ORIGINAL CLINICAL RESEARCH REPORT

Relationship Between Glottic View and Intubation Force During Macintosh and Airtraq Laryngoscopy and Intubation

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BACKGROUND: Because intubation-mediated cervical spine and spinal cord injury are likely determined by intubation force magnitude, understanding the determinants of intubation force magnitude is clinically relevant. With direct (Macintosh) laryngoscopy, when glottic view is less favorable, anesthesiologists apply greater force. We hypothesized that, when compared with direct (Macintosh) laryngoscopy, intubation force with an optical indirect laryngoscope (Airtraq) would be less dependent on glottic visualization.

METHODS: Using data obtained in a prior clinical study, we tested whether the slope of the intubation force versus glottic view relationship differed between intubations performed in 14 patients who were intubated twice, once with a Macintosh and once with an Airtraq videolaryngoscope. Slopes were compared using least-squares linear regression and robust regression.

RESULTS: The slope of the intubation force (N) versus glottic view (%) relationship with the Macintosh (−0.679 [standard error {SE}, 0.147]) was significantly more negative than that of the Airtraq (−0.076 [SE, 0.246]). The least-squares regression difference in slopes was −0.603 (SE, 0.287); $P = .046$. The robust regression difference in slopes was −0.747 (SE, 0.187); $P = .0005$. Thus, when compared with the Macintosh, intubation force magnitude with Airtraq laryngoscopy was less dependent on glottic visualization.

CONCLUSIONS: Previously, we reported that intubation force with the Airtraq was less in magnitude compared with the Macintosh. Our current study adds that intubation force also is less dependent on glottic view with Airtraq compared with the Macintosh. (Anesth Analg 2022;135:815–9)

KEY POINTS

- **Question:** Does the relationship between glottic view and intubation force differ between direct (Macintosh) laryngoscopy and indirect (Airtraq) laryngoscopy?
- **Findings:** Compared with the Macintosh, intubation force magnitude with Airtraq laryngoscopy was less dependent on glottic visualization.
- **Meaning:** Force differences between direct and indirect laryngoscopes may depend, at least in part, on the mediating effect of glottic view.

GLOSSARY

ASA = American Society of Anesthesiologists; **CONSORT** = Consolidated Standards of Reporting Trials; **POGO** = percentage of glottic opening; **SD** = standard deviation; **SE** = standard error

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[a] In the original study, POGO scores were also determined by offline analysis of images obtained using external camera systems. For the Airtraq (n = 14), offline POGO scores ([mean ± SD] 92% ± 10%) were comparable to those reported verbally (90% ± 10%). In contrast, for the Macintosh, offline POGO scores (n = 13: 60% ± 15%) were less than those reported verbally (n = 14: 74% ± 16%). The most likely explanation is that the Macintosh camera system was not perfectly aligned with the anesthesiologists' line of sight and did not record the anesthesiologists' actual glottic view. Thus, for this new study, only verbally reported POGO scores are used.

[b] The interquartile range equals the difference of the third quartile and the first quartile.[14] The upper inner fence equals the third quartile plus 1.5 times the interquartile range.[14] The upper outer fence equals the third quartile plus 3.0 times the interquartile range.[14]

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[c] In the original study, Airtraq intubation force equaled (mean ± SD) 10.4 ± 2.8 N and Macintosh intubation force equaled 48.8 ± 15.8 N, Wilcoxon signed-rank $P = .0001$.

[d] We repeated calculations with the 14 Airtraq observations and the 9 Macintosh observations with glottic views ≥75%. The estimated differences in slopes were −0.795 (SE, 0.395; $P = .059$) and −0.671 (SE, 0.258; $P = .018$) with least squares and robust regression, respectively.

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Although rare, cervical spinal cord injury from tracheal intubation, with both direct[1] and video laryngoscopes,[2] continues to be reported. The most likely cause of cord injuries caused by tracheal intubation is the force applied by the laryngoscope. For example, a recent computational model of tracheal intubation suggests patients who have cervical myelopathy may be at increased risk of injury from acute compressive cord strain, even with routine Macintosh intubation force magnitudes.[3] Patients who have ankylosing spondylitis experience cervical spine fractures from forces that do not typically cause fractures.[2,4,5] Thus, understanding the determinants of intubation force magnitude with direct and indirect laryngoscopy is clinically relevant.

