The Laryngoscope

TRIOLOGICAL SOCIETY CANDIDATE THESIS

Mallampati Class, Obesity, and a Novel Airway Trajectory Measurement to Predict Difficult Laryngoscopy

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Objectives/Hypothesis: To determine whether Mallampati class correlates with Cormack-Lehane grade in obese adults, and investigate a novel airway trajectory measurement (ATM) to anticipate difficult laryngoscopy.

Study Design: Retrospective cohort plus a pilot study.

Methods: One hundred eighty-four nonobese and 160 obese adults underwent laryngoscopy. Spearman correlations, gamma coefficients (G), and Kendall's τ investigated body mass index (BMI):Mallampati, BMI: Cormack-Lehane, and Mallampati:Cormack-Lehane. A z test compared the two groups. Twenty-six volunteers had neck x-rays taken in the sniffing position to examine trajectories to the larynges (ATM).

Results: Positive predictive value of high Mallampati for difficult laryngoscopy was 8.57%. BMI did not correlate with Mallampati ($r = 0.055$ [nonobese], $r = -0.056$ [obese]) or Cormack-Lehane [$r = -0.014$ [nonobese], $r = -0.022$ [obese]). Among nonobese adults, gamma coefficients for BMI:Mallampati was 0.039 ($P = .63$), for BMI:Cormack-Lehane was 0.02 ($P = .85$), and for Mallampati:Cormack-Lehane was 0.43 ($P = .004$). Among obese adults, gamma coefficients for BMI:Mallampati was -0.127 ($P = .16$), for BMI:Cormack-Lehane was 0.014 ($P = .88$), and for Mallampati:Cormack-Lehane was 0.365 ($P = .01$). Kendall's τ were comparable to gamma coefficients in all analyses. When comparing gamma coefficients for Mallampati:Cormack-Lehane among the nonobese and obese, z = 0.04 ($P = .98$). In the ATM study, only Mallampati and upper lip bite test had a significant relationship (G = 1.00, $P < .001$).

Conclusions: Mallampati correlates poorly with Cormack-Lehane, regardless of BMI. Pilot data suggest that ATM is feasible.

Key Words: Obesity, difficult laryngoscopy, Mallampati, Cormack-Lehane, airway trajectory measurement.

Level of Evidence: 4.

***Laryngoscope*, 125:161–166, 2015**

INTRODUCTION

In 1985, Mallampati presented a classification to predict difficult laryngoscopy in adults.[1] This correlated with glottic exposure similar to the Cormack-Lehane grades: (1) glottis is visible, (2) only the posterior glottis is visible, (3) only the epiglottis is visible, and (4) even the epiglottis cannot be exposed.[2] In 1987, Samsoon and Young modified the Mallampati classification to a four-class system,[3] which also better aligns them with the Cormack-Lehane grades. This present study uses the modified Mallampati and Cormack-Lehane systems.[1–3]

In the Mallampati study, four of the 210 patients (1.9%) were obese.[1] In 2008, 34% of the US population was obese, so Mallampati assessments may not be accurate (World Health Organization [WHO], http://apps.who.int/bmi/).[4] Unrecognized difficult intubation during general anesthesia could lead to cerebrovascular ischemia, aerodigestive tract trauma, and death. Therefore, a reliable method to identify patients at risk for difficult laryngoscopy would better prepare the operating team without over utilizing difficult airway resources. If Mallampati class does not serve this purpose, then alternative assessments should be evaluated. Bridging this knowledge gap would ultimately improve patient safety.

MATERIALS AND METHODS

The institutional review board approved this project. First is a retrospective cohort study of nonobese (body mass index [BMI] < 30 kg/m^2) and obese adults (BMI ≥ 30 kg/m^2) undergoing general endotracheal anesthesia. This BMI criterion is defined by the WHO. The data collected include BMI, Mallampati class, and Cormack-Lehane grade (Fig. 1).

