# Comparative study of airway assessment tests to predict difficult laryngoscopy & intubation

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## Abstract

**Introduction:** Prediction of potentially difficult airway management during pre-operative period is determined by anatomy of oropharynx & range of movement of neck, clinically evaluated by various tests like Modified Mallampati Test, Upper Lip BiteTest, Thyromental Distance, ratio of Height to thyromental distance etc. We performed a study to compare significant direct relationship between MMT, ULBT, TMD, RHTMD & Cormack-Lehane (C-L) scale.

**Aims and Objective:** 1) To elucidate the role of MMT, ULBT, TMD and RHTMD as simple bedside airway predictive tests & to study their direct correlation with difficult laryngoscopic view, using C-L grading.
2) To compare their ability to predict difficult laryngoscopy in various combinations.

**Materials and Methods:** Type of study - prospective, observational & single blind.

**Sample Size:** 450, 20-60 years, male/female, ASA I/II.
Pre-operatively anaesthesiologist not involved in intubation evaluated & assessed ULBT, MMT & TMD in sitting position. Patient induced & laryngoscopy performed with Macintosh blade No.3 in sniffing position & laryngoscopic view determined by C-L grading.

**Result:** On comparing CL-grading with other tests such as MMT, ULBT, TMD & RH MD in assessing difficult intubation, it was observed that there was statistically significant association with p <0.05. Kappa coefficient was highest for MMT & RHTMD with CL-grading as compared to other tests. MMT had highest sensitivity & lowest positive predictive value, ULBT had highest specificity & lowest negative predictive value. MMT & RHTMD had highest diagnostic accuracy followed by other tests.

**Conclusion:** We conclude that no single airway predictor test is sufficient for predicting difficult intubation. So, a combination of two or more airway predictor tests may predict difficult airway better.

**Keywords:** Difficult intubation, Mallampati test, Upper lip bite test, Thyromental distance, RHTMD.

## Introduction

In airway management tracheal intubation using direct laryngoscopy remains Gold standard. Of all anaesthetic deaths, 30-40% are attributed to inability to manage difficult airway. Prediction of potentially difficult airway management duringpre-operative period is determined by anatomy & range of movement of oropharynx & neck which is clinically evaluated by various tests like MMT, ULBT, TMD, RHTMD etc.

Modified Mallampati Test indicates significant correlation between the ability to visualise pharyngeal structures & ease of laryngoscopy & intubation. Its classification is based on observation of pharyngeal structures with mouth fully open & tongue maximally protruded without phonation.

Upper Lip Bite Tests is based on fact that range & freedom of mandibular movement & architecture of the teeth have pivotal role in facilitating laryngoscopic intubation. It is classified according to the ability to bite the upper lip with lower teeth.

Thyromental distance & Ratio of Height to Thyromental distance are other predictive tests for difficult laryngoscopy.

To the best of our knowledge there was no study to clarify which method predicted difficult laryngoscopy more accurately.

So, we have performed prospective, single blind study to compare significant direct relationship between MMT, ULBT, TMD, RHTMD & Cormack-Lehane scale.

## Materials and Methods

**Type of Study**
Prospective, observational, single-blind study.

**Hospital Setting**
Our hospital where this study was conducted is a tertiary care teaching institute from central India. Department of anesthesia was the primary site for this study.

**Duration of Study**
Study commenced in December 2015 and was completed in November 2017.

**Ethics Committee Permission**
The study was initiated only after obtaining permission from the Institutional Ethics Committee. (IEC)

**Sample Size**
450 patients of either sex (accuracy with 95% confidence interval)

**Sample Size Estimation**
The reported incidence of difficult intubation ranges from 0.5 to 18%. Also, the sensitivity, specificity for different tests like MMT, TMD, RHTMD and ULBT have been reported in study carried out by Shah PJ et al. (2013). These data were used to estimate the sample size for the proposed study.

The formula used for estimation of sample size was:
 n=Z2P (1-P)2

Where *Z* is 1.96 for 5% significance level, *P* is the targeted sensitivity or specificity, and *n* is the $(TP + FN)$ if *P* is sensitivity and $(FP + TN)$ if *P* is specificity.

