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ORIGINAL ARTICLE

Effect of jaw thrust and cricoid pressure maneuvers on glottic visualization during GlideScope videolaryngoscopy

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Abstract
Purpose During performance of direct laryngoscopy in the difficult-to-visualize airway, several maneuvers have the potential to impact glottic visualization, including jaw thrust and cricoid pressure. The effect of these maneuvers on glottic visualization during videolaryngoscopy has not been studied. We evaluated the effect of jaw thrust and cricoid pressure maneuvers on both visualization of the glottis and the area of glottic opening visible during GlideScope-aided videolaryngoscopy.
Methods One hundred patients were enrolled in this study. After induction of general anesthesia, videolaryngoscopy was followed by jaw thrust and cricoid pressure maneuvers performed in random order. Laryngeal anatomy was recorded continuously and was saved as digital images following the initial laryngoscopy and after each maneuver. Glottis grade [modified Cormack and Lehane (C&L)] was recorded, as was the total glottic area.
Results There was improvement in glottis grade when utilizing jaw thrust maneuver in comparison to GlideScope videolaryngoscopy alone (31% improved, 4% worsened; $P < 0.001$). There was no difference in glottis grade when using the cricoid pressure maneuver in comparison with videolaryngoscopy alone (39% improved, 20% worsened; $P = 0.19$). Glottic opening area, however, was greater when utilizing the jaw thrust maneuver in comparison with videolaryngoscopy alone ($P < 0.001$), but smaller when utilizing the cricoid pressure maneuver in comparison with videolaryngoscopy alone ($P < 0.001$).
Conclusions The jaw thrust maneuver was superior to videolaryngoscopy alone in improving the modified C&L grade and the visualized glottic area; however, no significant improvement was noted with cricoid pressure. We therefore recommend the use of jaw thrust as a first-line maneuver to aid in glottic visualization and tracheal intubation during GlideScope videolaryngoscopy.

Keywords Airway management · Cricoid pressure maneuver · Jaw thrust maneuver · GlideScope videolaryngoscopy

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Introduction

Visualization of the glottis continues to challenge anesthesiologists during attempted tracheal intubation. The ability to visualize the glottis in anesthetized patients who received muscle relaxation agents was assessed by Cormack and Lehane [1], who described four grades, ranging from “full visualization of the glottis” (grade 1) to “neither glottis nor epiglottis seen” (grade 4). This grading system was later modified by Yentis and Lee [2], who subdivided glottis grade 2 into 2a (part of the vocal cords visible) and 2b (only the arytenoids or the very posterior origin of the cords visible). Both the ability to visualize the glottis and the total area of the glottic opening (area between the vocal cords) affect the ease of tracheal intubation. In patients with poor initial visualization of the glottis because of difficult anatomy or obesity, external manipulation of the larynx may provide a better view of laryngeal anatomy. Several techniques, such as a simple jaw thrust, or more advanced maneuvers, have been shown to alter glottic visualization. Studies investigating the “laryngeal lift” and the “BURP” (backward, upward, rightward, pressure) maneuvers have shown both to be efficacious, although not in all instances [3–5]. Cricoid pressure or the Sellick maneuver, although not employed primarily in an attempt to improve glottis visualization, is commonly used during rapid-sequence induction of anesthesia and intubation to prevent regurgitation of gastric contents and pulmonary aspiration. Previous studies have demonstrated that cricoid pressure may worsen glottic visualization [3]. Despite these data, some anesthesiologists seem to apply cricoid pressure in an attempt to improve the view of the glottis during routine laryngoscopy in addition to using it during rapid-sequence induction and intubation scenarios. Even with the advent of videolaryngoscopy and its ability to provide improved glottic views, practitioners continue to utilize airway maneuvers seeking to obtain an optimal glottic view. Within this context, our study was designed to critically evaluate the effect of the jaw thrust and cricoid pressure maneuvers on both visualization of the glottis and the area of glottic opening visible during GlideScope-aided videolaryngoscopy.

