Comparison of Upper Lip Bite Test and Ratio of Height to Thyromental Distance with Other Airway Assessment Tests for Predicting Difficult Endotracheal Intubation

D. Shobha, Maitri Adiga, D. Devika Rani, Sudheesh Kannan, S. S. Nethra
Department of Anesthesiology, Bengaluru Medical College and Research Institute, Bengaluru, Karnataka, India

Abstract

Background and Aims: Unanticipated difficult intubation or the failed intubation in operating room and in emergency department is an imperative source of anesthesia-related patient’s mortality. The aim of this study is to compare the predictive value of upper lip bite test (ULBT) and ratio of height to thyromental distance (RHTMD) with other commonly used preoperative airway assessment tests for predicting difficult intubation in Indian population. Materials and Methods: In this prospective, single-blinded observational study, 260 adult patients of either sex, belonging to American Society of Anesthesiologists physical Status I and II undergoing elective surgical procedure under general anesthesia were included in the study. ULBT, RHTMD, inter-incisor gap, modified Mallampati grade, horizontal length of the mandible, head and neck movements, sternomental distance, and TMD were assessed preoperatively and correlated with Cormack and Lehane’s grading during laryngoscopy under anesthesia. Statistical analysis was done by Chi-square and Fisher’s exact test. Results: ULBT and RHTMD had highest sensitivity (66.7% and 63.3%), specificity (99.1% and 89.6%), positive predictive value (90.9% and 44.2%), and negative predictive value (96.9% and 95.0%), respectively, when compared to other parameters in predicting difficult airway. Conclusion: ULBT and RHTMD may be used as a simple bedside airway assessment tools for prediction of difficult intubation.

Keywords: Airway assessment test, difficult laryngoscopy, ratio of height to thyromental distance, upper lip bite test

INTRODUCTION

The assessment of the patient’s airway is an integral part of the preoperative workup. Difficult airway management continues to be the single most common cause of morbidity and mortality attributable to anesthesia. The purpose of the preoperative airway assessment should, therefore, be able to predict potential problems which might be encountered in the operating room, allowing a management plan to be developed ahead of time.\[1\]

The 4th National Audit Project found that failure to assess for and identify potential difficulty or the application of poor judgment in the management planning may contribute to a poor outcome.\[2\] Incidence of difficult airways is poorly defined and varies according to the setting. In a meta-analysis by Cook et al.,\[3\] incidence of failed intubation was approximately 1 in 2000 in the elective setting,\[4,5\] 1 in 300 during rapid sequence intubation in the obstetric setting,\[6,7\] and 1 in 50–100 in the emergency department.\[7\] Intensive Care Unit,\[8\] and prehospital settings.\[9\]

There is no single method of prediction of difficult intubation that is both highly sensitive and highly specific. Several preoperative airway assessment tests such as mouth opening or inter-incisor gap (IIG), head and neck movement (HNM), modified Mallampati test (MMT), Wilson risk score, horizontal length of mandible (HLM), sternomental distance (SMD), and thyromental distance (TMD) may be used to predict difficult intubations, but sensitivity and positive predictive value (PPV) of these individual tests are low (33%–71%), whereas false positive (FP) results are high.\[10-14\] There is ongoing research.
to device a simple bedside test, to anticipate difficult tracheal intubation, which has high sensitivity, specificity, PPV, negative predictive value (NPV), likelihood ratio (LR) with minimal FP, and false-negative values.

While several studies have evaluated such predictive criteria individually or in arbitrary combinations, there has not been sufficiently powered systematic multivariate analysis of readily available clinical variables such as upper lip bite test (ULBT), ratio of height to TMD (RHTMD), IIG, MMT, HNM, and TMD studied simultaneously and published in literature, especially those comparing RHTMD with ULBT among the Indian population.

Hence, we conducted this study to evaluate and compare various predictive tests such as ULBT, RHTMD, IIG, MMT, TMD, and HNM in isolation, with an attempt to determine a more accurate, simple, and clinically applicable airway assessment test for predicting difficult intubation in Indian population.