In the present case, sensitivity of different methods as reported in the study has been used to estimate the sample size for the study.

Accordingly, the total sample size *N* is given by:

$N = (TP + FN)$/Incidence rate

The sensitivity of MMT was reported as 70.15%, while specificity was 61.02%. Considering the incidence rate of 18% and the desired precision level of 10%, the estimated sample size was 451.

Using data for TMD (sensitivity of 7.46% and specificity of 98.06%), and the same incidence and the precision levels, the estimate of sample size was 145.

For RHTMD, the sensitivity and specificity were 71.6% and 92.01% respectively. Accordingly, the sample size estimate was 445.

The sensitivity and specificity of ULB were 74.6% and 91.5% respectively. Using these parameters the sample size estimate was 412.

Considering these results, a sample size of 450 should be adequate and would provide a diagnostic efficiency of tests.

Written informed consent was taken from all patients

**Inclusion Criteria:**
1. ASA Grade I OR II
2. Age: 20-60 yrs.
3. Elective surgeries under General Anaesthesia with intubation

**Exclusion Criteria:**
1. Edentulous patient.
2. Patient unable to open the mouth.
3. Pharyngolaryngeal pathology.
4. History of Thyroid/Neck surgery.
5. Limitations of Temporomandibular or Atlanto axial joint movements
6. Pregnant patient.
7. Patient refusal.

## Materials and Methods

Preoperatively Anaesthesiologist not involved in intubation had evaluated and assessed the ULBT class and MMT class.

Determination of ULBT class: Patient made in sitting position. Patient was asked to bite the upper lip with the lower incisors.

Class I: Lower incisors can bite upper lip above the vermilion line.
Class II: Lower incisors can bite upper lip below the vermilion line.
Class III: Lower incisors can't bite upper lip.
ULBT of class III, was considered as markers of a potentially difficult intubation.
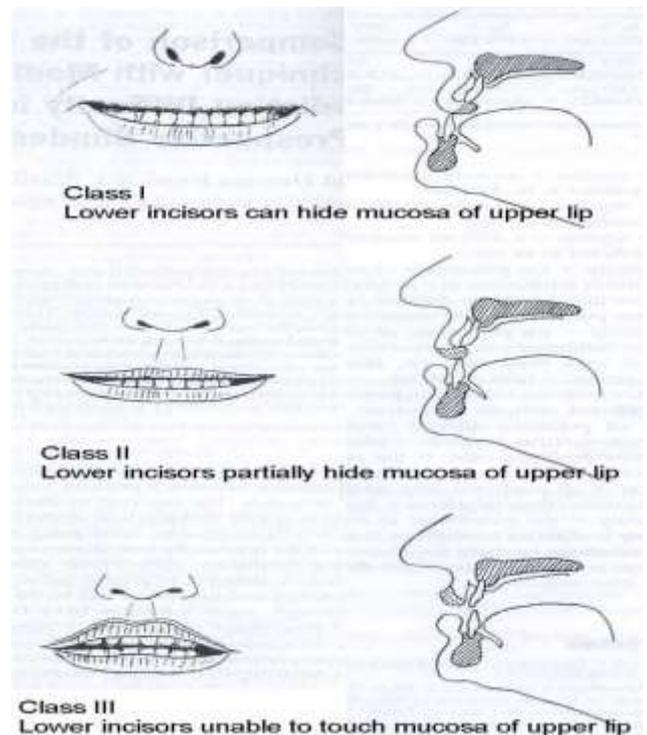


**Fig. 1: Schematic frontal and lateral view of the upper lip bite test**

Classification of oropharyngeal view was done according to MMT, wherein the patient was made to be in sitting position with mouth fully open and tongue maximally protruded, and patient was asked not to phonate.