A minimum of 160 patients is needed per group based on the following assumptions: (1) type I error, $\alpha = 0.05$; (2) type II error, $\beta = 0.80$; and (3) the correlations approach 1. These

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Editor's Note: This Manuscript was accepted for publication June 23, 2014.

Presented as a Triological Society candidate thesis paper at the Triological Society 117th Annual Meeting at COSM, Las Vegas, Nevada, U.S.A., May 15–16, 2014.

This work was performed at Altru Hospital, Grand Forks, North Dakota, U.S.A.

The authors have no funding, financial relationships, or conflicts of interest to disclose.

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DOI: 10.1002/lary.24829

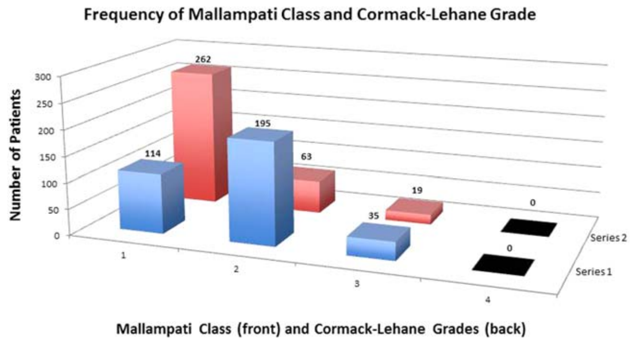

Fig. 1. Frequency of Mallampati class and Cormack-Lehane Grade. Series 1 (front) is the assigned Mallampati classes (I to IV). Series 2 (back) is for Cormack-Lehane grades (1 to 4). Both series represent all patients, nonobese, and obese. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

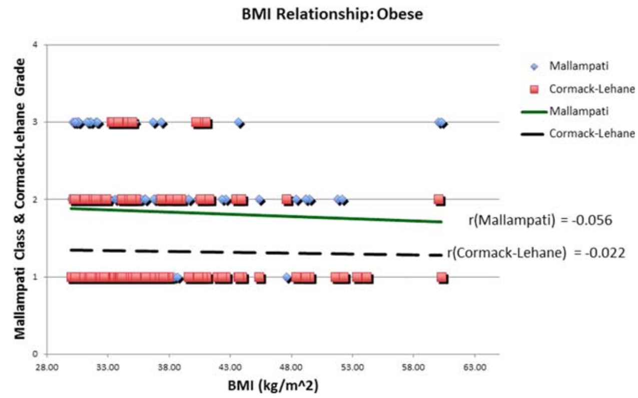

Fig. 3. Body mass index (BMI) correlation in the obese. BMI as a function of preoperative Mallampati class and intraoperative Cormack-Lehane grade for the obese. Spearman correlations were $r_{Mallampati} = -0.056$ and $r_{Cormack\text{-}Lehane} = -0.022$ for the obese. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

statistical assumptions are supported by the original Mallampati study,[1] in which the positive predictive value (PPV) and negative predictive value (NPV) were 93.3% and 92.8%, respectively.[1,5] Furthermore, a previously reported correlation index for Mallampati class and Cormack-Lehane grade is $r = 0.904$.[6] A z test for two gamma coefficients (G) then compares the data for the nonobese and obese patients.

The relationships between BMI:Mallampati and BMI:Cormack-Lehane are evaluated with Spearman correlations (Figs. 2 and 3). The relationships between BMI:Mallampati, BMI:Cormack-Lehane, and Mallampati:Cormack-Lehane are studied with Kendall's τ and are reported for comparison.

