Head-Elevated Laryngoscopy Position: Improving Laryngeal Exposure During Laryngoscopy by Increasing Head Elevation

Study objective: The objective of this study was to determine the effect of increasing head elevation and neck flexion on the quality of laryngeal view during laryngoscopy.

Methods: Laryngoscopy with a straight blade was performed on 7 fresh human cadavers. Laryngeal views were recorded with the direct laryngoscopy video system, and the laryngoscopy angle was measured throughout the procedure with an angle finder attached to the handle of the laryngoscope. Each cadaver had laryngoscopy initiated with the head lying flat on the table and with atlanto-occipital extension. The head was then progressively elevated as much as possible (the head-elevated laryngoscopy position), increasing neck flexion and the laryngoscopy angle. Three physicians blinded to the laryngoscopy angle graded the quality of laryngeal view using the percentage of glottic opening (POGO) score.

Results: The laryngoscopy angle ranged from a mean of $32^\circ \pm 8^\circ$ (1 SD) with the head flat on the table to a mean of $67^\circ \pm 8^\circ$ with the head-elevated laryngoscopy position. The mean midposition laryngoscopy angle was $49^\circ \pm 6^\circ$. Comparing the 3 positions, mean POGO scores $\pm 1$ SD significantly increased from $31\% \pm 10\%$ (flat position) to $64\% \pm 12\%$ (midposition) to $87\% \pm 13\%$ (head-elevated laryngoscopy position). Both the midposition and the head-elevated laryngoscopy position compared with the flat position were statistically significant at a $P$ value of less than .0001. The midposition also differed significantly from the head-elevated laryngoscopy position ($P<.0007$). Additionally, there was a significant linear relationship among the 3 positions ($P<.0001$).

Conclusion: Increasing head elevation and laryngoscopy angle (neck flexion) significantly improves POGO scores during laryngoscopy on fresh human cadavers.

INTRODUCTION

The importance of proper head and neck positioning for optimizing laryngeal view during laryngoscopy has been recognized since the procedure was first described by Kirstein in 1895. Reference textbooks routinely emphasize slight elevation of the head, extreme atlanto-occipital extension, and lifting the handle of the laryngoscope in a 45° direction.

Direct laryngoscopy is the mainstay of emergency airway management, and despite the proliferation of difficult airway devices, alternative methods of intubation are used extremely infrequently in all settings. Whether in the emergency department or in the operating room, there is a large discrepancy between the incidence of difficult laryngoscopy (ie, multiple attempts or poor laryngeal view), which ranges from 5% and 18%, and the rate of failed laryngoscopy, which ranges from less than 0.4% in the ED to 0.05% in the operating room. In most instances, difficult laryngoscopy correlates with poor laryngeal exposure. A study of nearly 1,200 cases in the operating room identified patient repositioning among the most common means of facilitating intubation after an initial failed laryngoscopy but did not define specific positioning changes.

The assumptions regarding optimal positioning for laryngoscopy have historically received little scientific scrutiny. Two recent studies have questioned standard practice regarding head and neck positioning but seemingly came to different conclusions, with one suggesting that increasing neck flexion was beneficial, and the other concluding there was little benefit to mild head elevation (and neck flexion) over simple extension. Neither of these studies used direct laryngoscopy imaging to dynamically record laryngeal view and instead relied on estimations of transiently observed laryngeal view at different positions, each using a nonvalidated system of grading laryngeal view. Each also had other issues that potentially limit the value of their conclusions. One study used a curved blade, introducing the significant (and unmeasured) variable of how the tip of the blade interacts with the hyoepiglottic ligament and vallecula because minor changes in force and direction at this location can markedly alter laryngeal exposure. The other study did not standardize positioning through measurements between patients or in any way measure head elevation or laryngoscopy angle in the different positions.

The authors’ prior research has combined the use of the direct laryngoscopy video system with a validated means of assessing recorded laryngeal images (ie, the percentage of glottic opening [POGO] score). Through prior video recordings of laryngoscopy and our own clinical practice, we had anecdotal evidence suggesting that increasing head elevation was a simple, effective, and easily applied means of improving laryngeal exposure.

This study was designed to apply laryngeal imaging and POGO scoring to objectively assess the effect of dynamically increasing head elevation and associated neck flexion on the quality of laryngeal view. Quantifying the amount of head elevation is difficult to dynamically measure, and a specific amount of head elevation can have greater or less effect on resultant neck flexion depending on a patient’s body habitus. Lifting the patient’s head, however, also changes the directional force along the laryngoscope handle, as well as the operator’s angle of view down the lumen of the blade. This laryngoscopy angle can be readily measured with an angle finder and can serve as a means of quantifying the change in position resulting from head elevation.