**Materials and Methods**

This is a prospective, single-blinded observational study done with the clearance of Ethical Committee. Informed written consent of 260 patients of either sex, aged 18–65 years, American Society of Anesthesiologist Status I and II undergoing elective surgical procedures under general anesthesia were enrolled for the study. Uncooperative and unwilling patients, history of burns involving head and neck, trauma and airway surgeries, tumor or mass in the neck or airway, patients with restricted mobility at neck and mandible, patients with inability to sit, edentulous or need awake intubation, pregnant females, and patients with body mass index (BMI) ≥35 were excluded from the study. All patients were examined preoperatively to assess airway parameters, the day before surgery by the same anesthesiologist to avoid interobserver variability.

Height and weight were recorded and BMI calculated. Height was measured in centimeters from vertex to heel with the patient standing.

The oropharyngeal view was assessed using:

1. **MMT:** Sampson and Young’s modification of Mallampati test recorded oropharyngeal structures visible upon maximal mouth opening. Each patient when seated was asked to open mouth maximally and to protrude the tongue without phonation. The view was classified as Grade 0 - epiglottis visualized, Grade 1 - good visualization of palate, fauces, uvula, and tonsillar pillars, Grade 2 - pillars obscured by the base of the tongue but the soft palate, fauces, and uvula visible, Grade 3 - soft palate and base of the uvula visible, and Grade 4 - soft palate not visible

2. **RHTMD:** TMD was measured from the bony point of the mentum to thyroid notch while head was fully extended and mouth closed. RHTMD was calculated as

\[ \text{RHTMD} = \frac{\text{height (in cm)}}{\text{TMD (in cm)}} \]

and graded as

\[ \text{Grade 1 <23.5 and Grade 2 ≥23.5} \]

3. **Upper lip bite test:** ULBT was done to assess the range of freedom of the mandibular movement and the architecture of the teeth concurrently. It was done by assessing the ability of the patient to touch the vermilion line of upper lip with lower incisors. This test was graded 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

4. **IIG:** It was assessed by asking each patient to open the mouth to maximum extent. The distance between upper and lower incisor at the midline is measured, which is usually ≥3.5 cm

5. **TMD:** TMD was measured from the bony point of the mentum whereas the head is fully extended and mouth closed using a rigid ruler. The distance was rounded to nearest 0.5 cm and graded as Class 1: >6.5 cm, Class 2: 6–6.5 cm, and Class 3: <6 cm

6. **SMD:** SMD was measured from sternal notch to the mentum in centimeter with head fully extended on the neck with the mouth closed which is normally >12.5 cm

7. **Horizontal length of the mandible:** It was measured from angle of the mandible to the mentum. A length of ≥9 cm was considered normal

8. **Maximum range of HNM:** was noted as Grade 1 ≤80° or Grade 2 ≥80°. The patient was first asked to extend the head and neck fully, where a pencil was placed vertically on the forehead and then while the pencil was held firmly in position, the head and neck were flexed.

The airway assessment parameters which predicted difficult laryngoscopy are listed in Table 1.

Patients were kept nil orally for 8–10 h preoperatively. In operation theater, intravenous (IV) line was secured with 18-gauge IV cannula and Ringer’s lactate infusion was started. Electrocardiogram, noninvasive blood pressure, and peripheral oxygen saturation monitor were connected to the patient, and basal heart rate, blood pressure, and oxygen saturation

| Table 1: Values of various predictors of difficult laryngoscopy |
|---------------------------------------------------------------|
| **Predictors** | **Cut-off values** |
| Mallampati grade | Grade 3 and Grade 4 |
| ULBT | Grade 3 |
| IIG | ≤3.5 cm |
| TMD | ≤6 cm |
| RHTMD | ≥23.5 |
| SMD | ≤12.5 |
| HLM | ≤9 cm |
| HNMs | ≤80° |

