SBA
Sociedade Brasileira de Anestesiologia

Brazilian Journal of ANESTHESIOLOGY

ORIGINAL INVESTIGATION

The impact of introducing a videolaryngoscope in the initial training of laryngoscopy for undergraduate medical students: a simulation randomized trial

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Received 22 May 2020; accepted 26 February 2021
Available online 3 April 2021

KEYWORDS
Airway management;
Intubation;
Intratracheal;
Medical students;
Mannequins;
Laryngoscopy

Abstract
Introduction: Adequate and continuous airway management by health professionals is fundamental to ensure patient safety and protection. Among several techniques, laryngoscopy for orotracheal intubation is considered a basic skill, so it is taught and learned in medical school and used during the future years of professional practice. However, in some clinical scenarios, physical and anatomical characteristics can make laryngoscopy exceedingly difficult. In the last decade, some new devices have emerged to apply indirect or video-assisted imaging systems, so-called videolaryngoscopes. They have shown great efficiency in difficult intubation cases and have improved teaching and training. Our study introduced a videolaryngoscope, the McGrath™ MAC, in the regular laryngoscopy training rotation for 3rd-year undergraduate medical students and evaluated whether there was any associated optimization of the students' performance.
Method: Students from two different classes and years (2017 and 2018) were randomly divided into two groups and received theoretical and practical training in the techniques of Direct Laryngoscopy (DL) and Videolaryngoscopy (VL). The students in each group applied the manoeuvres and simulated three tracheal intubation attempts on mannequins. They were evaluated for their success rate on the first attempt, the time required to finalize the intubation, and the visualization of the glottic structures according to the classification of Cormack-Lehane (C&L).

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https://doi.org/10.1016/j.bjane.2021.02.048

Results: Two hundred and four students with an average age of 21 ± 2 years participated in the study; the groups were similar. There was a significant difference between the VL and DL groups in the 1st attempt success rate (97% and 89.4%, respectively, $p = 0.0497$ − 95% CI), but such a difference was not seen for the other attempts or regarding the number of oesophageal intubations (3% and 7.7%). The students in the VL group were faster than those in the DL group in all intubation attempts; in parallel, the vast majority of the VL group reported excellent visualization conditions, with 75% of the attempts classified as Cormack-Lehane grade 1.
Conclusion: The introduction of a videolaryngoscope in medical students' training improved the visualization of anatomical structures and allowed tracheal intubation maneuvers to be performed faster and with a higher success rate on the first attempt. Thus, under the conditions of this prospective study, the videolaryngoscope had a positive impact on training and proved to be a promising tool for teaching laryngoscopy.

Introduction

Adequate management and continuous control of the airway by health professionals are essential for ensuring the safety and protection of patients. The main control techniques and maneuvers are taught early in the medical undergraduate phase and are used regularly during the subsequent years of professional practice. They are considered basic skills for medical practice. However, even with knowledge and training, unexpected difficulties often arise, and airway management can present itself as a major challenge to medical teams, especially in emergency cases. Unfortunately, these difficulties can cause airway trauma and injuries that are highlighted by studies that have analyzed court lawsuits related to medical complications (closed claims analysis).[1−3] The damage can vary over a wide spectrum of severities, from mild mucous membrane or tissue lesions and dental fractures to very severe lesions in the cardiac and cerebral tissues caused by hypoxia.[1−3] An important British study, the NAP4 (National Audit Project 4),[4] found the same scenario of problems and strongly suggested improvement of teaching techniques and constant training in airway management as a way to prevent these complications.

To date, direct laryngoscopy is the main procedure for evaluating the structures of the oral cavity and glottic region for either diagnostic and therapeutic purposes or to enable the introduction of an endotracheal tube. However, when there is limited visualization of these structures due to anatomical changes or limitations in positioning (limited cervical and head mobilization), laryngoscopy can be extremely difficult, and tracheal intubation eventually becomes impossible.[5,6] In recent decades, new devices have emerged, and optical or video-assisted technology has been added to improve the angle and visual field of laryngoscopists. The visualization of the glottis became indirect and helped with the management of the airway. These devices are called videolaryngoscopes and are being rapidly incorporated into medical practice, helping with the teaching and training processes.[7−12]