Materials and methods

Study patients and personnel

One hundred patients undergoing elective surgery at Mayo Clinic Florida from February 2009 until January 2010 were enrolled into this institutional review board-approved prospective crossover study. All patients undergoing elective surgical procedures in all surgical disciplines and requiring orotracheal intubation were candidates for the study. Exclusion criteria included known difficult airway anatomy, patient age less than 13 or more than 99 years, and patients requiring an awake tracheal intubation. Staff anesthesiologists, certified registered nurse anesthetists (CRNAs), student nurse anesthetists (SRNAs), and anesthesia residents were eligible to operate the videolaryngoscope and perform the orotracheal intubation. Two experienced anesthesiologists (with 10 and 20 years of clinical experience, respectively), performed jaw thrust and cricoid pressure maneuvers on all 100 study patients.

Sample size justification

Initial power analysis was based on the original Cormack and Lehane grading and determined that 100 patients would be required for 85% power at the 5% significance level to detect a clinically meaningful difference in glottis grade using jaw thrust or cricoid pressure maneuvers in comparison to videolaryngoscopy alone using the Wilcoxon signed-rank test. This sample size was determined under the assumption that the distribution of glottis grade for videolaryngoscopy alone was 50% grade 1, 35% grade 2, 10% grade 3, and 5% grade 4. A clinically meaningful difference was defined as 98% no change in glottis grade and 2% worsening by one grade for those with grade 1 airway by videolaryngoscopy alone; 20% improvement by one grade, 78% no change, and 2% worsening by one grade for those with grade 2 airway by videolaryngoscopy alone; 20% improvement by one grade and 80% no change in those patients with grade 3 airway by videolaryngoscopy alone; 10% improvement by two grades, 10% improvement by one grade, and 80% no change for those with grade 4 airway by videolaryngoscopy alone. Following initiation of the study, the primary endpoint was considered the modified Cormack and Lehane grading rather than the original grading; as the same significance assumptions were made, thus the power analysis was not changed.

Protocol

Following informed written patient consent and placement of a peripheral intravenous catheter, each patient was moved to the operating room and pre-oxygenated with 100% oxygen via face mask. After standard American Society of Anesthesiologists (ASA) monitor application (ECG leads, noninvasive blood pressure cuff, and pulse oximetry), anesthesia was induced with i.v. propofol, and muscle relaxation to facilitate tracheal intubation was administered at the discretion of the consultant anesthesiologist. At the end of succinylcholine-induced fasciculations or 2–3 min after administration of a nondepolarizing agent, a routine laryngoscopy attempt was made using the GlideScope (Verathon, Bothell, WA, USA) videolaryngoscope, as per usual clinical routine, to visualize the posterior pharynx and the vocal cords. The laryngoscope was manipulated by the operator so as to provide the best view of the glottis, and the anatomy of the larynx in this view was recorded and saved as a digital image (Fig. 1a) that did not contain any identifying patient characteristics. Then, one of the investigators performed, in a predetermined computer-generated random order, either a jaw thrust (providing mandibular advancement with two hands under the angles of the mandible) or a cricoid pressure maneuver (applying a constant pressure that replicated the usual force applied during rapid-sequence induction scenarios), and the posterior laryngeal anatomy obtained with the maneuver was recorded as a second digital image (Fig. 1b). Last, the investigator performed the alternate maneuver (cricoid pressure or jaw thrust) and the posterior laryngeal anatomy was recorded as a third digital image (Fig. 1c). Tracheal intubation was accomplished as per usual clinical routine to end the study. In a subset of 27 patients, an additional baseline digital image was captured between airway maneuvers. This image was compared to the baseline image to determine any variability in magnification between the two airway maneuvers and to ensure consistent assessments. A blinded investigator unaware of which of the three images was recorded as baseline or with cricoid pressure or jaw thrust maneuver was asked to grade the view of the images according to the modified Cormack and Lehane grading system of laryngoscopic views; images were presented to this investigator in a random order. A second blinded investigator measured the glottic area (in pixels squared) of each recorded digital image using OsiriX Imaging Software (Version 3.7.1; Pixmeo SARL, Geneva, Switzerland) (Fig. 2).