ULBT=Upper lip bite test, HNMs=Head and neck movement, HLM=Horizontal length of the mandible, TMD=Thyromental distance, RHTMD=Ratio of height to thyromental distance, IIG=Inter incisor gap, SMD=Sternomental distance
were recorded. Patient was premedicated with injection glycopyrrolate 0.01 mg/kg, injection midazolam 0.05 mg/kg, injection fentanyl 2 µg/kg intravenously, and preoxygenated with 100% oxygen. Induction of anesthesia was done with injection propofol 2 mg/kg body weight intravenously and injection vecuronium 0.1 mg/kg IV was administered once mask ventilation confirmed. Laryngoscopy was done using Macintosh blade Size 3 or 4 by an experienced anesthesiologist who was blinded to preoperative airway assessment details, and the view was classified as per Cormack-Lehane’s Scale:[20] Grade 1 - vocal cords visible, Grade 2 - only posterior commissure or arytenoids visible, Grade 3 - only epiglottis visible, and Grade 4 - none of the above visible without any external laryngeal manipulation.

Cormack and Lehane Grade 1 and 2 was considered as easy visualization whereas Grade 3 and 4 was considered as difficult visualization. A maximum of three attempts were allowed with conventional laryngoscope. In case of failure of first two attempts, third attempt was by another senior experienced anesthesiologist. If there was failure to intubate at third attempt, alternate measures such as use of supraglottic device, bougie was done as per the discretion of attending anesthesiologist. External laryngeal manipulation was used to improve visualization after first attempt. Use of additional gadgets/maneuvers during intubation was noted. Oxygenation was ensured in between attempts at intubation. Intubation was done with appropriate sized endotracheal tubes. Confirmation of intubation was done by bilateral auscultation of lung fields and capnography. Number of attempts at intubation was noted. Maintenance of anesthesia was done with oxygen, nitrous oxide, and isoflurane. At the end of surgery, isoflurane disconnected, and after adequate respiratory efforts, injection neostigmine and injection glycopyrrolate were administered to reverse neuromuscular blockade. Patient was extubated after adequate recovery and shifted to the postanesthesia care unit.

Statistical analysis
Sample size was calculated using area under receiver operating characteristic (ROC) curve. Before the start of the present study retrospective analysis of records of 100 patients in the past 1 year revealed an incidence of 7% difficult airway, and an area under ROC generated for ULBT showed a value of 0.88. We assumed that there would be decrease in area under ROC with a larger sample size and assumed a 12% reduction from this value. To detect an absolute difference of 7% (0.07), area under curve (0.78–0.85) between the two tests (ULBT and RHTMD), in predicting difficult intubation, a minimum area under curve (0.78–0.85) between the two tests (ULBT, RHTMD, and MMT, respectively).

Table 2: Demographic data based on Cormack and Lehane’s laryngoscopy grading

| Variables | Easy (CL 1 and 2) | Difficult (3 and 4) |
|-----------|------------------|------------------|
| Age       | 38.72±10.85      | 43.57±13.12      |
| Height    | 155.53±8.08      | 152.84±3.52      |
| Weight    | 62.47±5.87       | 67.03±9.57       |
| BMI       | 22±2.2           | 25.56±3.87       |
| Sex       | 96/134           | 13/17            |

BMI=Body mass index, CL=Cormack-Lehane’s

The clinical data were entered in a Microsoft excel sheet. Continuous data are presented as mean ± standard deviation. Categorical variables including airway assessment parameters and Cormack-Lehane grading are grouped as easy and difficult and presented in tabular format. Using these data sensitivity, specificity, positive LR, and negative LR of each test were calculated. Patients’ data and value of the airway predictors were compared using Chi-square tests and P < 0.05 was considered statistically significant. ROC curve was generated by plotting the sensitivity of airway assessment parameters against Cormack and Lehane grading and area under ROC closer to one meant that the test had better discriminative power to differentiate between easy and difficult airway.

RESULTS
The incidence of difficult laryngoscopy was 11.5% (30 out of 260). All thirty patients had Cormack Lehane Grade 3 glottic view with no Grade 4 and no failed intubations. All the patients were demographically comparable in easy and difficult laryngoscopic groups [Table 2].