Traditional laryngoscopy teaching models use formal lectures to describe the technique and anatomical images to recognize reference structures of the larynx and then proceed to practical training on mannequins and simulators to improve skills. In a traditional medical school, students have their first introduction to the techniques of airway management and training for laryngoscopy during their rotation in the discipline of anesthesiology and pain treatment in the 3rd year of the undergraduate medicine course. This course has theoretical classes, skills training workshops using mannequins, and guided tours of the operating room.[13]

Direct laryngoscopy is a maneuver that requires knowledge of the technique, complex psychomotor skills, and the recognition of anatomical structures. It represents a challenge for instructors, who cannot directly evaluate the performance and success of the maneuver. After all, visualization of the larynx is only possible individually. The videolaryngoscopes allow a shared experience between student and instructor since both simultaneously visualize the images through the video screen; they even enable immediate orientations and corrections by the instructor and greater understanding of the maneuver by the student.[14] The effectiveness of video training has been highlighted in the literature. Groups of inexperienced laryngoscopists (medical students, paramedics, and physicians with a history of no or a small number of laryngoscopies) achieved high success rates in tracheal intubation when trained with the use of videolaryngoscopes.[15]

Thus, we hypothesized that the introduction of the videolaryngoscope into the laryngoscopy teaching and training program of students in the 3rd year of medical graduation optimizes and facilitates learning. We simulated intubation using a training mannequin. The primary objective of this study was to evaluate the success rate of the first attempt of tracheal intubation and the time to achieve a successful intubation with the use of the McGrath™ MAC videolaryngoscope compared with intubations using a direct laryngoscope with a Macintosh blade. The secondary objective was to observe the Cormack-Lehane classification visualized before intubation with both techniques.

Methods

After approval by the Ethics Committee on Research in Human Beings and registration on Plataforma Brasil (http://plataformabrasil.saude.gov.br/login.jsf) under the number 73259717.2.0000.5479 and approval number: 2.251.017, a randomized prospective study using a simulation was conducted at a traditional medical school with the participation of undergraduate medical students attending the third year of the medicine course and performing a rotation in the discipline of Anesthesiology and Pain Treatment in the years of 2017 and 2018. Students filled out an informed consent form by agreeing to participate in the study. The sample size was considered to be the total number of students in the classes of 2017 and 2018 (208 students), and all of them agreed to participate and were included. The exclusion criteria were students who had any previous practical training in laryngoscopy, those who did not fully complete the training, and any students who refused to participate in the study.

The students received theoretical classes and practical training in the techniques of laryngoscopy (direct or video) and were subsequently evaluated when performing laryngoscopies and intubations using simulation mannequins. The training was initiated with a 60-minute theoretical presentation of the concepts and techniques for airway management with an emphasis on Direct Laryngoscopy (DL) and Videolaryngoscopy (VL) techniques.

They were randomly divided into two groups: The Direct Laryngoscopy Group (DLG) and the Videolaryngoscopy Group (VLG). The participant distribution was obtained through a ''List randomizer'' program on www.random.org. The participants were allocated sequentially and were randomly assigned regarding their group and order of entry into the study.

The main researcher was helped by two collaborators who performed data collection, completion of the standard form, and the provision of information about the procedure. They were all anesthesiologists with training and experience in difficult airway management.

In the DLG training, the students first met and were trained in using the direct laryngoscope and Macintosh blade number 3.0 (produced by Goldstar Medical Instruments-Pakistan) and tracheal tube number 7.0 with a cuff balloon (Mallinckrodt brand, produced by Covidien-USA). No stylet was used inside the tracheal tube during the simulated intubations.

The instructor demonstrated the equipment operation and performed oral tracheal intubation by direct laryngoscopy in the training mannequin. The model used was the Air-Sim Multi™ (manufactured by Tru-Corp Company, North Ireland). This model consists of a head with an articulated jaw that allows mouth opening and the introduction of a laryngoscope blade. The interior of the oral cavity reproduces the anatomy of the human pharynx, larynx, and trachea. There is a connection with two inflatable balloons that simulate pulmonary insufflation when receiving a volume of gas. The cervical region of the mannequin was also articulated and allowed for positioning in flexion or extension of the neck. During the training, the mannequin's neck was fixed in a neutral position, representing an easy intubation scenario.