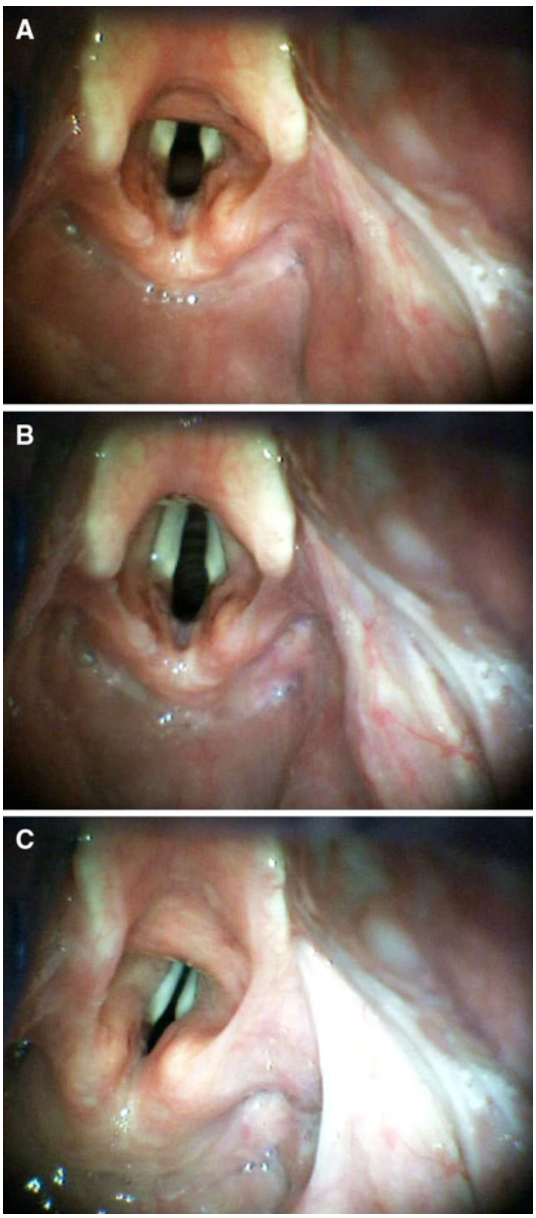

Fig. 1 Glottic image baseline with videolaryngoscopy alone (**a**); glottic image with jaw thrust (**b**); glottic image with cricoid pressure (**c**)

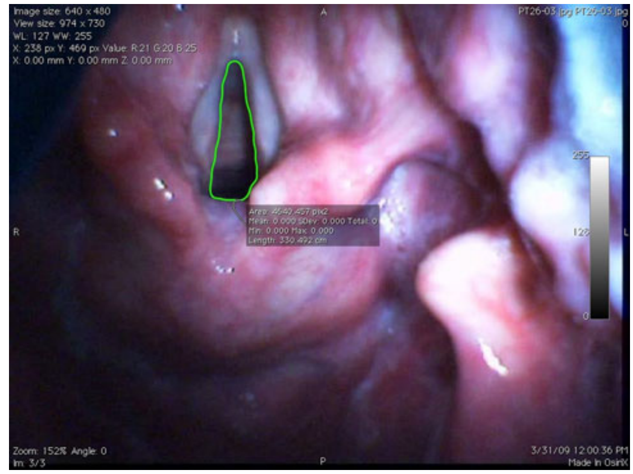

Fig. 2 Glottic opening area measurement

Data collection and endpoints

In addition to previously mentioned information, the following demographic, pre-procedure, and procedural information of interest was collected from each patient: age, sex, race, height, weight, body mass index (BMI), preoperative Mallampati score, mouth opening (in cm), thyro-mental distance (in cm), upper lip bite test (3 grades: grade 1 = ability to reach upper lip vermillion border with lower jaw teeth, grade 2 = ability to reach upper lip, grade 3 = cannot reach upper lip), and the intubating provider duration of clinical experience (years). The primary endpoint of this study was glottis grade according to the modified Cormack and Lehane scale (1, 2a, 2b, 3, and 4), and the secondary endpoint was glottic opening area.

