

A comparison of the ratio of patient's height to thyromental distance with the modified Mallampati and the upper lip bite test in predicting difficult laryngoscopy

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ABSTRACT

Background: The aim of the present study was to compare the ability to predict difficult visualization of the larynx from the following preoperative airway predictive indices, in isolation and combination: modified Mallampati test (MMT), the ratio of height to thyromental distance (RHTMD) and the Upper-Lip-Bite test (ULBT). **Methods:** We collected data on 603 consecutive patients scheduled for elective surgery under general anesthesia requiring endotracheal intubation and then evaluated all three factors before surgery. An experienced anesthesiologist, not informed of the recorded preoperative airway evaluation, performed the laryngoscopy and grading (as per Cormack and Lehane's classification). Sensitivity, specificity, and positive and negative predictive value, Receiver operating characteristic (ROC) Curve and the area under ROC curve (AUC) for each airway predictor in isolation and in combination were determined. **Results:** Difficult laryngoscopy (Grade 3 or 4) occurred in 41 (6.8%) patients. The main endpoint of the present study, the AUC of the ROC, was significantly lower for the MMT (AUC, 0.511; 95% CI, 0.470–0.552) than the ULBT (AUC, 0.709; 95% CI, 0.671–0.745, $P=0.002$) and the RHTMD score (AUC, 0.711; 95% CI, 0.673–0.747, $P=0.001$). There was no significant difference between the AUC of the ROC for the ULBT and the RHTMD score. By using discrimination analysis, the optimal cutoff point for the RHTMD for predicting difficult laryngoscopy was 21.06 (sensitivity, 75.6%; specificity, 58.5%). **Conclusion:** The RHTMD is comparable with ULBT for prediction of difficult laryngoscopy in general population.

Key words: Difficult laryngoscopy, endotracheal intubation, RHTMD, thyromental distance, ULBT

INTRODUCTION

The importance of preoperative prediction of a difficult airway is obvious: 85% of all mistakes regarding airway management result in permanent cerebral damage^[1] and up to 30% of all anesthetic deaths can be attributed to the management of difficult airways.^[2]

Difficult laryngoscopy (characterized by poor glottic

visualization) is synonymous with difficult laryngoscopy in most patients.^[3] Difficult laryngoscopy is described in 1.5%–13% of patients.^[4–9] The ability to predict a difficult tracheal intubation permits anesthesiologists to take precautions to decrease the risk.^[10] Preoperative assessment is essential for the risk of difficult airway management, but which anatomical landmarks and clinical factors are the best predictors is a controversy.^[11,12]

Several investigations explain prediction schemes by applying a single risk factor or a multifactorial index.^[4,9,13] One test for difficult laryngoscopy is the Upper-Lip-Bite test (ULBT), assesses the possibility of a patient to cover the mucosa of the upper lip with the lower incisors.^[14] Grade 1 (the lower incisors can completely cover the upper lip's mucosa) and Grade 2 (the lower incisors can touch the upper lip but cannot completely cover the mucosa) are considered to predict easy laryngoscopy and are compared

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with Grade 3 of the ULBT (the lower incisors fail to bite the upper lip), which was noticed to be associated with difficult laryngoscopy.

Another test for difficult laryngoscopy is the thyromental distance (TMD), which is different according to patient size.^[15] Nevertheless, numerous studies question whether the TMD is either sensitive or specific enough to be used as the only predictor of difficult laryngoscopy.^[13]

Even though Schmitt *et al.*^[16] showed that the ratio of height to TMD [RHTMD5 Height (cm)/TMD (cm)] had a better predictive value than the TMD, no published study has quantified its sensitivity, specificity, and positive predictive value (PPV) versus the Upper-Lip-Bite test and the Mallampati classification^[17] revised by Samssoon and Young for evaluating patient's airway for difficult laryngoscopy. To the best of our knowledge there was no study to clarify which method predicted difficult laryngoscopy more accurately. It seem the predictive power of three methods was not similar.

So, we performed a prospective, blind study of the predictive value of the Mallampati classification revised by Samssoon and Young versus the RHTMD and the ULBT methods of airway assessment for difficult laryngoscopy in patients requiring tracheal intubation for general anesthesia.