Class I – Soft palate, fauces, uvula, and pillars are seen
Class II - Soft palate, fauces, and uvula are seen.
Class III – Soft palate and base of uvula
Class IV – Soft palate not visible. MMT Class III and IV was considered as markers of a potentially difficult intubation.
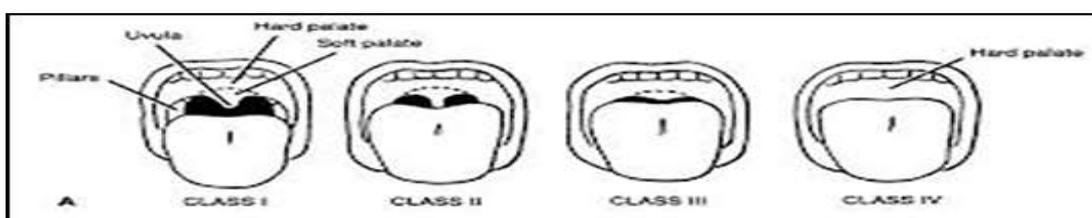


**Fig. 2: Mallampatti test**

Thyromental Distance (TMD) was measured from the bony point of the mentum while the head was fully extended and the mouth closed, using a rigid ruler. The distance was rounded to nearest 0.5 cm and graded[1] (Table A).

Class I - >6.5 cm
Class II - 6-6.5 cm
Class III- <6 cm



**Fig. 3: Thyromental distance. Ruler measurement from thyroid cartilage to menton of mandible**

Height, body weight, and body mass index (BMI) was assessed also. Height of the patient was measured in centimeters from vertex to heel with the patient standing and was rounded to the nearest 1 cm.

Ratio of Height to Thyromental Distance (RHTMD) was calculated and graded [2] (Table A) RHTMD = Height (in cms)/TMD (in cms).

Preparation of patients included over-night fasting for 8-10 hours. On the day of surgery, in the pre-operative room written and informed consent was checked and NBM status was confirmed. Intravenous line was secured. In the OT, three lead ECG, pulse oximetry (heart rate and $SpO_2$), non-invasive arterial pressure (NIBP) were connected to the patient. Patient was pre-medicated with injection Ranitidine 50 mg iv in drip and injection Ondansetron 4 mg iv and intravenous fluid was started.

Premedication with injection Midazolam 0.5mg/kg, injection Glyccopyrolate 0.004mg/kg, injection Fentanyl 1μg/kg. Induction with injection Propofol 2mg/kg and injection Succinylcholine 2mg/kg, laryngoscopy was done with Macintosh blade no 3, with neck flexion (35º) & head extension (15º) in sniffing position & the laryngoscopic view would be determined using Cormack-Lehane grading system as follows:

Grade I: Full view of glottis.
Grade II: Glottis partly exposed, ant. commissure not seen.
Grade III: Only epiglottis seen.
Grade IV: Epiglottis not seen.

No external laryngeal pressure was applied while reporting the laryngeal view. C-L grades I & II was considered as "easy intubations" grades III & IV as "difficult intubations". Data was analysed using kappa agreement & calculation of sensitivity, specificity, positive predictive value, negative predictive value, accuracy with their 95% confidence interval.

**Table A: Grading of various predictive tests**

| Test | Easy | Difficult |
|---|---|---|
| MMT (Mallampati test) | I / II | III / IV |
| ULBT (upper lip bite test) | I / II | III |
| TMD (thyromental distance) | I / II | III |
| RHTMD (ratio of height to thyromental distance) | <23.5 | >23.5 |
| CL GRADING (Cormack-Lehane grading) | I / II | III / IV |

## Results

**Table 1: Descriptive statistics for demographic parameters**

| Parameters | Mean± SD | Range |
|---|---|---|
| Age (in years) | 40.99 ±10.99 | 21-60 |
| Gender | No. | (%) |
| Male | 208 | 46.2 |
| Female | 242 | 53.8 |