The 2011-year operating schedule was reviewed to identify study patients. Exclusion criteria were: children, nasotracheal intubation, emergency intubation, fiberoptic-assisted intubation, existing tracheostomies or laryngectomies, laryngeal mask airway cases, regional anesthesia without intubation, and incomplete charts. Inclusion criteria were adult ($\geq$18 years) male and female patients undergoing direct laryngoscopy for the purpose of general endotracheal anesthesia. Graphical presentations were performed with Microsoft Excel 2008 for Mac (Microsoft Corp., Redmond, WA) and statistical analyses with SPSS Statistics version 19 (SPSS, Chicago, IL). Predictive values for high Mallampati class (III or IV) and obesity on predicting difficult laryngoscopy (Cormack-Lehane grade 3 or 4) were also calculated (Table I).

The separate pilot study consisted of 9 male and 17 female volunteers. After informed consent, 72-inch lateral neck x-rays were taken in the sniffing position with the mouth opened widely. Mallampati classes and upper lip bite test (ULBT) were assigned by the first author.[7] ULBT classes are: I = lower incisors can bite above the upper lip vermillion, II = lower incisors bite below the vermillion, and III = lower incisors cannot bite the upper lip. Airway trajectory measurement (ATM) trajectories were measured from maxillary incisors (alveolus if edentulous), through the vallecula, and projected onto the larynx (Fig. 4). If the ATM projects to the arytenoids or anterior to them, then it was favorable (Fig. 5). If the projection lies posterior to the arytenoids, then the designation was unfavorable (Fig. 6). Direct laryngoscopies were not performed in this

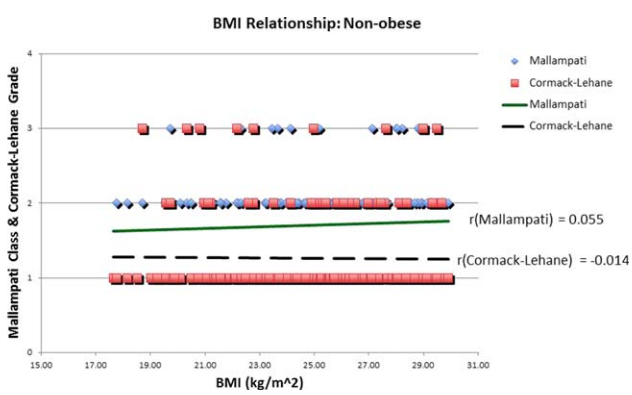

Fig. 2. Body mass index (BMI) correlation in the nonobese. BMI as a function of preoperative Mallampati class and intraoperative Cormack-Lehane grade for the nonobese. Spearman correlations were $r_{Mallampati} = 0.055$ and $r_{Cormack\text{-}Lehane} = -0.014$. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

TABLE I.
Mallampati Class as a Predictor for Difficult Laryngoscopy.

	Cormack-Lehane 3, 4	Cormack-Lehane 1, 2	Total
Nonobese			
Mallampati III, IV	2	12	14
Mallampati I, II	7	163	170
Total	9	175	184
Obese			
Mallampati III, IV	1	20	21
Mallampati I, II	9	130	139
Total	10	150	160
All patients			
Mallampati III, IV	3	32	35
Mallampati I, II	16	293	309
Total	19	325	344

The positive predictive values of high Mallampati class (III or IV) on difficult laryngoscopy (Cormack-Lehane grade 3 or 4) for nonobese, obese, and all patients are 14.29%, 4.76%, and 8.57%, respectively. The corresponding negative predictive values are 95.88%, 93.53%, and 94.82%, respectively.