METHODS

This prospective observational study was approved by the Ethics Committee of our university, and all patients gave written, informed consent. We then studied 603 consecutive American Society of Anesthesiologists (ASA) physical status I–III adult patients scheduled to receive general anesthesia requiring endotracheal intubation for elective orthopedic, ophthalmologic, urologic, abdominal, and gynecologic surgery.

Patients with a history of previous surgery, burns, or trauma to the airways or to the cranial, cervical, and facial regions, patients with tumors or a mass in the above-mentioned regions, patients with restricted motility of the neck and mandible (eg, rheumatoid arthritis or cervical disc disorders), inability to sit, edentulous, or need awake intubation were excluded from the study.

Patient data collected included sex, age, weight, height, and body mass index (BMI). The subsequent three predictive test measurements were carried out on all patients by a single physician:

1. MMT: Samssoon and Young's modification of the Mallampati test^[18] recorded oropharyngeal structures visible upon maximal mouth opening. While seated,

each patient was asked to open his or her mouth maximally and to protrude the tongue without phonation.^[17] The view was classified as (a) good visualization of the soft palate, fauces, uvula, and tonsillar pillars; (b) pillars obscured by the base of the tongue but the soft palate, fauces, and uvula visible; (c) soft palate and base of the uvula visible; and (d) soft palate not visible.^[18]

2. RHTMD: TMD was measured from the bony point of the mentum while the head was fully extended and the mouth closed.^[8] Then the ratio of height to TMD was calculated.
3. ULBT: The ULBT was rated as Class 1 if the lower incisors could bite the upper lip above the vermilion line, Class 2 if the lower incisors could bite the upper lip below the vermilion line and Class 3 if the lower incisors could not bite the upper lip.^[14]

On arrival in the operating room, routine monitoring, including noninvasive arterial blood pressure, an electrocardiogram, and oxygen saturation, were introduced. Induction of anesthesia was with 4 mg/kg of sodium thiopental intravenous (i.v.). Atracurium 0.6 mg/kg i.v. was administered to facilitate endotracheal intubation. The patients' lungs were ventilated by mask with 100% oxygen.

A single anesthesiologist with 9 years experience in anesthesia, who was not informed of the preoperative classes, performed laryngoscopy and evaluated difficulty of laryngoscopy at intubation. The head of the patient was placed in the "sniffing" position and laryngoscopy was done using a Macintosh #4 blade to visualize the larynx and the view was classified using the Cormack and Lehane's (CL) classification^[19] without external laryngeal manipulation: (I = vocal cords visible; II = only posterior commissure or arytenoids visible; III = only epiglottis visible; IV = none of the foregoing visible).

Difficult visualization of the larynx (DVL) was described as CL III or IV views on direct laryngoscopy. Easy visualization of the larynx (EVL) was defined as CL I or II view on direct laryngoscopy. Confirmation of successful intubation was by bilateral auscultation over the lung fields and capnography.

A prospective power analysis revealed that assuming an incidence of difficult laryngoscopy of 5%, 603 patients provide a power of more than 80% to detect an improvement of discriminating power (measured by the area under Receiver operating characteristic (ROC) curve) of an absolute value of 7% (eg, from 60% to 67%) with a type I error of 5% and using a two-sided alternative hypothesis.

Using these clinical data (the Mallampati score, the

RHTMD, the ULBT score, and the CL classification) recorded for each patient and the sensitivity, specificity, positive likelihood ratio (+LR) and negative likelihood ratio (–LR), PPV, and negative predictive value (NPV) of each test were calculated. Secondly, combinations of predictors were also formulated.

The area under ROC curve (AUC)^[20] was used as the main endpoint of the study to determine whether or not the score was clinically valuable.

A value of 0.5 under the ROC curve indicates that the variable performs no better than chance and a value of 1.0 implies perfect discrimination. A larger area under the ROC curve denotes more reliability^[21] and good discrimination of the scoring system. Additionally, the ROC curves were used to recognize the optimal predictive cutoff points for each test.

BMI was determined from weight (kg)/height² (m). Patient data and value of the airway predictors were compared using *t* tests for continuous variables and Mann–Whitney *U* test for MMT or ULBT. Differences between the AUC values of three predictive tests were analyzed using MedCalc statistical software 9.3.6.0, and a *P* value of 0.05 was defined as statistically significant. All other calculations were performed using the SPSS version 16.0.