Each student trained with the DL for 5 minutes and had to accomplish at least three successful tracheal intubations. The students performed tracheal intubation and insufflated the tracheal tube cuff with 5 mL of air. The success of the attempt was proven when the student connected a manual ventilation device (Ambu Silicone Oval Resuscitator manufactured by AMBU LTD, China) to the positioned tracheal tube, and then pulmonary ventilation was observed in the mannequin balloons.

The VLG training initiated with the demonstration of the operation of the MacGrath™ MAC videolaryngoscope (manufactured by Medtronic, South Ireland) preloaded with Mac blade number 3 (a blade similar to the Macintosh blade). Additionally, there was a tracheal tube number 7.0 with a cuff balloon. This videolaryngoscope is formed by a handle with a 2.5-inch crystal liquid screen attached, and the power source is a detachable non-rechargeable 250-minute life battery. In the lower portion, there is an angled metal rod where internally the lighting and image capture systems are located. The blades have a similar design to traditional Macintosh blades, but they are made of disposable plastic transparent material and have an internal channel that allows for introduction and fixation on the metal rod.

The instructor demonstrated the operation of the equipment and performed the videolaryngoscopy technique using the Tru-Corp Air-Sim Multi™ Mannequin. Each student trained the VL for 5 minutes and had to accomplish at least three successful tracheal intubations. The students performed tracheal intubation and insufflated the tracheal tube cuff with 5.0 mL of air. Similar to the DLG group, no stylet was used inside the tracheal tube. The success of the attempt was proven by observation of the pulmonary ventilation inflating the mannequin's balloons.

After the training period, the next phase of evaluation and data collection was initiated. Each student performed three attempts of tracheal intubation of the Mannequin Air-Sim Multi™ using the device they had previously trained on. DLG used a direct laryngoscope with Macintosh blade number 3, and VLG used the MacGrath™ MAC videolaryngoscope with a Mac 03 blade. Students were also asked to describe the degree of visualization of the structures according to the Cormack-Lehane (C&L) classification.[16] The C&L classification represents a score that objectively describes the glottis view during laryngoscopy. Near each mannequin, there was a reminder card where the techniques were described with a tutorial, step by step, and photos illustrating the C&L classification.

The following were recorded: success in the first attempt at laryngoscopy; the time required to obtain successful Tracheal Intubation (TI); and the Cormack-Lehane classification visible before intubation as reported by the student.

The beginning of the time count was considered when the student picked up the laryngoscope, and it was finished when pulmonary ventilation was observed. The maximum tolerated time for each attempt was 120 seconds. The attempt was considered unsuccessful when the tolerated time was exceeded. The attempt was declared a failure when esophageal intubation was observed. In both situations, the students were asked to stop and to try again.

The variables studied were the age and gender of the students; the time required to obtain successful Tracheal Intubation (TI); the success rate on the first attempt of laryngoscopy; and the Cormack-Lehane classification.

When the data collection phase was finished, the students in each group were introduced to the technique of the other group, providing equal training opportunities to avoid any impairment or differences in curricular learning.

The primary outcome was the success rate on the first tracheal intubation attempt and the time required to obtain successful tracheal intubation.

Statistical analysis

The students' ages were described according to their classes and by using summary measures (mean and standard deviation) that were compared using Student's unpaired *t*-test. The normal distribution of the variables age and sex were evaluated with the D'Agostino & Pearson test. We described the first attempt success rate, rate of esophageal intubation, and the degree of visibility during the first attempt using absolute and relative frequencies according to each group, and we verified the association between them using the Chi-Square test or Fisher's exact test. The Mann-Whitney test was used to compare the degrees of visibility between the groups. The mean times of the successful first attempts by group were compared by using Student's *t*-test. Variance analysis (ANOVA) was performed with repeated measurements to determine the ratio of the execution times of the three attempts in the VL and DL groups separately, with p < 0001. When the result was significant, the Tukey multiple comparison test was performed to identify for which groups or attempts there were differences.

IBM-SPSS for Windows version 20.0 software was used to perform the analyses, and Microsoft Excel 2019 software was used to tabulate the data. The tests were performed at a significance level of 5%.