Statistical analysis

Numerical variables were summarized with the sample median, minimum, and maximum; categorical variables were summarized with number and percentage. To evaluate the primary aim of the study, we compared glottis grade and glottic opening area using the jaw thrust and cricoid pressure maneuvers to videolaryngoscopy alone using the Wilcoxon signed-rank test. P values ≤ 0.025 were considered statistically significant after Bonferroni correction for multiple testing. Statistical analyses were performed using S-Plus (version 8.0.1; Insightful Corporation, Seattle, WA, USA).

Results

Table 1 shows demographic, pre-procedure, and procedural information for the 100 study patients. Median age was 66 years (range, 19–91 years); 53% of patients were men; and 81% of patients were Caucasian. Median BMI was 27 (range, 18–48).

Table 1 Patient characteristics

	Summary (n = 100)
Age	66 (19, 91)
Gender (male)	53 (53%)
Race	
Caucasian	81 (81%)
African American	8 (8%)
Hispanic	4 (4%)
Asian or Pacific Islander	2 (2%)
Other	3 (3%)
Weight (kg)	81 (44, 131)
Height (cm)	170 (149, 196)
Body mass index (BMI)	27 (18, 48)
Preoperative Mallampati score	
1	22 (22%)
2	49 (49%)
3	27 (27%)
4	2 (2%)
Mouth opening (cm)	4.5 (3.0, 8.0)
Thyro-mental distance (cm)	5.5 (3.0, 10.0)
Upper lip bite test (reach of lower incisors)	
Upper lip vermillion border	55 (55%)
Upper lip	40 (40%)
Cannot reach upper lip	5 (5%)
Years of experience of intubating operator	3 (0, 36)
Training level of intubating operator	
Resident	49 (49%)
CRNA	42 (42%)
Student CRNA	7 (7%)
Attending physician	2 (2%)

The sample median (minimum, maximum) is given for numerical variables (range)

A summary of glottis grade for each maneuver is displayed in Table 2, where comparisons of jaw thrust and cricoid pressure maneuvers with GlideScope videolaryngoscopy alone are also provided. Glottis grade was either 1, 2a, or 2b in all patients for each maneuver. There was evidence of a significant improvement in glottis grade when utilizing the jaw thrust maneuver in comparison to videolaryngoscopy alone ($P < 0.001$), where glottis grade improved in 31% of patients and worsened in only 4% with the maneuver. There was no difference in glottis grade when using the cricoid pressure maneuver in comparison with videolaryngoscopy alone ($P = 0.19$); in this patient group, glottis grade improved in 39% of patients, but worsened in 20%.

An evaluation of differences in the study secondary endpoint (glottic opening area) between maneuvers is shown in Table 3. Mirroring the results involving the primary endpoint of glottis grade, there was a significant increase in glottic opening area when utilizing the jaw thrust maneuver in comparison with videolaryngoscopy alone ($P < 0.001$); the median increase in glottic opening area (in pixels squared) for jaw thrust in comparison with videolaryngoscopy alone was 507 (range, −2,368 to 3,973) pixels squared, and the median percentage change in glottic opening area for jaw thrust in comparison with videolaryngoscopy alone was 12% (range, −63% to 1,773%). In contrast, there was evidence of a significantly decreased glottic opening area when utilizing the cricoid pressure maneuver when compared with videolaryngoscopy alone ($P < 0.001$); the median decrease in glottic opening area for cricoid pressure in comparison with videolaryngoscopy alone was −1,042 (range, −7,318 to 3,906) pixels squared, and the median percentage change in glottic opening area for cricoid pressure in comparison to videolaryngoscopy alone was −27% (range, −100% to 524%).

To ensure that changes in glottic opening area were not caused by changes in videolaryngoscope magnification, the glottic area was measured before the jaw thrust maneuver and also before the cricoid pressure maneuver in a subgroup of 27 patients. The median absolute difference between these two baseline glottic opening areas was 590 (range, 40–3,258) pixels squared, indicating a moderate degree of variability.