RESULTS

A total of 603 patients were included in the study. Demographic data, BMI and the mean for the RHTMD are presented in Table 1. DVL was observed in 41 (6.8%) patients. There was no failed intubation.

There were significant differences in weight, BMI, and RHTMD between the DVL and EVL patients [Table 1]. The distribution of MMT, ULBT, the CL grades are shown in Table 2. The measures used to explain the predictive properties of the three models are shown in Table 3.

The main endpoint of the present study, the AUC of the ROC, was significantly lower for the MMT (AUC, 0.511; 95% CI, 0.470–0.552) than the ULBT (AUC, 0.709; 95% CI, 0.671–0.745; *P*=0.002) and the RHTMD score (AUC, 0.711; 95% CI, 0.673–0.747; *P*=0.001) [Table 3]. There was no significant difference between the AUC of the ROC for the ULBT and the RHTMD score.

Predictive values of the three single or combined predictors are shown in Table 3. Using discrimination analysis, a ULBT Grade 3 and MMT Grade 3 were considered as the cutoff points for predicting difficulty. The MMT was the most sensitive of the single tests with a sensitivity of 87.37%. The ULBT was the least sensitive of the single tests with a sensitivity

of 66.01 but had highest specificity and PPV compared with the other two tests. The RHTMD had the highest NPV and the AUC of ROC curve among single predictors.

The combination of the three tests decreased the positive likelihood ratio and the AUC of ROC curve compared with the RHTMD and the ULBT as single predictors. The combination with the best results was the Mallampati test–RHTMD with specificity, the positive likelihood ratio, the PPV, the AUC of ROC curve of 80.50%, 1.36%, 94.9%, and 0.535, respectively. The various other combinations resulted in decreased specificity, the PPV, negative likelihood ratio, and the AUC of ROC curve.

By using discrimination analysis, the optimal cutoff point for the RHTMD for predicting difficult laryngoscopy was 21.06 (sensitivity, 75.6%; specificity, 58.5%). The multivariate analysis odds ratios (95% CI) of

Table 1: Demographic data, BMI and mean for RHTMD of all patients

Variable	Value	ELV (n=562)	DLV (n=41)	<i>P</i> value
Sex				0.165
Men n (%)	361 (59.9)	333 (92.2)	28 (7.8)	
Female n (%)	242 (40.1)	229 (94.6)	13 (5.4)	
Age (years)	38.9±13.8	38.4±13.6	45.6±14.4	0.001
Weight (kg)	69.8±11.3	69.6±10.8	73.9±15.3	0.017
Height (cm)	169.6±8.5	169.8±8.4	165.8±9.8	0.015
BMI (kg/m ²)	24.4±3.9	24.2±3.9	26.7±4.4	0.001
ASA class n (%)				
I	470 (78)			
II	196 (22)			
RHTMD	20.1±2.6	19.8±2.3	22.4±4.2	0.000

Data are presented as mean±SD or number (%). DVL=Difficult visualization of the larynx; EVL=Easy visualization of the larynx; BMI=Body mass index; RHTMD=Ratio of height to thyromental distance

Table 2: Distribution of MMT, ULBT, and laryngoscopic view of all patients

Variable	Number of patients (%)
Mallampati class	
I	77 (12.8)
II	326 (54.1)
III	193 (32.1)
IV	7 (1.2)
ULBT	
I	382 (63.3)
II	205 (33.9)
III	16 (2.6)
Laryngoscopic view	
I	218 (36.2)
II	344 (57.0)
III	38 (6.3)
IV	3 (0.5)

MMT=Samssoon and Young's modification of the Mallampati test; ULBT=Upper-Lip-Bite test

Table 3: Predictive values for MMT, ULBT, and RHTMD and their combinations to predict the occurrence of a Grade 3 or 4 intubation according to the modified Cormack–Lehane classification

