. The positioning of the image fiber bundle tip close to the blade tip changes the viewpoint from
a straight line of sight, as required for conventional laryngoscopy (Fig. 3). Also, because the viewpoint is closer to the glottis, a wider view is transmitted to the video monitor. The same blade was used for the direct and the video-assisted view; thus, the physical design of the blade cannot be the reason for the difference in views. We used MVL 3 or 4 blade in all cases. It has the same height, width, and curvature as the traditional Macintosh no. 3 and 4 blade. The length does not create a problem because it is not always necessary to insert the entire blade into the mouth. However, occasionally, blade placement was cumbersome, particularly in obese patients with large chests or breasts, because the optical and electric cables emerged from the top of the handle. A shorter handle and lateral exit of the cables may eliminate this problem.

We have yet to fully investigate other blade designs (eg, Miller 1 or 3) with the fiberoptic bundle; however, because the fiberoptic bundle remains attached to the handle, other blade designs can easily be adapted to this video monitor system. Further work will be required to determine the best blade design for the video monitor system. The optimal blade design for the video system may differ from what is best for the performance of traditional laryngoscopy. However, it may be useful for the new blade design to afford a conventional direct view as a backup in case of video failure (electronic failure or blood/secretions on the lens) during laryngoscopy.

Our study does have several limitations. First and foremost, because this study is not blinded, there is substantial potential for observer bias. The use of multiple hospitals and investigators who have not had any role in the development of the video laryngoscope may help minimize such bias. Second, the anesthetic induction technique was not standardized and patients served as their own control regardless of anesthetic technique. Third, there was variation between centers in terms of patient selection. A separate study has since been performed investigating patients with known or expected difficult airways, a subgroup of this patient population. Fourth, we did not randomize the order in which the 2 techniques were performed. Laryngoscopy using traditional direct vision was always performed first, followed by video laryngoscopy. Nonetheless, an adequate depth of anesthesia and the degree of neuromuscular blockade were constant between the 2 techniques. Fifth, laryngoscopists were more experienced with one technique (laryngoscopy using direct vision vs the monitor view); thus, we may be underestimating the true superiority of the MVL.

Lastly, we did not assess the ease of tracheal intubation. Indeed, there are several definitions of a difficult intubation [25], and the study protocol did not specify the conditions under which an alternative method of intubation should be used. It is possible that even with the improved video monitor view, manipulation of the tip of the ET through the glottic opening could be difficult. Indeed, Cooper et al found that although laryngoscopy with the Glidescope resulted in a higher incidence of good or excellent laryngeal views compared with direct laryngoscopy, the intubation failure rate (3.7%) was higher than that in most studies of direct laryngoscopy.

However, in our study, the rate of unsuccessful intubation with the MVL using the monitor view (3 cases or 0.3%) is comparable with the rate of failed intubation in previous studies [20,26-32]. The direct views in these 3 cases were graded 2a, 3, and 4, with only the grade 3 view improving to 2b with the video monitor. In the patient with the 2a view on both direct and video laryngoscopy, it was impossible to get the tip of the tube anterior enough to pass through the glottis using either direct or video laryngoscopy. It may be easier to pass the ET with the MVL because it is shaped so similarly to the traditional Macintosh laryngoscope blade and there is more room to manipulate the ET (smaller profile than the Glidescope and less angle between the advancing ET and the axis of the larynx [33]).

The success rate with either device may improve with prior mannequin experience. The process of manipulating an ET while viewing the events and video monitor is unfamiliar to most. This may be aided by the use of a stylent with an appropriate curve, by various devices that permit movement of the tip of the tubes, or by the placement of a bougie. In all 3 of the cases (0.3%) in whom intubation was unsuccessful, a flexible fiberoptic bronchoscope was used to place the ET after failure of placement under direct or video-assisted vision. Thus, although this study demonstrates that video laryngoscopy improves the view of the glottic structures, it provides no evidence that the incidence of failed intubation is decreased. Further investigation is warranted with this device in patients with known difficult airways.
Acknowledgments

Karl Storz Endoscopy provided the video intubation equipment used for this study, which were made available to the study centers at reduced cost after the study.

We thank Fumihiko Fujita for helpful discussions, Ms Beverly DeRussy for data abstraction, and Dawn Iannucci for the preparation of this manuscript.

References