MATERIALS AND METHODS

The study was performed on 7 fresh human cadavers, 4 male and 3 female, at the medical school morgue at the University of Pennsylvania School of Medicine. Laryngoscopy was performed with a Henderson laryngoscope blade (Karl Storz Endoscopy, Inc., Culver City, CA). Like the Miller blade, the Henderson blade is a straight blade with a narrow flange height, but it has a slightly different-shaped lumen and a completely straight visible distal tip (Figure 1). The upturned tip of the Miller blade or any curved blade design could potentially cause a discrepancy between the laryngoscopy angle (as measured and defined below) and the opera-
IMPROVING LARYNGEAL EXPOSURE BY INCREASING HEAD ELEVATION
Levitan et al

The laryngoscopy angle was measured with a commercially available angle finder obtained at a local hardware store (Home Depot, Inc., King of Prussia, PA), which was attached lengthwise to the laryngoscope handle with plastic cable ties (Figures 2 and 3). Because of the perpendicular position of the straight Henderson blade to the handle and the manner that the angle finder was affixed on the handle, the resultant angle on the angle finder correlated with the angle of the laryngoscope blade relative to the patient. For example, if the blade was oriented parallel to both the floor and the long axis of the patient (with the handle pointing straight up toward the ceiling), this would represent a laryngoscopy angle of 0°. If the blade was positioned pointing vertically downward and perpendicular to both the floor and the long axis of the patient (with the handle now parallel to the patient), this would represent a laryngoscopy angle of 90°.

Laryngoscopy was initiated with the head flat on the table, with the occiput resting on the table and the head extended at the atlanto-occipital joint (Figure 2). The head was then progressively lifted from the table to a height as high as possible (by the laryngoscopist’s right hand), which simultaneously increased the degree of neck flexion and the laryngoscopy angle displayed on the angle finder (Figure 3).

Figure 1.
The Henderson straight laryngoscope blade (Karl Storz Endoscopy, Inc.). The blade is straight along its entire length, has a relatively small flange height, and has a visible distal tip.

Figure 2.
Laryngoscopy with the head flat on the table with an angle finder attached lengthwise to the laryngoscope handle. The laryngoscope angle is approximately 40°. Inset is the view of the larynx as displayed by the direct laryngoscopy video system worn by the laryngoscopist. The POGO score is approximately 30%.

Figure 3.
Laryngoscopy with the head fully elevated (ie, the head-elevated laryngoscopy position). The laryngoscopist is using the right hand to elevate the head. The laryngoscopy angle is approximately 80°, and the POGO score in the inset is approximately 90%.
The laryngeal view was imaged continuously by using the Airway Cam direct laryngoscopy video system (Airway Cam Technologies, Inc., Wayne, PA).\textsuperscript{19} The direct laryngoscopy video system uses a head-mounted miniature video camera that is aligned with the line of sight of the laryngoscopist’s dominant pupil. Video recording was done with a Sony GVD-300 (Sony Corporation, Tokyo, Japan) digital videocassette recorder, capturing 30 frames per second. In addition to the video recordings made with the direct laryngoscopy video system, a Sony DCR-PC1 (Sony Corporation) digital camcorder was simultaneously operated by an assistant to record the laryngoscopy angle as seen from a position perpendicular to the patient. The video recordings of laryngeal view and the angle finder were synchronized and superimposed with Adobe Premier 6.0 video editing software (Adobe Systems, Inc., Seattle, WA; Figures 2 and 3).

The synchronized video clips were reviewed by 1 of the authors (RML), and laryngoscopy angles were recorded in 3 positions on each patient: head flat on the table, full elevation, and a midposition that was selected by observing the range of head elevation on the videotapes for each cadaver. Full elevation position was the greatest amount of head elevation and greatest amount of neck flexion achievable in each cadaver. The laryngeal views at the 3 positions were graded by 2 emergency physicians (CCM, JEH) and 1 anesthesiologist (EAO) using the POGO score.\textsuperscript{20,21} The 3 physicians were blinded to the laryngoscopy angle associated with each laryngeal view, as well as to each other’s POGO scores.

The POGO score describes how much of the glottic opening is visible; a 100\% POGO score includes visualization of the entire glottic opening from the anterior commissure of the vocal cords to the interarytenoid notch (Figure 4). A POGO score of 0\% corresponds with no visualization of laryngeal structures (ie, epiglottis or tongue-only views). The POGO score has been shown to have excellent intrarater and interrater reliability and to correlate with success of intubation, as well as with need for rescue intubation devices.\textsuperscript{20,21,24}

POGO scores were assigned to each cadaver at 3 positions from the videotape recordings: head flat on the table, midposition, and full elevation. A 3-way analysis of variance in repeated measures (1 observation per cell) was used where the 2 repeated measures were rater of neck flexion achievable in each cadaver. The laryngeal views at the 3 positions were graded by 2 emergency physicians (CCM, JEH) and 1 anesthesiologist (EAO) using the POGO score.\textsuperscript{20,21} The 3 physicians were blinded to the laryngoscopy angle associated with each laryngeal view, as well as to each other’s POGO scores.