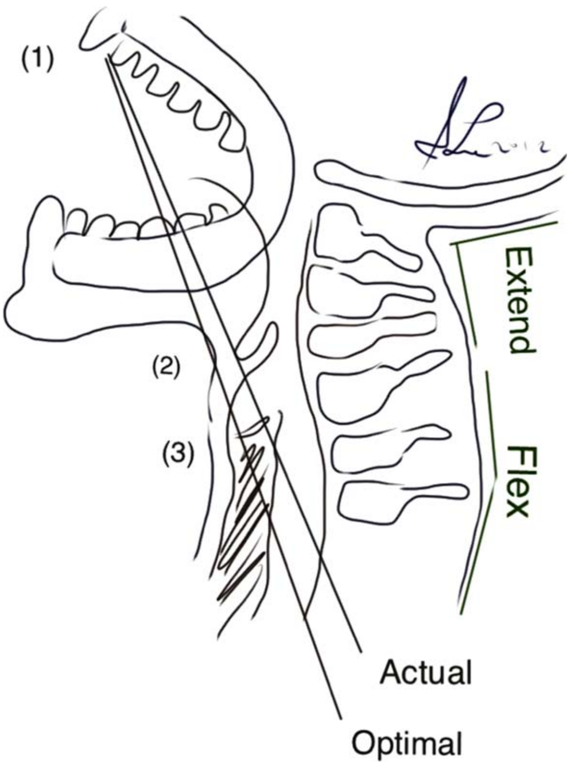

Fig. 4. Airway trajectory measurement. The actual trajectory is a line from the maxillary incisors (1), through the vallecula (2), and extends to project onto the larynx (3). Optimal projection starts at (1) and projects onto the anterior glottic introitus. Sniffing position with the mouth open helps to align the actual and optimal projections. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

feasibility study. Relationships for Mallampati and ULBT, Mallampati and ATM, and ULBT and ATM were evaluated with gamma coefficients for nonobese and obese groups.

RESULTS

One hundred eighty-four nonobese (control) and 160 obese adults were included in this study. Linear correlation for BMI and Mallampati was $r_{\text{Mallampati}} = 0.055$ for the nonobese and $r_{\text{Mallampati}} = -0.056$ for the obese. Linear correlation for BMI and Cormack-Lehane grade was $r_{\text{Cormack-Lehane}} = -0.014$ for the nonobese and $r_{\text{Cormack-Lehane}} = -0.022$ for the obese (Figs. 2 and 3).

The PPV of a high Mallampati class (III or IV) to predict a difficult laryngoscopy (Cormack-Lehane grades 3 or 4) in the nonobese was 14.29% and 4.76% for obese patients. NPVs were 95.88% (nonobese) and 93.53% (obese). The PPV of obesity to predict difficult laryngoscopy was 6.25%, and NPV was 95.11% (Table I).

In the nonobese group, for BMI:Mallampati $G = 0.039$ ($P = .63$), for BMI:Cormack-Lehane $G = 0.02$ ($P = .85$), and for Mallampati:Cormack-Lehane $G = 0.43$ ($P = .004$). Kendall's $\tau = 0.032$ ($P = .63$), 0.011 ($P = .85$), 0.193 ($P = .004$), respectively. In the obese group, gamma coefficients for BMI:Mallampati was $G = -0.127$ ($P = .16$), for BMI:Cormack-Lehane $G = 0.014$ ($P = .88$), and for Mallampati:Cormack-Lehane $G = 0.365$ ($P = .01$).