Table 1 provides the descriptive statistics for demographic parameters. The mean age of the study groups was 40.99±10.99 years. Among the study groups 46.2% were males, 53.8% were females.
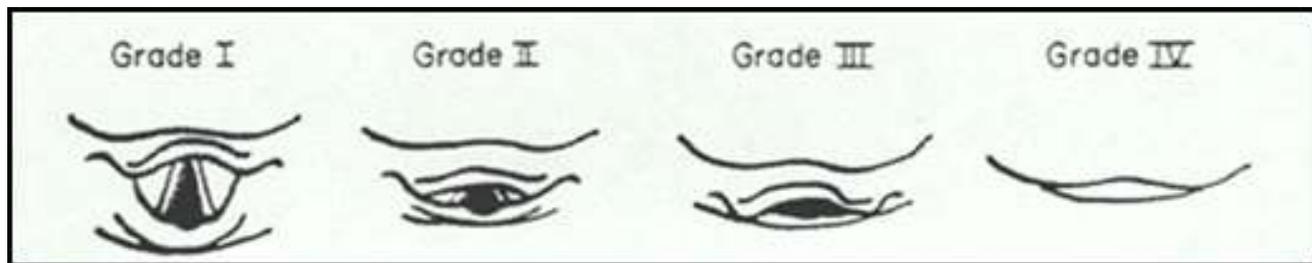


**Fig. 4: Cormack-Lehane grading system**

**Table 2: Cormack-Lehane grading comparison with demographic parameters**

| Parameters | Easy (n=420) | Difficult (n=30) | P-value* |
|---|---|---|---|
| Age (in years) [mean± SD] | 39.96±10.49 | 55.93±5.66 | **< 0.001 (S)** |
| Gender [No. (%)] | | | |
| Male | 190 (45.2) | 18 (60.0) | 0.168 (NS) |
| Female | 230 (54.8) | 12 (40.0) | |

*Obtaining using Chi Square test and independent t-test; S: Significant; NS: Not Significant

Table 2 provides the descriptive statistics according to C-L grading. Based on Laryngoscopic grading method to assess difficulty in intubation there was significant difference in age with P-value < 0.05. For gender distribution, there was insignificant difference with p-value of 0.168 by using chi square test.

**Table 3: Comparison of various predictive tests with Cormack-Lehane grading and estimation of kappa coefficients**

| Predictive tests | Intubations | C-L grading | | Kappa coefficient | P-value* |
|---|---|---|---|---|---|
| | | Difficult (n=30) | Easy (n=420) | | |
| | | No. (%) | No. (%) | | |
| MMT | Difficult | 30 (100.0) | 8 (1.9) | 0.87 (0.79-0.96) | < 0.001(S) |
| | Easy | 0 | 412 (98.1) | | |
| ULBT | Difficult | 7 (23.3) | 0 | 0.36 (0.17-0.56) | < 0.001(S) |
| | Easy | 23 (76.7) | 420 (100.0) | | |
| TMD | Difficult | 17 (56.7) | 2 (0.5) | 0.68 (0.52-0.83) | < 0.001(S) |
| | Easy | 13 (43.3) | 418 (99.5) | | |
| RHTMD | Difficult | 26 (86.7) | 4 (1.0) | 0.86 (0.76-0.95) | < 0.001(S) |
| | Easy | 4 (13.3) | 416 (99.0) | | |

S: Significant

Table 3 provides the comparison of different tests with C-L grading and estimation of kappa coefficients. In this study comparing C-L grade with other test such as MMT, ULBT, TMD, and RHTMD in assessing the difficulty in intubation, it was observed that there was statistically significant association with p-value < 0.05. Kappa coefficient was highest for MMT and RHTMD with C-L grading as compare to other tests.

**Table 4: Sensitivity, specificity, PPV, NPV of various predictive test**

| Laryngoscopic view | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | Accuracy |
|---|---|---|---|---|---|
| MMT | 100 (88-100) | 98.10 (96-99) | 79 (63-90) | 100 (99-100) | 98.2 |
| ULBT | 23.33(10-42) | 100 (99-100) | 100 (59-100) | 95 (92-97) | 94.9 |
| TMD | 56.67 (37-75) | 99.52 (98-100) | 89 (67-99) | 97 (95-98) | 96.7 |
| RHTMD | 86.67 (69-96) | 99.05 (98-100) | 87 (69-96) | 99 (98-100) | 98.2 |

Table 4 provides the sensitivity, specificity, positive predictive value, negative predictive value and accuracy of different predictive tests MMT, ULBT, TMD and RHTMD with Laryngoscopic view in predicting difficulty in intubation. MMT had highest sensitivity (100%), ULBT had highest specificity (100%) and positive predicted value (100%), and MMT had highest negative value (100%). MMT and RHTMD had highest diagnostic accuracy followed by other tests.