Test	Sensitivity (%)	95% CI	Specificity (%)	95% CI	+ LR	- LR	+ PPV (%)	- NPV (%)	AUC of ROC curve	P value
MMT	87.37	84.3–90.0	14.63	05.6–29.2	1.02	0.86	93.3	07.8	0.511	0.8101
ULBT	66.01	61.9–69.9	73.17	57.1–85.8	2.46	0.46	97.1	13.6	0.709*	0.0001
RHTMD	75.62	71.9–79.1	58.54	42.1–73.7	1.82	0.42	96.2	14.9	0.711*	0.0001
M + U	99.30	98.2–99.8	07.32	01.6–19.9	1.07	0.10	93.6	42.9	0.533	0.4868
M + R	26.51	22.9–30.4	80.50	65.1–91.2	1.36	0.91	94.9	07.4	0.535	0.4615
U + R	99.11	97.9–99.7	04.88	0.70–16.6	1.04	0.18	93.5	28.6	0.520	0.6728
M + U + R	99.64	98.7–99.9	02.44	0.40–12.9	1.02	0.15	93.3	33.3	0.510	0.8226

M, MMT; MMT=Modified Mallampati test; U, ULBT; ULBT=Upper-Lip-Bite test; R, RHTMD; RHTMD=Ratio of height to thyromental distance (TMD); CI=Confidence interval; AUC=Area under a Receiver-Operating or Characteristic Curve (ROC). *P<0.05 vs MMT. There was no significant difference between the AUC of the ROC for the ULBT and the RHTMD score

the RHTMD, Mallampati class, and ULBT were 2.84 (1.29–6.25), 1.06 (0.566–2.01), and 0.144 (0.0474–0.436), respectively. The multivariate analysis relative risk (95% CI) of the RHTMD, Mallampati class, and ULBT were 2.53 (1.18–5.39), 1.064 (0.523–2.013), and 0.242 (0.106–0.500), respectively.

DISCUSSION

Unexpected difficult tracheal intubation has been recognized as a major contributory factor to anesthetic-related morbidity and mortality.^[22] Accordingly, the search for a predictive test that has ease of applicability and accuracy of prediction (discriminating power) persists.

The incidence of difficult laryngoscopy was 1.3%, 1.5%, 1.8%, 3.5%, 4%, 4.5%, 4.9%, 7%, 8%, and 13%,^[17,23-26] depending on the criteria used to characterize it. In our study, the incidence of DLV was 6.8%, which is comparable with some of the other studies.^[4,5,27] Variations in the incidence of DVL have been attributed to different factors, such as different anthropomorphic features among populations, lack of uniformity in describing or grading laryngeal views, cricoid pressure application, head position, degree of muscle relaxation, and type or size of laryngoscope blade.^[28]

Analysis of our data revealed that the AUC of ROC for RHTMD and ULBT was 0.711 and 0.709, respectively, whereas the AUC for the corresponding Mallampati score was only 0.511. The findings of the current study suggest that the AUC of ROC curve for RHTMD for predicting difficult laryngoscopies may not be significantly different from the ULBT.

Preferably, any preoperative evaluation scheme for difficult laryngoscopy should be highly sensitive, specific, and should have a high PPV with few negative predictions. The PPV for the RHTMD (96.2%) was not significantly different from that of the ULBT (97.1%) signifying that a positive RHTMD or ULBT is not different for prediction

of a difficult airway. The NPV of the two tests (14.9% vs 13.6%, respectively) was not significantly different.

In the present study, the sensitivity, specificity, PPV, and NPV of the ULBT were demonstrated to be 66.1%, 73.2%, 97.1%, and 13.6%, respectively. These values were 76.5%, 88.7%, 28.9%, and 98.4%, respectively, in the original study by Khan *et al.*^[14]

Eberhart *et al.*^[29] re-assessed the ULBT in their study published in 2005; the sensitivity, specificity, PPV, and NPV they obtained were 28.2%, 92.5%, 33.6%, and 90.6%, respectively. In 2007, Hester *et al.*^[30] presented a study that determined a sensitivity of 55%, a specificity of 97%, PPV of 83%, and NPV 90% for the ULBT.

All the three above studies measured the ULBT with the modified Mallampati classification as a comparison. From the results of the investigations by Khan *et al.*^[14] and Hester *et al.*^[30] a conclusion could be obtained that the ULBT was superior to the modified Mallampati in almost every aspect for difficult airway prediction. Wilson *et al.*^[24] explained five risk factors that are important in predicting difficult laryngoscopy, consist of weight ($P=0.05$), jaw movement ($P=0.001$), head and neck movement ($P=0.001$), buck teeth ($P=0.001$), and receding mandible ($P=0.001$).