Results

Among the 208 students in the anesthesiology internship group in 2017 and 2018 who were invited to participate in the study, all agreed to participate, but four were excluded for having already participated in previous airway management courses (workshops with laryngoscopy skill training), so the final sample included 204 students. The D'Agostino & Pearson test was performed and showed that the students in both classes (2017 and 2018) constituted a homogeneous

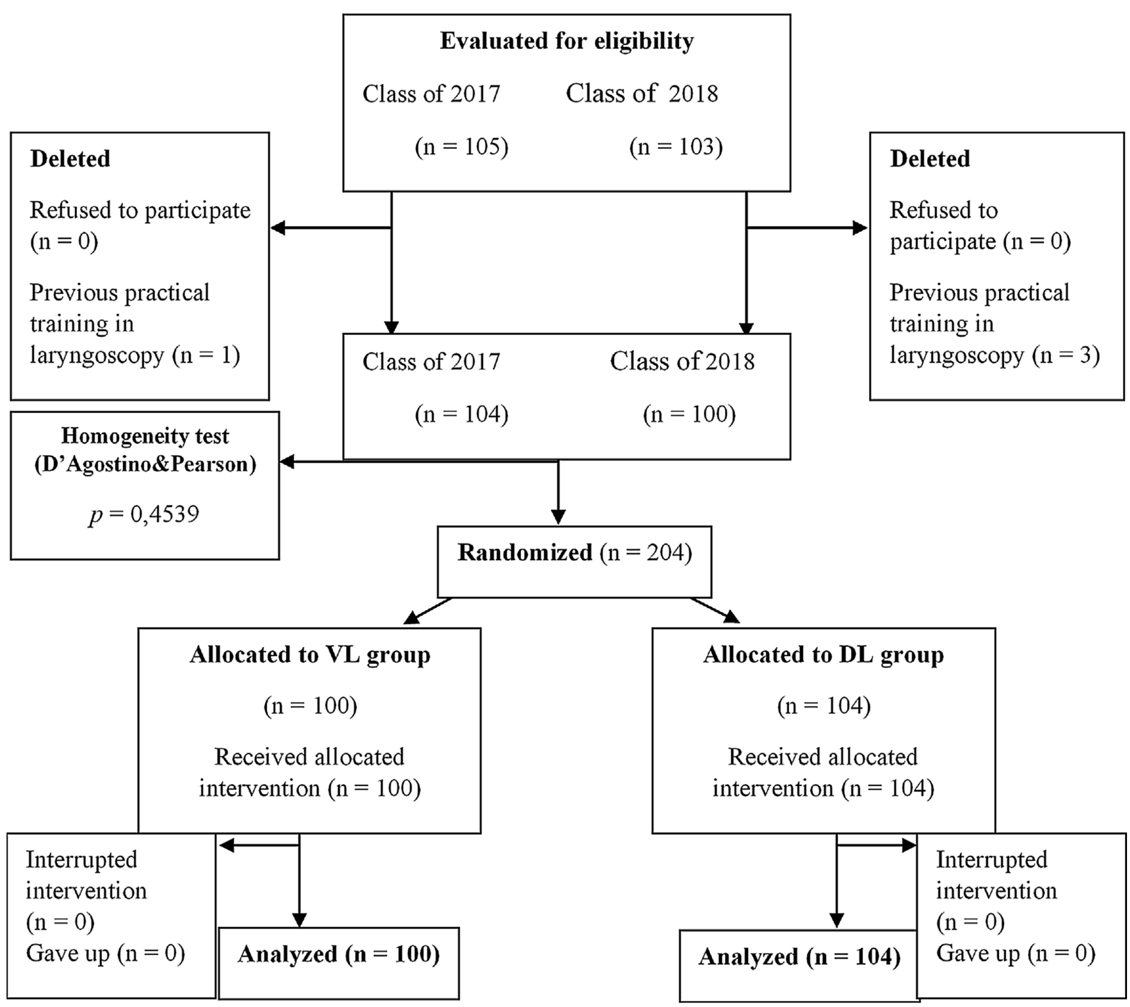

Figure 1 Flowchart of the participants of the study stages.

Table 1 Anthropometric data (age) and gender distribution of the two groups studied.