**Table 5: Sensitivity, specificity, PPV and NPV of airway predictive test in combinations**

| Airway Tests | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) |
|---|---|---|---|---|
| ULBT+MMT | 100 | 98 | 79 | 100 |
| ULBT+TMD | 67 | 100 | 100 | 97.6 |
| **ULBT+RHTMD** | **90** | **99** | **87.1** | **99.2** |
| ULBT+MMT+TMD | 100 | 98 | 79 | 100 |
| ULBT+MMT+RHTMD | 100 | 97 | 71.5 | 100 |

Table 5 provides the sensitivity, specificity, positive predictive value, negative predictive value of airway predictive tests in combinations. Combination of ULBT and MMT test, combination of ULBT, MMT and TMD as well as combination of ULBT, MMT and RHTMD had 100% sensitivity. The combination ULBT and RHTMD had a sensitivity of 90%, while ULBT and TMD had 67%.

As regards specificity, ULBT and TMD had the highest specificity of 100%, followed by ULBT and RHTMD with 99%, ULBT and MMT as well as ULBT, MMT and TMD with 98% each, and followed by ULBT, MMT and RHTMD with 97%.

The positive predictive value of ULBT and TMD was 100%, followed by ULBT, RHTMD with 87.1%, ULBT and MMT as well as ULBT, MMT and TMD with 79%.

The negative predictive value for ULBT and MMT, ULBT, MMT and TMD as well as ULBT, MMTT and RHTMD was 100%, followed by ULBT and RHTMD with 99.2%, and ULBT and TMD with 97.6%.

## Statistical Method
### Sensitivity and Specificity for combination of tests

$$Sensitivity \text{ of combination of tests} = 1 - \prod_{i=1}^{n}(1 - sensitivity_{Test_i})$$

$$Specificity \text{ of combination of tests} = 1 - \prod_{i=2}^{n}(1 - specificity_{Test_i})$$

where $i = 1,2,...n$ indicate the number of tests used.

## Discussion

Unexpected difficult intubations are probably the result of lack of accurate predictive tests for difficult intubation and inadequate preoperative examinations of the airway.

Ideally, any preoperative assessment of difficult tracheal intubation should have high sensitivity and specificity to result in minimal false positive or negative values. Sensitivity and specificity are dependent on each other, an increase in one of them usually results in decrease of other.

The current study was undertaken to study the predictive values as well as to elucidate the role of MMT, ULBT, TMD and RHTMD as simple bedside airway predictive tests in prediction of preoperative difficult airway assessment.

We hypothesised that there will be a significant direct relationship between the MMT, ULBT, TMD RHTMD and Cormack and Lehane scale. To test the validity of this hypothesis, we conducted this study in patients undergoing general anaesthesia. We used the Cormack-Lehane system as the gold standard for testing the validity of MMT, ULBT, TMD and RHTMD so, in this study 450 subjects were classified into 'Easy' and 'Difficult' groups based on degree of difficulty in intubation. There were 420 cases of easy intubation, while 30 cases of difficult intubation. The mean age of patients in the easy group was 39.96 ±10.49 years, while that of the difficult group was 55.93±5.66 years. Difference in the means was statistically significant with P-value < 0.001.

Similarly in the study conducted by Prakash et al.[3] it was observed an association between difficult laryngoscopy and old age. For the age-related increase in difficult laryngoscopy they have mentioned osteoarthritic changes and poor dentition is the major responsible factor.

The gender distribution in two groups was insignificantly different with p-value of 0.168 as per Chi-square test. Savva et al.[4] also did not report any difference in age, sex, weight or height between easy and difficult laryngoscopy groups.