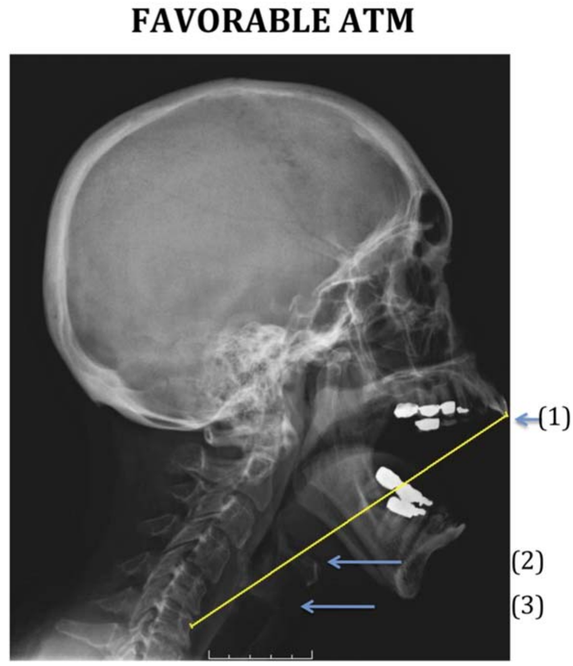

Fig. 5. Favorable airway trajectory measurement (ATM). Standard 72-inch lateral neck x-ray, taken in the sniffing position with the mouth opened widely, demonstrating a favorable airway trajectory measurement. Maxillary incisors (1), vallecula (2), and larynx (3) are as labeled. A linear projection is drawn from (1), through (2), and projects successfully onto (3). [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

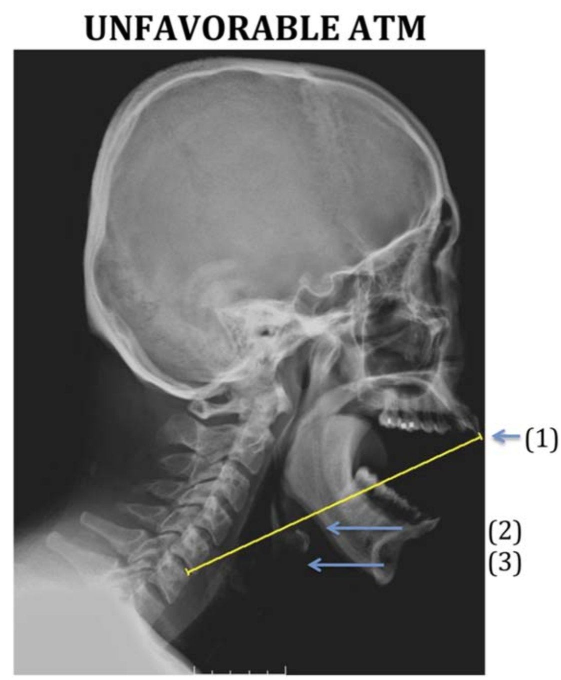

Fig. 6. Unfavorable airway trajectory measurement (ATM). Standard 72-inch lateral neck x-ray, taken in the sniffing position with the mouth opened widely, demonstrating an unfavorable airway trajectory measurement. Maxillary incisors (1), vallecula (2), and larynx (3) are as labeled. A linear projection is drawn from (1), through (2), and projects posterior to the larynx (3). [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

TABLE II.
Gamma Coefficient and Kendall's τ for the Correlation Comparisons.

Groups	Gamma Correlation and Kendall's τ		
	Correlations	G, P Value [95% CI]	τ, P Value
Nonobese (n = 184)	BMI: Mallampati	0.039, .63 [−0.12 to 0.2]	0.032, 0.63
	BMI: Cormack-Lehane	0.02, .85 [−0.19 to 0.23]	0.011, 0.85
	Mallampati: Cormack-Lehane	0.438, .004 [0.17 to 0.71]	0.193, .004
Obese (n = 160)	BMI: Mallampati	−0.127, .16 [−0.30 to 0.05]	−0.106, .16
	BMI: Cormack-Lehane	0.014, .88 [−0.16 to 0.19]	0.009, .88
	Mallampati: Cormack-Lehane	0.365, .01 [0.08 to 0.65]	0.189, .01

BMI = body mass index; CI = confidence interval; G = gamma coefficient.

Kendall's $\tau = -0.106$ ($P = .16$), 0.009 ($P = .88$), 0.189 ($P = .01$), respectively (Table II). In comparing gamma coefficients for Mallampati:Cormack-Lehane among the nonobese and obese, z = 0.04 ($P = .98$).