With direct laryngoscopy and intubation, in addition to patient weight and sex,[6] glottic visualization appears to affect intubation force magnitude. In 2 clinical studies, anesthesiologists applied greater force when Macintosh glottic visualization was less favorable.[7,8] Although 4 clinical studies report indirect laryngoscopes apply less force than conventional direct laryngoscopy (Airtraq [Prodol Meditec][9]; Glidescope [Verathon Inc][10–12]), the relationship between glottic view and intubation force with indirect laryngoscopes is unknown. Cordovani et al[12] reported intubation forces in patients who had risk factors for difficult tracheal intubation. In patients randomized to Macintosh intubation, force magnitude with failed intubations (5 of 20 patients, all with poor glottic view) was 50% greater than that with successful intubations (median [interquartile range], 24 [22–26] vs 16 [13–29] N, respectively). In contrast, in patients randomized to Glidescope intubation, failed intubation occurred in 3 of 24 (12%), none of whom had poor glottic visualization. With the Glidescope, intubation force with failed intubations did not greatly differ (12% greater) from successful intubations (19 [13–24] vs 17 [9–21] N, respectively). This latter finding suggests, but does not establish that, with the Glidescope, glottic view may not appreciably influence intubation force.

Based on these observations, we hypothesized that, when compared with conventional direct (Macintosh) laryngoscopy and intubation, intubation force magnitude with indirect laryngoscopy would be less dependent on glottic visualization. To test this hypothesis, we conducted a post hoc analysis of data obtained in our prior clinical study in which each patient underwent 2 tracheal intubations, one with direct (Macintosh) laryngoscopy and the other with an optical indirect laryngoscope (Airtraq).[9] We tested whether the slope of the intubation force versus glottic view relationship differed between the Macintosh and Airtraq.

METHODS

The University of Iowa institutional review board determined that this study does not meet the regulatory definition of human subjects research because it is a secondary analysis of deidentified previously collected data from a previously approved project (202111089). The determination waived the requirement for institutional review board review and for written informed consent. Original data from a prior randomized clinical trial, without patient identifiers, were used. The original study had been approved by the University of Iowa institutional review board (201102721), and written informed consent was obtained from all patients. The original study was registered before patient enrollment at https://www.clinicaltrials.gov (NCT01369381, principal investigator: Bradley J. Hindman, date of registration: June 8, 2011). Original study methods and results were reported in detail in a previous publication[9] and adhered to the applicable Consolidated Standards of Reporting Trials (CONSORT) statement for reporting of randomized clinical trials.

In brief, the study population consisted of 14 adults with American Society of Anesthesiologists (ASA) physical status classification of I or II (9 females and 5 males; age [mean ± standard deviation {SD}] 47 ± 20 years; weight, 73.5 ± 13.1 kg) undergoing elective surgery requiring general anesthesia and oral endotracheal intubation. Inclusion criteria were intended to enroll patients who were likely to be easy to intubate with a Macintosh-3 blade (eg, Mallampati I [n = 8], Mallampati II [n = 6], thyromental distance ≥6.0 cm, and other criteria). Exclusion criteria (n = 19) were intended to exclude patients who might be at increased risk of intubation and/or other study-related complications (eg, cervical spine disease, gastroesophageal reflux, and other criteria).