	VL (n = 100)	DL (n = 104)	Total
Age (mean ± SD) (years)	25.1 ± 2.5	21.9 ± 1.4	21.7 ± 2
Sex			
Male	56 (56.0%)	57 (54.8%)	113 (55.4%)
Female	44 (44.0%)	47 (45,2%)	91 (44.6%)

VL, Videolaryngoscopy group; DL, Direct Laryngoscopy group; SD, Standard Deviation.

Table 2 Description of the successful outcome in the attempts of tracheal intubation with VL and DL.

	1st TI attempt		2nd TI attempt		3rd TI attempt	
	VL	DL	VL	DL	VL	DL
Sucess rate	97%	89.40%	99%	96.20%	98%	97.10%
***p*[a]**	0.0497		0.3693		0.9999	

VL, Videolaryngoscopy group; DL, Direct Laryngoscopy group.
[a] Fisher's exact test.

Table 3 Description of successful tracheal intubation times in the 1st, 2nd, and 3rd attempts in groups VL and DL.

	1st TI attempt		2nd TI attempt		3rd TI attempt	
Group	VL	DL	VL	DL	VL	DL
Average[a]	38.25	43.01	33.36	39.71	28.67	32.76
DP[a]	15.06	13.34	16.52	14.86	11.99	12.22
95% IC[a]	35.08–41.43	40.17–45.85	30.06–36.65	36.74–42.67	26.26–31.07	30.32–35.2
p[b]	0.0280		0.0049		0.0186	

TI, Tracheal Intubation; VL, Videolaryngoscopy group; DL, Direct Laryngoscopy group; 95% CI, 95% Confidence Interval.
[a] Time in seconds.
[b] Unpaired *t*-test.

group with respect to age and distribution regarding gender. After that, randomization was performed and 100 students were allocated to group VL and 104 to group DL (Fig. 1).

The mean age and standard deviation of the total group of participants (n = 204) was 21.7 ± 2 years, with 113 men and 91 women (Table 1).

There was a significant difference between the DL and VL groups in the success rate of tracheal intubation only on the first attempt, with results of 89.4% and 97%, respectively (Fisher's exact test, $p = 0.0497$), with superior performance of the VL group (Table 2). In the 2nd and 3rd attempts, there were no differences between the groups.

Regarding the number of oesophageal intubations, no significant difference was observed between the groups (Fisher's exact test, $p = 0.2147$). The rates for groups DL and VL were 7.7% and 3%, respectively.

Table 3 shows the mean values, respective standard deviations, 95% confidence intervals, and respective *p*-values (significance of the unpaired Student's *t*-test) of the time required for successful tracheal intubation (including the 1st, 2nd, and 3rd attempts) in both groups. The statistical analysis showed a significant difference between the two groups for all attempts, with shorter times in the VL group. Variance analysis and Tukey's test of multiple comparisons were performed and showed a significant difference only between the 1st and 3rd attempts (Table 4).

Table 4 Result of comparisons between tracheal intubation attempts at groups VL and DL.

Comparison	VL	p	DL	*p*
1st attempt – 2nd attempt		0.0877		0.2358
1st attempt – 3rd attempt		< 0.0001		< 0.0001
2nd attempt – 3rd attempt		0.0365		0.0007

Tukey's test, multiple comparisons.

Table 5 Description of the visualization of the Larynx according to the Cormack-Lehane classification in groups VL and DL.

	Cormack-Lehane Classification			
	1	2	3	4
VL (n = 100)	75 (75.0%)	23 (23.0%)	02 (2,0%)	0
DL (n = 104)	33 (33.7%)	66 (67.3%)	05 (5.1%)	0

$p < 0.0001$.

The results regarding the degree of visualization of the structures according to the Cormack-Lehane classification (C&L) at the time of intubation for both groups can be seen in Table 5, with a significant difference between the two groups ($p < 0.0001$) and a higher frequency of C&L grade 1 in group VL (75%).