For the pilot study, average BMI was 26.97 kg/m^2 (range, 21.61–34.29 kg/m^2). Nineteen of 26 (73%) volunteers were nonobese. Anatomical landmarks could be identified and ATM performed in about 2 minutes for all volunteers. Mallampati classes were I (n = 8), II (n = 9), III (n = 9), and IV (n = 0). ULBT classes were I (n = 14), II (n = 10), and III (n = 2). There were 20 favorable (Fig. 5) and six unfavorable (Fig. 6) projections. Evaluation of the relationship between Mallmapati and ULBT showed G (n = 19, nonobese) = 0.50 ($P = .13$) and G (n = 7, obese) = 1.00 ($P < .001$). Evaluation of the relationship between Mallmapati and ATM showed G (n = 19, nonobese) = −0.73 ($P = .86$) and G (n = 7, obese) = −0.33 ($P = .61$). For the relationship between ULBT and ATM, G (n = 19, nonobese) = 0.33 ($P = .56$) and G (n = 7, obese) = 0.00 ($P > .99$). Thus, the nonobese and obese volunteers did not differ (z test) on the Mallampati:ATM and ULBT:ATM comparisons because neither gamma coefficient is significantly different from zero. The two volunteer groups do differ in the Mallampati:ULBT comparison because the nonobese gamma coefficient is not significantly different from zero whereas the obese gamma coefficient is.

DISCUSSION

Mallampati and modified Mallampati preoperative assessments were reported to correlate with Cormack-Lehane grades,[1–3] but criticisms include interobserver variability, incorrect assignment, and limited reliability.[5,8–14] Furthermore, <2% of the patients were obese in the original Mallampati study.[1] However, the preobese (BMI 25–29.99 kg/m^2) and obese (BMI $\geq$30 kg/m^2) groups now represent 64% of the US population. Despite these concerns, both classifications are simple and widely used.

Theories to explain difficult intubation in obese patients include: fatty tissue in the neck, chest, abdomen, and pharynx may compromise intubation[15]; limited neck extension, anatomy distortion, and tissue reactivity[16,17]; fat distribution[18]; large necks[19]; diabetes mellitus[8,20]; and obstructive sleep apnea.[21] Men were also more likely to require fiberoptic intubation than women in a retrospective study.[22] These factors are believed to compromise laryngoscopy and therefore tracheal intubation.[14]

In this study, the PPV of obesity to predict difficult laryngoscopy is 6.25%, and the NPV is 95.11%. A z test for two gamma coefficients to investigate for a difference between the nonobese and obese groups is z = 0.04 ($P = .98$). Together, these data suggest that obesity is a poor predictor for difficult laryngoscopy, and that Mallampati classes and Cormack-Lehane grades do not differ between the nonobese and obese groups.

In a 2004 Italian study of 1,956 adults, the linear correlation between Mallampati class and Cormack-Lehane grade was 0.904,[6] but the BMIs are not reported. This present study shows no such correlation (Figs. 2 and 3). A Czech Republic study of 1,518 patients found the PPV of a high Mallampati class on predicting difficult laryngoscopy was 10.7%, and the NPV was 98.6%.[5] This compares well with the PPV = 8.57% and NPV = 94.82% for all patients in this present study (Table I). In contrast, Mallampati's study had PPV = 93.3% and NPV = 92.8%.[1,5] This variability raises concern about the reliability of Mallampati assessments. The results of this present study also did not show obesity to predict a high Mallampati class: $PPV_{Nonobese} = 14.29\%$ and $NPV_{Nonobese} = 95.88\%$ versus $PPV_{Obese} = 4.76\%$ and $NPV_{Obese} = 93.59\%$.

Inaccurate assignment of Mallampati classes and Cormack-Lehane grades are well documented.[11–13] In the present study, one anesthesia record states "cords clear grade 3 view." By definition, the vocal folds are not visualized in a grade 3 view.[2] Another anesthesia record reports "glidescope used grade 1 view." The issue here is that Cormack-Lehane grades are not intended for fiberoptic laryngoscopy. Such a patient meets the exclusion criteria for this study, but it illustrates misuse of the grading system.