## Upper LIP Bite Test

ULBT has the potential to evaluate both jaw movement and buck teeth simultaneously, providing additional support for its use as an airway assessment test.

ULBT has many obvious advantages. Firstly, it is a simple bedside method that involves the assessment of jaw subluxation and presence of buck teeth. Secondly, the three classes are clearly demarcated and delineated, making interobserver variations highly unlikely and its use is not dependent on skill or experience level.

In the present study ULBT had the least sensitivity of 23.33%, specificity of 100%, PPV of 100%, NPV of 95% and accuracy of 94.9%. This is in contrast to the results obtained by Khan et al,[5] Azmat Ali et al,[6] Ali et al[7] and Karci et al[8] wherein they found a sensitivity of 76.5%, 91.5%, 87.5%, and 13% respectively.

Khan et al[5] comdpare ULBT with MMT and concluded that the upper lip bite test with sensitivity 76.5%, specificity 88.7%, PPV 28.9% and NPV 98.4% is an acceptable option for predicting difficult intubation as a simple, single test.

Azmat Ali et al[6] calculated accuracy, sensitivity, specificity, positive predictive value and negative predictive value of ULBT which were 95.5%, 91.5%, 96%, 72.8% and 98.9% respectively. They found that ULBT is a highly accurate, sensitive and specific test for predicting difficult intubations.

Ali et al[7] obtained accuracy 91.9%, sensitivity 87.5%, specificity 92.9%, PPV 71.6% and NPV 97.3% of upper lip bite test. They mentioned the probable reasons for high sensitivity (87.5%) was lack of inter-observer variance as well as ethnic difference.

Our study with sensitivity of ULBT 23.33%, is in concordance with the study done by Eberhart et al[9], wherein they found sensitivity of 26.2%. They found major reason for this failure to be a more frequent incidence of difficult laryngoscopy in study patients. They hypothesized that this was because of the variability of clinical experience in the anaesthesiologists performing the endotracheal intubation.

The specificity of ULBT in our study was 100%, which correlates with the studies done by Khan et al[5] (88.7%), Eberhart et al[9] (92.5%), Hester et al[10] (97%).

The lower sensitivity 23.3% of ULBT in our study can be explained due to low incidence of ULBT Class III in our study i.e. 7 out of 450 patients. (Table 3)

We found that repeated demonstrations were required for the patients to perform ULBT and a few still failed to understand the procedure inspite of our efforts. Also in

some, there was a reflex movement of upper lip in the reverse direction over the upper teeth which may have altered the point of meeting of vermilion line with lower incisors.

## Modified Mallampati Test (MMT)

Modified Mallampati Test (MMT) assessment gives significant correlation between the ability to visualize pharyngeal structures and ease of laryngoscopy and intubation. Because, as the degree to which oropharyngeal structures could be visualized upon examination should correlate with structures that could be on laryngoscopy. Disadvantage is that, MMT does not consider the patient's dentition or variation in the degree of mandibular range of motion and the patients with small mouth opening or altered level of consciousness could be misclassified, hence its validity of assessment is influenced by the experience and the skill of the anesthetist. The specificity of Modified Mallampati test (MMT) was 100% in our study. This is in contrary to the results obtained by Khan et al,[5] Eberhart et al[9] and Hester et al[10] wherein they reported specificity of MMT as 66.8%, 61.0%, and 75% respectively.

Hester et al[10] obtained sensitivity 11%, specificity 75%, PPV 9%, NPV 79%. They suggest that MMT is a subjective instrument in predicting difficult airway, with inter-observer variation significantly altering the results.

This discrepancy may be explained by the fact that in our study both the preoperative evaluation of airway predictors and intubation were done by different persons. So the chances of inter-observer bias as reported by many authors may be an issue here.[5]

## Thyromental Distance and Ratio of Height to Thyromental Distance (RHTMD)

The TMD was measured with the head fully extended and the mouth closed. For the thyromental distance (TMD) varying "critical distances", ranging from 5.5 to 7 cm are used to predict a difficult laryngoscopy.[2] This makes comparison of results difficult and questions the predictive value of this test.