ULBT, RHTMD, and MMT predicted difficult intubation in 20, 19, and 15 patients out of thirty patients, respectively [Table 3]. Multivariate analysis showed ULBT, RHTMD to have highest sensitivity (66.7% and 63.3%), specificity (99.1% and 89.6%), PPV (90.9% and 44.2%), and NPV (96.9% and 95.0%) compared to other parameters [Table 4]. ULBT (90.9%) had the highest LR for positive test compared to other tests, whereas RHTMD and MMT had LR of 44.2% and 42.1%. The area under the ROC curve [Figure 1] plotted comparing sensitivity and specificity of different methods of airway assessment with Cormack and Lehane grading [Table 5] showed an area of 0.829 (95% confidence interval [CI]: 0.725–0.933), 0.764 (95% CI: 0.658–0.871), and 0.719 (95% CI: 0.606–0.832) for ULBT, RHTMD, and MMT, respectively, which was clinically and statistically significant when compared with other tests (P < 0.001) [Figure 2]. The odds ratio was 228, 14.8, and 10.8 and relative risk was 21.63, 8.7, and 6.67 for ULBT, RHTMD, and MMT, respectively.

DISCUSSION
Prediction of the difficult airway is a challenge, particularly in the critically ill and in emergency situations. Airway assessment is valuable as it helps to anticipate difficult intubation and plan the management appropriately. There is no single method of prediction of difficult intubation that is both highly sensitive and highly specific.
Preoperative airway assessment test should be highly sensitive to predict maximum number of patients of difficult laryngoscopy and highly specific to predict easy laryngoscopy correctly. This study was conducted to compare ULBT and RHTMD with other airway assessment tests to determine a near accurate, simple, and clinically applicable airway assessment test for predicting difficult laryngoscopy in Indian population, and we observed that ULBT is the best predictive test for difficult intubation.

Badheka et al.\textsuperscript{[15]} concluded that ULBT can be used as a simple bedside screening test for prediction of difficult intubation, but it should be combined with other airway assessment tests for better airway predictability. RHTMD can also be used as an acceptable alternative. Shah et al.\textsuperscript{[16]} showed that ULBT is the best predictive test for difficult laryngoscopy in apparently normal patients, but RHTMD can also be used as an acceptable alternative. Khan et al.\textsuperscript{[21]} also showed an increase in the incidence of Cormack and Lehane Grade 3 and 4 as the ULBT grade showed a rise from 1 to 2 and from 3 to 4. In concurrence with other studies, even our study reveals that upper lip bite test is a simple, reliable, and sensitive airway assessment test for predicting difficult intubation. RHTMD also has good sensitivity in predicting difficult intubation.

In our study, we evaluated the efficacy of upper lip bite test, RHTMD, MMT, IIG, HLM, and SMD to predict difficult endotracheal intubation and ULBT had the highest sensitivity, specificity, PPV, NPV, odds ratio, and relative risk of among all the predictive tests included in the study.

The results were comparable to the studies by Badheka et al.,\textsuperscript{[15]} Shah et al.,\textsuperscript{[16]} and Khan et al.\textsuperscript{[21]} The age, height, weight, and BMI were comparable between patients with easy and difficult laryngoscopy [Table 2]. The second best test in our study was RHTMD with second highest sensitivity, specificity, PPV, NPV, odds ratio, and relative risk of among all the predictive tests included in the study.