Patients were orotracheally intubated twice, once using a Macintosh-3 and once using an Airtraq size-3 ("regular") videolaryngoscope, in random order. During each intubation, 2 faculty anesthesiologists were asked to achieve the best possible glottic view using only the laryngoscope; no external forces were applied to the head, neck, or airway. Patients were extubated and mask ventilated between the first and second intubations, and the interval between intubations was approximately 5 minutes.[9]

During both intubations, glottic view, laryngoscope force, and cervical spine motion were recorded. Laryngoscope force was measured using thin force mats that covered the entire contact surface of each type of laryngoscope blade. Force was measured continuously, with maximum intubation force being present when the laryngoscope was in final position, immediately before the endotracheal tube was placed in the glottis. Immediately after each intubation, anesthesiologists verbally reported their observed glottic visualization using the percentage of glottic opening (POGO) score, corresponding to the percentage of the total distance between the anterior commissure and inter-arytenoid notch.[13a]

Cervical spine motion was recorded using continuous lateral C-arm fluoroscopy. Image analysis was used to calculate segmental intervertebral motion between the occiputs to C5 (data not reported in this study).

Statistical Analysis

N = 28 observations were obtained by random sequence of group for each of the 14 patients. The 4-parameter linear regression model included the common intercept and 3 factors: laryngoscope (binary variable [Macintosh 1 and Airtraq 0]), percent glottic opening (continuous variable), and their interaction (the main factor of interest). For estimation of parameters, in our previous study of maximum intubation forces,[6] there were 3 of 101 observations that were mild outliers, exceeding the upper inner fence, and 1 of 101 extreme outliers, exceeding the outer inner fence.[b] Therefore, as done in the earlier study,[6] both least-squares linear regression and robust regression were used, the latter to account for outliers. If the sample size was large, robust regression would be more suitable than least-squares regression because of the outliers. However, our sample size was not large and cannot be increased given that the experiment was completed 10 years ago for a different purpose. Accordingly, because we could not know whether least-squares or robust regression was more accurate, we performed both. The robust regression command used was Stata's rreg with default options (biweight Huber tuning constant set to 7 times the median absolute deviation from the median residual) and 24 degrees of freedom for the t-statistic (StataCorp).

RESULTS

Glottic view and maximum intubation force with both types of laryngoscopes are summarized in the Table.[9] Glottic views and intubation forces are shown graphically in the Figure. The slope of the intubation force (N) versus glottic view (%) relationship with the Macintosh (−0.679 [standard error {SE}, 0.147]) was significantly more negative than that of the Airtraq (−0.076 [SE, 0.246]). The least-squares regression difference in slopes was −0.603 (SE, 0.287), *P* = .046. The robust regression difference in slopes was −0.747 (SE, 0.187), *P* = .0005. Thus, the hypothesis was confirmed. Compared with the Macintosh, intubation force magnitude with Airtraq laryngoscopy was less dependent on glottic visualization.

DISCUSSIONS

In the current study, with the Macintosh, intubation force was inversely associated with glottic view. In contrast, in the same population of patients, with the Airtraq, intubation force was not only less in magnitude (previously reported[9c]) but also less dependent on glottic view. Suppose that (1) a 10 N difference in intubation force was the least clinically significant difference and (2) 20% difference in glottic view was the least clinically significant difference. If so, these differences would result in a slope of (10 N/20%) 0.5 N per degree. Because the observed difference in slopes between the Macintosh and Airtraq exceeded 0.5 N/degree (0.603 [least-squares regression]; 0.747 [robust regression]), the difference may be clinically important.

Table. Patient Glottic Visualization and Intubation Force Data

Variable	Macintosh (n = 14)	Airtraq (n = 14)
Percentage of glottic opening visualized, %	74 ± 16 75 (64–85)	90 ± 10 90 (79–100)
Maximum intubation force, N	48.8 ± 15.8 48.4 (35.5–66.0)	10.4 ± 2.8 10.7 (8.1–13.1)

Values are expressed as mean ± SD and median (interquartile range). Values were obtained when the laryngoscope was in final position, immediately before the endotracheal tube was placed in the glottis. Data were derived from Hindman et al.[9]

Abbreviation: SD, standard deviation.