Based on the theorized relationship between patient's height and TMD, the ratio of height and TMD (RHTMD) might improve prediction. Schmitt et al.[2] showed that the ratio of height to TMD (RHTMD) had a better predictive value than the TMD.

In the present study sensitivity, specificity for thyromental distance (TMD) was 56.67% and 99.52% respectively. In a study Salimi et al[11] reported a sensitivity of 55% and specificity of 88%, Khan et al[12] reported sensitivity of 73% and specificity of 82.2% for TMD.

In a study Salimi et al[11] reported a sensitivity of 55% and specificity of 88%. The low sensitivity obtained in their study might be due to anthropometric peculiarities in the study population.

So, variation in reported sensitivity in our study as well as various other studies may be because of anthropometric peculiarities.[11]

RHTMD had the sensitivity of 86.67% and specificity of 99.05%. Schmitt et al.[2] introduced RHTMD and found that it has good predictive value for predicting difficult laryngoscopy than TMD as it allows for individual's body proportions which are not allowed in TMD. Schmitt et al.[2] got sensitivity 81% and specificity 91% for RHTMD which is quite similar with our study findings i.e., sensitivity of 86.67% and specificity of 99.05%.

These findings are not consistent with those reported by Krobbuaban et al.[13] (sensitivity, 77%; specificity, 66%), Shah et al.[14] (sensitivity, 71.6%; specificity, 92%), Safavi et al.[15] (sensitivity, 75.6%; specificity, 58.5%). Although the different statistical values in our study, like, sensitivity of 86.67% and specificity of 99.05% for RHTMD varied from other studies, the conclusion of RHTMD test better than TMD test was comparable.

## Kappa Coefficient

Kappa is the most commonly reported measure in the medical literature for assessing interobserver agreement. The values of kappa range from -1 to +1, with -1 indicating perfect disagreement and +1 indicating perfect agreement between the raters.

In this study, C-L grading was considered as standard and all the other test results were compared with the standard. The comparison of ULBT with C-L grading resulted into a kappa coefficient of 0.36 with P-value < 0.001, indicating fair agreement. TMD test had the kappa value of 0.68 with P-value < 0.001, implying substantial agreement between the two tests. The kappa coefficient for MMT test was 0.87 with P-value < 0.001. In other words, the agreement between MMT test grading and C-L grading was almost perfect. RHTMD had a kappa coefficient of 0.86 with P-value < 0.001, it also indicates almost perfect agreement with C-L grading. (Table 4)

Preoperative airway assessment tests are screening tests, and therefore should be highly sensitive to predict the maximum number of patients of difficult laryngoscopy correctly and highly specific to predict easy laryngoscopy correctly. Test should also have a high PPV with few false-negative predictions. NPV is the probability that patients with a negative screening test truly do not have difficult laryngoscopy.

MMT (Mallampati test) have sensitivity 100%, specificity 98.10%, PPV of 79%, NPV of 100% and accuracy 98.2%. It suggests that MMT can predict difficult and easy laryngoscopy correctly that were truly difficult and easy because of sensitivity 100% & specificity 98.10% respectively. PPV 79% shows that MMT predicting less number of intubations to be difficult. With NPV 100%, MMT successfully predicted all intubations to be easy.

ULBT (Upper lip bite test) have sensitivity 23.33%, specificity 100%, PPV of 100%, NPV of 95% and accuracy 94.9%. With sensitivity of 23.3%, ULBT has predicted less number of patients with difficult laryngoscopy correctly that were truly difficult. Specificity of 100% indicates that ULBT predicted all easy laryngoscopies correctly which

were truly easy. PPV of 100% & NPV of 95% indicates correct prediction of difficult and easy intubation.

TMD (thyromental distance) have sensitivity 56.7%, specificity 99.5%, PPV of 89%, NPV of 97% and accuracy 96.7%. Sensitivity of 56.7% indicates low prediction of difficult laryngoscopy that were truly difficult. This may be because of anthropometric peculiarities. Specificity of 99.5% indicates prediction of almost all easy intubations that were truly easy. PPV of 89% indicates good percentages for correct prediction of difficult laryngoscopy.