In our study, ULBT=Upper lip bite test, MMT=Modified Mallampati test, IIG=Inter-incisor gap, HNM=Head and neck movement, HLM=Horizontal length of the mandible, SMD=Sternomental distance, TMD=Thyromental distance, RHTMD=Ratio of height to thyromental distance, CL=Cormack-Lehane’s grade.
Table 4: Validity of upper lip bite test, modified Mallampati test, inter-incisor gap, head and neck movement, horizontal length of the mandible, sternomental distance, thyromental distance, and ratio of height to thyromental distance with Cormack and Lehane score to predict difficult airway

| Parameter          | ULBT  | MMT   | IIG   | HNM  | HLM  | SMD  | TMD  | RHTMD |
|--------------------|-------|-------|-------|------|------|------|------|-------|
| Sensitivity (%)    | 66.67 | 53.33 | 6.667 | 13.33| 3.333| 3.333| 3.333| 63.33 |
| Specificity (%)    | 99.13 | 90.43 | 96.52 | 91.3 | 94.35| 93.48| 96.96| 89.57 |
| PPV (%)            | 90.91 | 42.11 | 20    | 16.67| 7.143| 6.25 | 12.5 | 44.19 |
| NPV (%)            | 95.8  | 93.69 | 88.8  | 88.98| 88.21| 88.11| 88.49| 94.93 |
| Diagnostic accuracy (%) | 95.38 | 86.15 | 86.15 | 82.31| 83.85| 83.08| 86.15| 86.54 |
| Likelihood ratio of a positive test | 76.67 | 5.576| 1.917 | 1.533| 0.5897| 0.5111| 1.095| 6.069 |
| Likelihood ratio of a negative test | 0.3363| 0.516| 0.967 | 0.9492| 1.025| 1.034| 0.997| 0.4094 |
| Diagnostic odds    | 228   | 10.81| 1.982 | 1.615| 0.5756| 0.4943| 1.099| 14.83 |
| Cohen’s kappa (unweighted) | 0.7443| 0.3922| 0.0449| 0.05079| 0.03019| 0.04| 0.004255| 0.4451 |

PPV=Positive predictive value, NPV=Negative predictive value, ULBT=Upper lip bite test, MMT=Modified Mallampati test, IIG=Inter-incisor gap, HNM=Head and neck movement, HLM=Horizontal length of the mandible, SMD=Sternomental distance, TMD=Thyromental distance, RHTMD=Ratio of height to thyromental distance

Table 5: Area under receiver operating characteristic curve of various airway assessment parameters

| Test result variables | Area | SE  | P          | Asymptomatic 95% CI |
|-----------------------|------|-----|------------|---------------------|
|                       |      |     |            | Lower bound | Upper bound        |
| ULBT                  | 0.829 | 0.053 | <0.001* | 0.725 | 0.933 |
| MMT                   | 0.719 | 0.058 | <0.001* | 0.606 | 0.832 |
| IIG                   | 0.516 | 0.057 | 0.776    | 0.404 | 0.628 |
| HNM                   | 0.523 | 0.058 | 0.680    | 0.410 | 0.636 |
| HLM                   | 0.488 | 0.055 | 0.836    | 0.380 | 0.597 |
| SMD                   | 0.484 | 0.055 | 0.776    | 0.377 | 0.592 |
| TMD                   | 0.501 | 0.056 | 0.979    | 0.391 | 0.612 |
| RHTMD                 | 0.764 | 0.054 | <0.001* | 0.658 | 0.871 |

ULBT=Upper lip bite test, MMT=Modified Mallampati test, IIG=Inter-incisor gap, HNM=Head and neck movement, HLM=Horizontal length of the mandible, SMD=Sternomental distance, TMD=Thyromental distance, SE=Standard error, CI=Confidence interval

MMT has been used regularly over the years clinically, but it does have a few limitations as pointed out by many previous studies. The definitive demarcation between Class 2 and 3 and between Class 3 and 4, the effect of phonation, and patients cooperation leads to high interobserver variability and decreased variability. In our evaluation, MMT had acceptable sensitivity, good specificity, and NPV. Although other studies had reported different reports of sensitivity, specificity, and PPV of IIG, HNM, HLM, and SMD, which is unacceptable in clinical practice.