Discussion

The findings of this study showed that there was significant superiority of VL over DL regarding the success rate of the first attempt of tracheal intubation (97% and 89.4%, respectively, $p = 0.0497$ 95% CI), but this finding was not obtained for any other attempts. There is evidence in the literature that beginner laryngoscopists perform better when using indirect laryngoscopy techniques and when they are initially trained with these techniques.[8,12,15,17,18] During airway management, tracheal intubation is considered a fundamental maneuver to ensure ventilation and oxygenation to the patient. Mort[19] showed that the greater the number of attempts and the longer the time for successful intubation, the higher the relative risk of serious clinical complications such as severe hypoxia, regurgitation of gastric contents with bronchial aspiration, and even cardiorespiratory arrest. Thus, some authors advocate the standardization of videolaryngoscopy as the technique of choice for the initial approach in all cases of tracheal intubation, considering it to be efficient and safer for patients, and recommending that all anesthesiologists receive adequate training and have access to these devices.[20]

However, in this study, no significant differences in the success rate were observed in the second and third attempts. An explanation for this may be due to one of the limitations of the study: the relatively short time available for student training before the data collection phase (5 minutes of training and at least three successful intubations). There is no consensus to define the minimum number of maneuvers during training to achieve laryngoscopy proficiency (a learning curve with a success rate above 90%), but retrospective studies and meta-analyses suggest approximately 50 intubations for DL and approximately 20−30 for VL.[11,21,22] The German Society of Anesthesiologists[11] (DGAI) recommends that after initial training with 100 laryngoscopies, professionals perform at least 10 intubations per year to maintain their ability. Perhaps by increasing the time and the number of maneuvers during the training phase, the competence acquired in each group could be more evident.

Students in the VL group were faster than those in the DL group in all intubation attempts. In parallel, most students in the VL group reported excellent viewing conditions (75% of the attempts received a Cormack-Lehane grade 1 classification). The VL technique favoured the visualization of glottic structures, which resulted in faster intubations. Similar data were reported by Herbstreit et al.,[23] who observed medical students undergoing training with VL and found an average intubation performance 11 seconds faster than that of the control group. Most likely, just a few seconds sooner or later to complete tracheal intubation would not have a major clinical impact in elective preoxygenated patients, but in critical care and emergency patients with a prior hypoxic condition, this is certainly an important issue.

The quality of the images on the device's screen with adequate brightness and high definition facilitated the recognition of important reference points, such as the epiglottis or vocal cords, and allowed the student to guide the tracheal tube more quickly and correctly. Another highlight for learning with VL is that the instructor accompanies the maneuver simultaneously viewing the screen and can make observations or instant corrections to guide the inexperienced laryngoscopist.[17,18,23−25] In the real clinical setting, this sharing of intubation experience allows a situational awareness by the entire care team and favours a quick and integrated response in cases of difficulty or urgency.

In the VL and DL groups, there was a significant decrease in intubation time with the progression of attempts between the first and third attempts. This can suggest a learning curve and a good result and effectiveness of the proposed training.

For logistical reasons and a lack of availability of the participants, it was not possible to follow the students in the post-study period and assess the degree of their retention of the trained technical skill. This type of follow-up could suggest the appropriate time interval to repeat the training to preserve knowledge and skills.

This study has other limitations. Training mannequins do not accurately reproduce the anatomy of the airway, the muscle tone of the structures, or the presence of secretions; therefore, the results do not directly represent what occurs in clinical practice. The neutral position of the mannequins did not replicate any difficult scenarios for laryngoscopy and tracheal intubation, which resulted in relatively high success rates in both groups.

Future studies with larger samples of participants evaluating the application of videolaryngoscopes in the training of different groups, such as academics, resident doctors, and experienced physicians, may present more relevant information about the value of these devices in the development and safety of laryngoscopy.

Conclusion

The introduction of the McGrath™ MAC videolaryngoscope in the 3rd-grade medical students' training program allowed them to better visualize the anatomical structures of the training mannequin and complete the orotracheal intubation maneuver more quickly and with a high success rate at the first attempt. Thus, under the conditions of this prospective study, the videolaryngoscope had a positive impact on training and proved to be a promising tool for teaching laryngoscopy.

The study followed strengthening the Guidelines for Health Care Simulation Research: Extensions to the CONSORT and STROBE Statements.

This study is registered at http://plataformabrasil.saude.gov.br/login.jsf under the number 73259717.2.0000.5479 and approval number: 2.251.017

Conflicts of interest

The authors declare no conflicts of interest.

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