Discussion

Videolaryngoscopy has been revolutionary in facilitating tracheal intubation. In teaching institutions, it offers the advantage of allowing the teaching physician to visually

Table 2 Glottis grade for each maneuver compared to videolaryngoscopy alone

Glottis grade	Videolaryngoscopy alone	Jaw thrust	Cricoid pressure	Jaw thrust vs. videolaryngoscopy alone			Cricoid pressure vs. videolaryngoscopy alone		
				No. (%) improved	No. (%) worsened	*P* value	No. (%) improved	No. (%) worsened	*P* value
1	43 (43%)	60 (60%)	50 (50%)	31 (31%)	4 (4%)	<0.001	39 (39%)	20 (20%)	0.19
2a	38 (38%)	33 (33%)	35 (35%)						
2b	19 (19%)	7 (7%)	15 (15%)						

P values result from a Wilcoxon signed-rank test in comparison with videolaryngoscopy alone

Table 3 Glottic opening area for each maneuver

Maneuver	Summary ($n = 100$)
Glottic opening area (pixels squared)	
Videolaryngoscopy alone	3,559 (195, 11,896)
Jaw thrust	4,038 (709, 12,753)*
Cricoid pressure	2,337 (0, 10,919)*
Change in glottic opening area (pixels squared)	
Jaw thrust, videolaryngoscopy alone	507 (−2,368, 3,973)
Cricoid pressure, videolaryngoscopy alone	−1,042 (−7,318, 3,906)
Percent change in glottic opening area	
Jaw thrust, videolaryngoscopy alone	12% (−63%, 1,773%)
Cricoid pressure, videolaryngoscopy alone	−27% (−100%, 524%)

Sample median (minimum, maximum) is given (range)

*Strong evidence of a difference from videolaryngoscopy alone at $P < 0.001$ from Wilcoxon signed-rank test

guide the procedure as well as to avoid more invasive techniques in patients in whom tracheal intubation is difficult. However, similar to other techniques, videolaryngoscopy has its limitations: airway trauma, lack of complete glottic visualization, and difficulty in passage of the tracheal tube despite adequate visualization of the glottic opening. Numerous case reports highlight the possibility of airway trauma with this device [6–12]. Documented trauma includes damage to the palatoglossal arch, soft palate perforation, and anterior tonsillar pillar perforation. Furthermore, many patients have airway anatomy that displaces the glottic opening anteriorly. With the GlideScope, the image of the anteriorly displaced glottis occasionally is truncated at the top of the video screen. Loss of visualization of the glottis in its entirety may also be the result of various degrees of blind spots just below the tip of the blade [13]. These factors prevent optimal visualization of the airway during attempted intubation of the trachea. Last, once visualization of the glottis is obtained during GlideScope videolaryngoscopy, the angle between the opening of the glottis and the axis of the trachea is often acute, making passage of the tracheal tube difficult. During advancement of the tracheal tube, the severe angulation of various stylets used for GlideScope-aided intubation direct the tube anteriorly. This sharp angulation causes the tip of the tube to hang up on the anterior commissure or tracheal cartilage. Cooper et al. [14] showed that the GlideScope improved the Cormack and Lehane grade of glottic view compared with direct laryngoscopy. However, this study described a number of failures to intubate despite an excellent glottic view. As a result, many authors have suggested various techniques (bending the stylet or using specific methods of approaching the glottic inlet such as the retro-molar approach) to aid in the advancement of the tracheal tube into the trachea [15–18].