RH MD (ratio of height to thyromental distance) have sensitivity 86.7% which indicates good percentage of intubation predicted difficult which were truly be difficult. With specificity of 99.05% this test had predicted nearly all easy intubation which were truly easy. PPV of 87%, NPV of 99% indicates good percentages for correct prediction of easy intubation. Accuracy of RHTMD is 98.2%.

To summarise, our study shows MMT had highest sensitivity (100%), ULBT had highest specificity (100%) and positive predictive value (100%), and MMT had highest negative predictive value (100%). MMT and RHTMD with accuracy of 98.2% had highest diagnostic accuracy followed by other tests. (Table 6)

So, safe outcome of anaesthesia continues to be an important goal for every anaesthesiologist. Unfortunately, there is still no test that can predict 100% of difficult laryngoscopies. Therefore we studied combination of various assessment methods in predicting the ease of intubation for improving the sensitivity rates.

We made 5 combinations of MMT, ULBT, TMD & RHTMD, as follows-
ULBT + MMT.
ULBT + TMD.
ULBT + RHTMD.
ULBT + MMT + TMD.
ULBT + MMT + RHTMD.

All these tests have their own statistical and predicitive values (sensitivity, specificity, positive predictive value PPV, negative predictive value NPV) which are different from each other. Like in our study, MMT had highest sensitivity (100%), ULBT had highest specificity (100%) and positive predictive value (100%), and MMT had highest negative predictive value (100%). (Table 5)

Combination of these tests was difficult due to above mentioned factors. So, to overcome this we considered these tests almost equivalent to obtain standardised statistical values. Hence, comparison of combinations of different airway predictive tests was possible.

ULBT + TMD combination has sensitivity 67%, specificity 100%, positive predictive value 100%, negative predictive value 97.6%. This combination provides almost perfect specificity (100%), positive predictive value (100%), negative predictive value (97.6%) but with lowest sensitivity (67%) among the combinations we made. So, it has not correctly predicted difficult laryngoscopies as a proportion of all laryngoscopies that were truly difficult. Hence, this combination stands last in order of choice.

ULBT + MMT + RHTMD combination has sensitivity 100%, specificity 97%, positive predictive value 71.5% and negative predictive value 100%. This combination have lowest positive predictive value of 71.5% among other combinations. So, it has not given the percentage of correctly predicted difficult laryngoscopies as a proportion of all predicted difficult laryngoscopies. This combination gives better results than ULBT + TMD. So ULBT + MMT + RHTMD is better combination than ULBT + TMD.

ULBT + MMT & ULBT + MMT + TMD, both of these combinations have sensitivity 100%, specificity 98%, positive predictive value 79% and negative predictive value 100%. These two combinations are near to ideal airway prediction model but with positive predictive value of 79% it has not correctly predicted difficult laryngoscopies that were truly difficult. This combination is better than both the combinations discussed above.

ULBT + RHTMD combination has sensitivity 90%, specificity 99%, positive predictive value 87.1% and negative predictive value 99.2%. This combination we think is ideal airway prediction model because though it has comparatively less sensitivity 90%, with positive predictive value 87.1%, specificity 99% and negative predictive value 99.2%, it predicts all difficult and easy intubations correctly.

Hence, ULBT + RHTMD with sensitivity 90%, specificity 99%, PPV 87.1% & NPV 99.2%; is the best combination among the combinations we made.

Such a combination is preferable because anatomic predictors of difficult intubation carry a low-sensitivity rate when used alone, whereas a multivariate composite risk index may achieve better results than single, independent criteria.[10] We suggest that further more studies needs to be carried out to prove the efficacy of such combinations of airway assessment tests for the prediction of difficult airway and intubation.

## Conclusion

We conclude that no single airway predictor is sufficient for predicting difficult intubation. A different combination of two OR more airway predictor have to be taken into consideration to arrive at near ideal airway prediction model.

So, in our study we found ULB + RHTMD is the best combination.

**Conflict of Interest:** None.

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