Ego bias is another concern. This would be when a provider assigns a lower Cormack-Lehane grade, whether intentionally or not, to advocate his/her laryngoscopy skills. For example, one anesthesia record for a nonobese patient indicates three laryngoscopies prior to successful intubation. Yet, the Cormack-Lehane grade is 1. It is not clear why a complete view of the larynx should require an anesthesia specialist to repeat the laryngoscopy three times to successfully intubate the trachea. Another way to illustrate ego bias is shown in Figure 1. Although a Gaussian distribution is not necessarily expected, the Mallampati distribution does not approximate the Cormack-Lehane distribution at all. The Cormack-Lehane curve is heavily skewed toward grade 1 views. This illustrates some possibilities: (1) ego bias, (2) Mallampati class does not correlate with Cormack-Lehane grade, (3) Mallampati and/or Cormack-Lehane scores are assigned incorrectly, (4) Mallampati over estimates difficult laryngoscopy, or (5) a combination of these.

Two studies compare surgical laryngeal exposure reported as a subjective visual analog scale (VAS) with Cormack-Lehane grades reported by the anesthesiologist.[16,17] In this cohort, 36 of 63 patients were obese, and there was a correlation between VAS and high BMI ($P = .007$) and neck size ($P = .06$). Major weaknesses of this study are the lack of a control group and the arbitrary VAS. Next was a cohort of 14 obese adults undergoing microlaryngeal surgery.[17] The same VAS correlated with the Cormack-Lehane grade. There was no correlation between BMI, neck size, or weight. Thirteen of the 14 patients were Mallampati IV, and one patient was Mallampati III. Cormack-Lehane grades ranged from 2 to 4, but the sample size could not allow for a sufficiently powered comparison. Weaknesses of this study include the lack of a control group and it is underpowered.

Another strategy to predict difficult laryngoscopy is the ULBT.[7] ULBT was introduced in a single-blinded prospective study of dentulous adults ($\geq$16 years) and obesity was not accounted for. The PPV for using the ULBT to predict difficult laryngoscopy was only 28.9%.[7] The PPV for Mallampati class in this study was 13%.

An intubation difficulty scale (IDS) was suggested to be a more objective measure than a single Cormack-Lehane grade.[23] IDS depends on seven factors: (1) the number of attempts, (2) operators, (3) alternative intubation techniques, (4) Cormack-Lehane grade, (5) lifting force, (6) need for external glottic pressure, and (7) position of vocal cords.[23] $IDS = 0$ means a single operator intubates easily on the first attempt. $IDS > 5$ reflects moderate to major difficulty. However, these seven factors are not specific, and a reliable method to predict difficult laryngoscopy is still lacking.

Weaknesses of this present study include its single-institution retrospective design, BMI as the sole definition of obesity, possibly incorrect Mallampati and Cormack-Lehane assignment, and uncontrolled patient positioning during laryngoscopy. This last confounding factor could not be eliminated in a retrospective study. This study also does not consider all factors that anesthetists may consider as predictors for difficult laryngoscopy, such as gender, neck mobility, fat distribution, trismus, arthritis, age, thyromental distance, and other medical conditions. Regarding BMI, it may not reflect an individual's complex body habitus and functional airway anatomy. Moreover, not all patients with a BMI $\geq$30 kg/m^2 are obese (e.g., a muscular physique also increases the BMI). Presently, how obesity exactly affects upper airway anatomy, ability to expose the glottis, and ease of intubation remain unclear.