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Figure 4.
POGO score. Full visualization of the glottic opening from the anterior commissure to the interarytenoid notch equals 100\%. When no portion of the glottis is seen (ie, epiglottis or tongue-only views), the POGO score equals 0\%. POGO scoring does not distinguish between these 2 situations.

Figure 5.
Mean laryngoscopy angles at 3 different head positions in 7 cadavers. The midposition was determined by reviewing videotaped images of laryngoscopy from a perspective perpendicular to the patient. Bars represent mean±1 SD.
and position to determine differences in position. A linear contrast was included to assess the linearity of the relationship. Data are presented as mean±SD POGO scores. Mean±SD laryngoscopy angles are also presented. All data were analyzed with SAS statistical software (version 8.0; SAS Institute, Inc., Cary, NC). A P value of less than .05 was considered statistically significant.

The study was approved by the Institutional Review Board of the University of Pennsylvania.

RESULTS

In all 7 cadavers, POGO scores improved with increasing head elevation and laryngoscopy angle (Figures 5 and 6).

The laryngoscopy angle ranged from a mean±SD of 32°±8° with the head flat on the table to a mean of 67°±8° with the head-elevated laryngoscopy position. The mean midposition laryngoscopy angle was 49°±6°.

Comparing the 3 positions, POGO scores significantly increased from a mean±SD of 31%±10% (flat position) to 64%±12% (midposition) to 87%±13% (head-elevated laryngoscopy position; Figure 6). Both the midposition and the head-elevated laryngoscopy position compared with the flat position were statistically significant at a P value of less than .0001. The midposition also differed significantly from the head-elevated laryngoscopy position (P<.0007). Additionally, there was a significant linear relationship among the 3 positions (P<.0001). There were no differences between raters (P=.14).

DISCUSSION

Our results validate the assertions of the early pioneers of laryngoscopy, who emphasized the importance of head elevation for optimal laryngeal exposure (Figure 7).1,28,29 Only 2 prior studies, however, have specifically examined how changing head and neck position in the same patient affects the resultant laryngeal view.16,17

Adnet et al17 compared laryngeal exposure in the “sniffing” position (defined as 7-cm occiput elevation) versus simple head extension (head flat) with a curved laryngoscope blade. They found no significant advantage to the sniffing position over simple head extension in routine practice. Their study used Cormack and Lehane grading, no objective recording of laryngeal views, and 7 different laryngoscopists performing the intubations. Their prior research has shown that Cormack and Lehane grading has poor intraobserver and interobserver reliability and that it is insensitive in detecting differences among the vast majority of patients at laryngoscopy.20,21 The most significant limitation of the study by Adnet et al is that they performed laryngoscopy with a Macintosh curved laryngoscope blade. Curved blades are significantly dependent on minor changes in the force applied to the hyoepiglottic ligament and tip placement in the vallecula.22,23 Collectively, these variables might have obscured the effect of changes in head positioning.
Hochman et al studied the effects of straight laryngoscope blade size, as well as head and neck positioning, on the force required for optimal laryngeal exposure. They concluded that increasing head elevation and neck flexion increased the incidence of full laryngeal exposure with less required force. Hochman et al characterized the position that optimized laryngeal exposure as “flexion-flexion,” referring to both atlanto-occipital flexion and cervicothoracic vertebrae flexion. An analysis of their photographs, however, suggests that the atlanto-occipital joint is not truly flexed (ie, the laryngoscopy angle is not >90°). In our study, the laryngoscopy angle was always less than 90°, even at full head elevation. For this reason and also because “head elevated” is a simpler term to describe the primary movement, we believe that “head-elevated laryngoscopy position” is a better term for this type of positioning than “flexion-flexion.”

Our study has several limitations; we had a small sample size, and all laryngoscopies were performed by one laryngoscopist. We only studied laryngoscopy with one blade design, and our results might not be transferable to more commonly used blades. Although we believe that fresh cadavers approximate the mechanical response to laryngoscopy in living patients, there might have been unrecognized different responses to tongue compression or other aspects of laryngoscopy that might have affected our results. There is stress relaxation of the pharyngeal tissues and tongue during laryngoscopy in live patients, and this might be different than the response in cadavers. We performed laryngoscopy repeatedly to minimize the effect of sequence on the results and did not observe significant differences between laryngeal views at various positions going up versus going down, but this was not specifically measured.