Numerous studies have shown the GlideScope to be superior in maximizing the view of the glottis compared to direct laryngoscopy [19]. Kim et al. reported in 203 pediatric patients that the "BURP" maneuver improved the graded view with the GlideScope [20]. However, many previous studies utilized only glottic grades to assess the view of the glottis. Our study assessed the view of the glottis with a more subjective modified Cormack and Lehane grading scale, but additionally used an objective measurement of a new metric, the glottic opening area. Other attempts at quantifying glottic view for research purposes have been explored in the past. The POGO (percentage of glottic opening) score is one such method that was shown to provide more inter- and intra-observer consistency in assessment of glottic opening [21]. However, the POGO measurement is a linear measurement from the anterior commissure to the posterior cartilages. This single-dimension score may in some cases have limitations, as the POGO score may be adequate (visualization of the entire anterior-to-posterior extent), despite total vocal cord apposition. In such a case, passage of the tracheal tube past the closed vocal cords may be difficult or impossible, despite an adequate POGO score. Our measurement of glottic opening area is a two-dimensional measurement that represents the entire opening between the vocal cords for passage of the endotracheal tube. The glottic area may be preferable to POGO score in predicting the ease of tracheal tube insertion, as POGO scores may be identical regardless of the degree of vocal cord apposition (i.e., maximally adducted or maximally abducted). In contrast, the glottic area takes into account not only the length of the glottic inlet visualized, but also the width of the inlet between the two vocal cords.

In our study, when compared to baseline view, jaw thrust provided a better subjective graded view of the glottic opening than cricoid pressure. Furthermore, the jaw thrust maneuver greatly improved the measured glottic opening area, whereas cricoid pressure greatly decreased the glottic area by forcing vocal cord apposition. Although our study did not examine length of time to intubation or difficulty of intubation, one may assume that a larger glottic opening area may facilitate tracheal intubation.

Our study design had several limitations. First, staff members were allowed to operate the GlideScope videolaryngoscope regardless of their experience with intubation techniques. However, this potential confounding factor is likely minimized by the fact that a poor view during one airway manipulation (jaw thrust or cricoid pressure) would likely be unchanged during the subsequent maneuver. Furthermore, the airway maneuvers could not be blinded, and the staff members performing the tracheal intubation were aware of cricoid pressure or jaw thrust maneuvers as they were being performed. This lack of blinding, however, is very unlikely to have introduced bias, as staff members were instructed not to adjust the laryngoscope after obtaining the best videolaryngoscopic view. Another potential limitation is that time between muscle relaxant administration and the start of intubation was not standardized. Most intubating staff members used clinical criteria (offset of succinylcholine-induced fasciculations) to determine optimal intubating conditions. This criterion may have been a source of bias if the patient became maximally relaxed between airway maneuvers. However, because the cricoid pressure and jaw thrust maneuvers were performed in random order, this is unlikely to have influenced only one patient group. We also found a moderate degree of variability in glottic areas measured in 27 patients between each airway maneuver. This finding suggests that minor movements of the videolaryngoscope between maneuvers may have occurred, leading to changes in glottic area because of magnification, rather than the airway maneuver itself. However, the maneuvers (cricoid pressure or jaw thrust) were performed in random order, such that bias in only one patient group is unlikely. We also only investigated one specific videolaryngoscope, the GlideScope; the literature is replete with studies that document the GlideScope may differ considerably from other indirect optical laryngoscopes, so our findings should only be applied clinically to the glottic area that is visualized during GlideScope-aided laryngoscopy. Finally, we only assessed a surrogate measure of the true outcome measure: the ease of tracheal intubation. As noted, an improved view of the glottic opening does not always guarantee successful tracheal tube passage.

Although this study confirms that videolaryngoscopy alone provides an excellent glottic view, we found a significant improvement in the graded glottic view as well as glottic opening area when utilizing the jaw thrust maneuver. Thus, it appears that the jaw thrust maneuver may be preferred to improve visualization of the glottic opening during videolaryngoscopy. Alternatively, tracheal tube passage through a glottic opening that is narrowed by the application of cricoid pressure may hinder an already difficult advancement of the tracheal tube during videolaryngoscopy. Forcing a tracheal tube through a glottic inlet in which the vocal cords are adducted by the cricoid pressure maneuver may increase the likelihood of trauma to the vocal cords. In conclusion, we recommend the use of the jaw thrust maneuver as a first-line maneuver, rather than applying cricoid pressure, to aid in intubation when using videolaryngoscopy.

Conflict of interest All authors have no conflict of interest.

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