A final point about the data in this present study is that there were no Mallampati class IV or Cormack-Lehane grade 4 patients in either group (Fig. 1). One concern may be whether or not a subgroup of patients with very high BMIs would be more likely to be Mallampati class IV or Cormack-Lehane grade 4. However, Figure 3 suggests that even the morbidly obese patients (BMI $\geq$40 kg/m^2) were mostly Mallampati classes I/II and Cormack-Lehane grades 1/2. In fact, the linear correlations are slightly negative, suggesting that as BMI increases, Mallampati classes and Cormack-Lehane grades decrease. The authors acknowledge that another explanation for this finding may be the presence of channeling bias. For example, if patients with high BMIs were anticipated to be difficult laryngoscopies, then they may be been channeled to undergo alternative intubation techniques such as with fiberoptic equipment. Such patients would have met the exclusion criteria for this study.

This study and the literature suggest a lack of reliable methods to identify patients at risk for difficult laryngoscopy. Therefore, the authors propose a novel technique, ATM, that is a minimally invasive, inexpensive, and objective way to predict difficult laryngeal exposure. ATM uses the sniffing position (SP) as described by Magill in 1936, but with the mouth opened.[24] SP aligns three axes: (1) oral axis, a tangential line across the dorsal tongue; (2) pharyngeal axis, a line connecting the uvula with the laryngeal surface of epiglottis, and (3) laryngeal axis, a line perpendicular to the glottis.[25–27] SP is considered the ideal position for direct laryngoscopy.[26–28] ATM uses a two-dimensional view of the patient optimally aligned for laryngoscopy (Fig. 4). The result is an objective, preoperative, radiographic assessment of the trajectory to the laryngeal airway and could be used for patients deemed to be at risk for difficult laryngoscopy. Costs inquiries suggest each x-ray would be $183, and a radiologist interpretation would be $46 at the study institution. Capital costs would be minimal because facilities providing general anesthesia would have x-ray capabilities. The costs associated with over- or underutilization of difficult airway resources and the medical, legal, and psychological ramifications of unintended airway compromise are beyond the scope of this article.

These pilot data reveal a few trends. First, for obese volunteers, Mallampati:ULBT shows a relationship ($G = 1.00$, $P < .001$). Second, the percentage of favorable and unfavorable projections (ATM) does not seem to differ between the nonobese and obese groups. This suggests that obesity (as defined by BMI alone) may not necessarily compromise the trajectory to the glottic airway. Third, Mallampati class distribution does not differ between the nonobese and obese groups, suggesting that obesity does not necessarily increase Mallampati class. This is consistent with the retrospective cohort portion of this study. Fourth, ULBT classes are higher in the obese group than the nonobese group. The relevance of this last point is unclear. In the absence of rigorous statistical analyses, these trends must be interpreted with caution.

Strengths of this novel ATM technique include its ability to potentially account for many factors that may affect laryngoscopy such as trismus, cervical immobility, body habitus, craniofacial abnormalities, and dentition. Limitations of ATM include the inability to account for the anterior/posterior rotation of the larynx; tissue reactivity; or any medial/lateral factors such as tracheal deviations or thyroid lesions, lingual tonsils, pharyngeal masses, or scoliosis. Moreover, there is a risk of radiation exposure to the patient with the use of ATM. Although a single x-ray has limited exposure, cumulative radiation in a lifetime may be significant.

These pilot data highlight the simplicity, feasibility, and limitations of the ATM. The reasonable cost, ease, and minimally invasive nature of this preoperative airway assessment tool has the potential to improve patient safety. Additional research is warranted to compare airway trajectories with the direct laryngoscopic views, with standardized patient positioning, to evaluate the effectiveness of ATM.

CONCLUSION

Mallampati class and obesity do not correlate with Cormack-Lehane grades. Additional training may be required to accurately assign Mallampati classes and Cormack-Lehane grades. Additional research is necessary to verify the usefulness of current airway classification systems or to develop a more reliable preoperative screening tool to identify patients at risk for difficult laryngoscopy. The ATM may be such a tool, and preliminary pilot data are promising.

Acknowledgments

The authors thank Ms. Cindy Flath for coordinating the research teams and Glen Yoshida, MD, FACS, for his mentorship and critical review of this manuscript.

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