Conclusion

Upper lip bite test is the best predictive test for difficult laryngoscopy out of all the predictive tests evaluated. RHTDM can be used as an acceptable alternative with a good predictability.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Yenti SM. Predicting difficult intubation – Worthwhile exercise or pointless ritual? Anaesthesia 2002;57:105-9.
2. Cook TM, Woodall N, Frerk C; Fourth National Audit Project. Major complications of airway management in the UK: Results of the fourth national audit project of the royal college of anaesthetists and the difficult airway society. Part 1: Anaesthesia. Br J Anaesth 2011;106:617-31.
3. Cook TM, MacDougall-Davis SR. Complications and failure of airway management. Br J Anaesth 2012;109-68-5.
4. Rose DK, Cohen MM. The incidence of airway problems depends on the definition used. Can J Anaesth 1996;43:30-4.
5. Samsoo GL, Young JR. Difficult tracheal intubation: A retrospective study. Anaesthesia 1987;42:487-90.
6. Hawthrone L, Wilson R, Lyons G, Dresner M. Failed intubation revisited: 17-year experience in a teaching maternity unit. Br J Anaesth 1996;76:680-4.
7. Sakles JC, Laurin EG, Rantapaa AA, Panicke EA. Airway management in the emergency department: A one-year study of 610 tracheal intubations. Ann Emerg Med 1998;31:325-32.
8. Nolan JP, Kelly FE. Airway challenges in critical care. Anaesthesia 2011;66:81-92.
9. Harris T, Ellis DY, Foster L, Lockey D. Cricoid pressure and laryngeal manipulation in 402 pre-hospital emergency anaesthetics: Essential safety measure or a hindrance to rapid safe intubation? Resuscitation 2010;81:810-6.
10. Shiga T, Wajima Z, Inoue T, Sakamoto A. Predicting difficult intubation in apparently normal patients: A meta-analysis of bedside screening test performance. Anaesthesiology 2005;103:429-37.
11. Merah NA, Wong DT, Ffolkes-Crabbe DJ, Kushimo OT, Bode CO. Modified mallampati test, thyromental distance and inter-incisor gap are the best predictors of difficult laryngoscopy in West Africans. Can J Anaesth 2005;52:291-6.
12. Tse JC, Rimm EB, Hussain A. Predicting difficult endotracheal intubation in surgical patients scheduled for general Anesthesia: A prospective blind study. Anesth Analg 1995;81:254-8.
13. El-Ganzouri AR, McCarthy RJ, Tuman KJ, Tanck EN, Ivankovich AD. Preoperative airway assessment: Predictive value of a multivariate risk index. Anesth Analg 1996;82:1197-204.
14. Domi R. The best prediction test of difficult intubation. J Anaesthesiol Clin Pharmacol 2010;26:193-6.
15. Badheka JP, Doshi PM, Vyas AM, Kacha NJ, Parmar VS. Comparison of the definition used. Can J Anaesth 1996;43:30-4.
16. El-Ganzouri AR, McCarthy RJ, Tuman KJ, Tanck EN, Ivankovich AD. Preoperative airway assessment: Predictive value of a multivariate risk index. Anesth Analg 1996;82:1197-204.
17. Mallampati SR. Clinical sign to predict difficult tracheal intubation (hypothesis) Can Anaesth Soc J 1983;30:316-7.
18. Schmitt HJ, Kirmse M, Radespiel-Troger M. Ratio of patient’s height to thyromental distance improves prediction of difficult laryngoscopy. Anaesth Intensive Care 2002;30:763-5.
19. Wilson ME, Spiegelhalter D, Robertson JA, Lesser P. Predicting difficult intubation. Br J Anaesth 1988;61:211-6.
20. Cormack R, Lehane J. Cormack-Lehane laryngoscopy grades. In: Maltby JR, editor. Notable Names in Anaesthesia. London: Royal Society of Medicine Press; 2002. p. 43-5.
21. Khan ZH, Maleki A, Makarem J, Mohammadi M, Khan RH, Zandieh A, et al. A comparison of the upper lip bite test with hyomental/thyro sternal distances and mandible length in predicting difficulty in intubation: A prospective study. Indian J Anaesth 2011;55:43-6.
22. Patil VU, Stehling LC, Zauder HL. Predicting the difficulty of intubation utilizing an intubation gauge. Anaesthesiol Rev 1983;10:32-3.