One of our techniques, the ULBT, evaluates a combination of jaw subluxation and the presence of buck teeth concurrently, apparently increasing its predictive value and reliability. The anesthesiologists who recorded the laryngeal view by the CL classification in our study were unaware of the ULBT and RHTMD evaluations of the patients prior to anesthesia. This blinded method reduced observer bias. The rulers and laryngoscope blades used were the same in order to decrease instrumental bias.

Considering that the ULBT is a simple objective evaluation that is not dependent on particular circumstances or specific instruments, it is of utmost importance to evaluate and

re-evaluate it in various conditions and make comparisons with alternative tests. In this study, it was found that the RHTMD was the useful predictor with a sensitivity, specificity, and PPV of 75.6%, 58.5%, and 96.2%, respectively.

Although the RHTMD and ULBT tests in this series were not highly sensitive, these two measurements resulted in the less amount of detection failure for difficult laryngoscopy than the MMT test. This is our most important finding.

Moreover, the likelihood ratio (LR1) for a positive test result may be a useful measure to judge the efficacy of a predictive tool in daily practice.^[31] This measure is the number of times more likely that a patient with a positive test result will present with a difficult laryngoscopy. The LR1 was 1.82 and 2.46 for the RHTMD and ULBT, respectively, whereas it was 1.02 for the Mallampati score.

Using a multivariate analysis, we noticed that the RHTMD had the highest odds ratio for prediction of a difficult laryngoscopy. Schmitt *et al.*'s^[16] study showed that RHTMD >25 can be used to predict difficult laryngoscopies for white men and women. They advocated that it might not apply to other races. In the present study, an RHTMD >21.06 was a determining factor for predicting a poor laryngeal view among our patients. This difference merits additional studies to determine the significance of ethnicity.

The RHTMD calculation is based on precise measurement of patient's TMD and height, so making interobserver variations highly unlikely when using this test (on the contrary to significant interobserver variations found with the MMT, which has been controversial).^[9,32] Many patients involuntarily phonate during assessment of the MMT score, which may considerably alter the Mallampati classification.^[28]

Tham *et al.*^[33] confirmed that prevention of phonation was a critical factor in accomplishing a reliable score. MMT in evaluating oropharyngeal view has had poor reliability in the study by Karkouti and colleagues,^[34] which could be due to the technicalities involved in the demonstration, and incongruity in evaluating and interpreting the observations.

Bilgin *et al.*^[35] showed that a low prediction value of MMT was due to involuntary phonation during test, which probably alters the Mallampati classification. Oates and colleagues^[36] showed that one critical factor in doing a reliable Mallampati score was maximal extrusion of tongue and opening of the mouth. Failure to employ these maneuvers strictly is a chief drawback when performing the evaluation.

The RHTMD has some limitations. It depends on accurate measurement of patient's TMD and height that lessens simplicity of this method. Also, the cutoff point of

RHTMD for prediction of difficult laryngoscopy is race dependent. The RHTMD cutoff point equal 21.06 may not be applicable in the other population. So, we recommend calculating cutoff point for each population separately.

The ULBT score of predicting difficult laryngoscopy has also some limitations. It is not appropriate for edentulous patients. In addition, the anthropological literature emphasized that there is ethnic variation in craniofacial configuration of populations. Moreover, review of dental literature shows that there are significant racial variation in morphology and morphometry of human mandible and maxillary bones.^[37] So, the ULBT may not be applicable for some populations.^[38-40] The predictive power of ULBT for prediction of difficult laryngoscopy must be calculated in each population independently.

Safe outcome of anaesthesia continues to be an important goal for every anesthesiologist. Unfortunately, there is still no test or group of tests that can predict 100% of difficult laryngoscopies. Our study was concerned only with elective surgical patients, and emergency patients were not considered. Even though the internal validity in the present study seems adequate, it may not be applicable to all subgroups of the general population (e.g., patients for emergency cesarean sections or toothless patients).

In conclusion, the RHTMD is comparable with ULBT as a useful bedside screening test for preoperative prediction of difficult laryngoscopy in general population. Compared with the RHTMD and ULBT, MMT is a poor predictor of difficult laryngoscopy when used as a single or combined bedside screening test. More studies with larger sample size in different populations are suggested for the documentation of our results.

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