Our study was a post hoc analysis of data from a study that was not designed to test the hypothesis considered in this report. Consequently, this study has numerous limitations, and its finding and conclusions should be considered to be tentative. A limitation of our Airtraq data is that glottic view was never <75%.[d] We speculate that, in circumstances in which Airtraq glottic views are <75%, anesthesiologists might apply greater force in an attempt to improve glottic view, potentially approaching Macintosh force values. For example, a recent case report describes a cervical spine fracture occurring in a patient with ankylosing spondylitis in whom the glottis could not be visualized with a videolaryngoscope.[2,15] In addition, there are case reports of videolaryngoscope blade fractures, which require hundreds of Newtons of applied force.[16]

Another limitation of our study was that anesthesiologists were tasked to achieve the best possible glottic view whereas, in clinical practice, a glottic view sufficient only to place the endotracheal tube in the glottis may more often be the goal. With the latter approach, anesthesiologists may apply less force than what was applied in this study, especially with the Macintosh. In 3 of 4 clinical studies that have compared intubation forces between the Macintosh and indirect laryngoscopes (including this study), only patients who were expected to be easy to intubate were enrolled.[9–11] In these 3 studies, mean intubation forces with the indirect laryngoscope as a percentage of the Macintosh values were 20% (Glidescope),[11] 21% (Airtraq),[9] and 45% (Glidescope).[10] In contrast, in the study by Cordovani et al,[12] in which only patients who had risk factors for difficult intubation were studied,

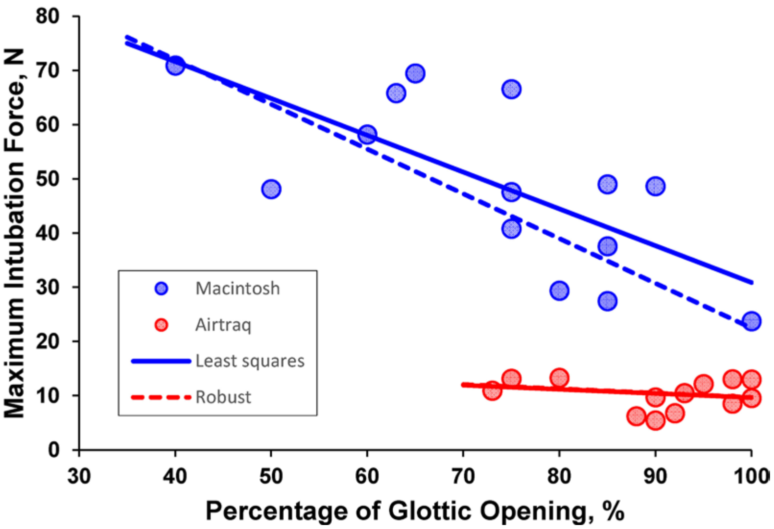

Figure. Individual patient values for percentage of glottic opening visualized and maximum intubation force. Macintosh values are shown in blue, and Airtraq values are shown in red. For graphical presentation, data points are jittered ±2% along the horizontal axis to reduce overlap. For the Airtraq, the least-squares and robust regression lines nearly entirely overlap. The pairwise Pearson correlation coefficient of the residuals by subject was 0.12 for the least-squares regression (N = 14).

the mean intubation force of the Glidescope was 81% of the Macintosh value. Collectively, these studies support the possibility that force differences between direct and indirect laryngoscopes may depend greatly on patient characteristics and/or clinical goals and circumstances.

Mean Macintosh force values have differed markedly among studies; 20 N,[10] 21 N,[12] 40 N,[11] and 48.8 N,[9] the latter as analyzed currently. These large force differences may be due, at least in part, to different force measurement methods, with the potential for marked underestimation of total applied force when force sensors do not cover the entire contact surface of the laryngoscope blade.[10,12]

In conclusion, compared with the Macintosh, intubation force magnitude with Airtraq laryngoscopy was less dependent on glottic visualization. Additional studies regarding the determinants of intubation force magnitudes with direct and indirect laryngoscopy, with varied patient populations and clinical conditions, are indicated.

DISCLOSURES

Name: Bradley J. Hindman, MD.
Contribution: This author helped design the study, obtain and analyze the data, and write the manuscript.
Name: Franklin Dexter, MD, PhD, FASA.
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