Our results focused on increasing glottic exposure, but full exposure of the glottis is not required for intubation, and the relevance of this degree of exposure for intubation, particularly anterior glottic exposure, is unknown. A prior study of nearly 6,000 patients found that increasing POGO scores by greater than 25% is clinically significant and that there is correlation between decreased POGO scores and the number of intubation attempts, as well as the need for rescue intubation devices. It is unclear from this limited study how...
effective the head-elevated laryngoscopy position would be in instances when it is truly needed (ie, when initial POGO scores are 0% or otherwise very low). We believe that the technique improves the view across the entire spectrum of laryngeal visualization, but we did not have enough cases of poor initial view to prove this in the present study.

Finally, although we believe that the head-elevated laryngoscopy position improves laryngeal view, the study only used cadavers, and the safety of this technique in living patients was not assessed. Obviously, aggressive manipulation of the neck, even the standard intubating position, is contraindicated in instances of potential or existent cervical spine injury or pathology.31,32

Ironically, there has been one case report of emergency intubation with extreme flexion positioning on a patient with ankylosing spondylitis and fixed flexion of the cervical spine.33 Mindful of the patient’s preprocedure cervical spine position, the clinician lowered the head of the bed into the Trendelenburg position and supported the patient’s head with a pillow; the resultant laryngoscopy angle was almost 90°, and the vocal cords were completely exposed.33

There is evidence from radiographic studies and clinical reports that increasing head elevation might be safer than increasing atlanto-occipital extension in situations of poor laryngeal exposure. Neurologic injury related to overaggressive head and neck extension during laryngoscopy has been reported, specifically central cord syndrome.34 Radiographic analysis has shown that extension from C1-C4 is near maximal in the standard intubating position, when the lower spine is relatively straight.35 For this reason, it has been suggested that if standard positioning is to be modified, any additional extension should be avoided, and instead additional flexion (ie, head elevation) should be attempted.35

Modifications of laryngoscopy techniques that can increase first-pass intubation success are critical in the emergency setting. Simple maneuvers that can improve laryngeal view without requiring special tools, extensive training, or expense are particularly valuable given the reliance in the ED on laryngoscopy and the clinical issues facing patients who require emergency intubation.5,36 We believe that the easiest, fastest, and most effective modification to improve view is external laryngeal manipulation.22 For patients in whom neck movement is not contraindicated, the head-elevated laryngoscopy position is a second modification that can be easily performed during initial laryngoscopy efforts if the laryngeal view remains inadequate. The simplest way to achieve the head-elevated laryngoscopy position is for the laryngoscopist to directly lift the patient’s head with his or her right hand. The right hand must be released to pass the tracheal tube, but for patients of normal dimensions, suspending the head with the laryngoscope only for a brief moment is not difficult. In situations of extreme obesity, effective head elevation can-
not be done singlehandedly by the laryngoscopist and instead requires massive amounts of support placed under the shoulders, as well as the head (Figure 8). Alternatively, as demonstrated by Hochman et al., the patient’s head can be supported by the laryngoscopist’s torso leaning inward, but with a standard stretcher, this requires the patient’s head to be positioned at the extreme edge of the bed. The head-elevated laryngoscopy position can also be easily achieved with an assistant, which was the technique advocated by Jackson and Jackson. We believe this is best accomplished by the assistant being at a position near the head of the bed, crouching down until his or her shoulders are at the level of the patient, and then lifting with both arms to support the patient’s head and shoulders.

This study demonstrates significantly improved POGO scores on fresh cadavers by using the head-elevated laryngoscopy position. We have had anecdotal success with the head-elevated laryngoscopy position in our ED during difficult laryngoscopies and believe the technique warrants prospective study with laryngoscopic imaging in living patients. Further study is needed to define its utility in cases of very poor initial laryngeal view, as well as to prove its safety and efficacy in the emergency setting.

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Author contributions: RML designed the study and performed all the laryngoscopies. CCM and EAO videotaped and provided assistance in the cadaver laboratories. CCM, EAO, and JEH performed POGO scoring of the laryngeal images. JEH and FSS were responsible for revising the paper, as well as the statistical analysis. RML takes primary responsibility for the paper as a whole.

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Dr. Levitan is the patent holder on the direct laryngoscopy video system used for videographic imaging of laryngoscopy in this study.

He is also a principal owner of Airway Cam Technologies, Inc., Wayne, PA, which produces and sells the imaging system.

Reprints not available from the authors.

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Levitan et al


