Predictive value of upper lip bite test and ratio of height to thyromental distance compared to other multivariate airway assessment tests for difficult laryngoscopy in apparently normal patients

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Abstract

Background: Various anatomical measurements and non-invasive clinical tests, singly or in various combinations can be performed to predict difficult intubation. Recently introduced "Upper lip bite test" (ULBT) and "Ratio of height to Thyromental distance" (RHTMD) are claimed to have high predictability. We conducted a study to compare the Predictive Value of ULBT and RHTMD with Mouth opening (Inter-Incisor gap) (IIG), Modified Mallampatti Test (MMT), Head and neck movement (HNM) and Thyromental Distance (TMD) for Difficult Laryngoscopy.

Materials and Methods: In this prospective, single blinded observational study, 480 adult patients of either sex, ASA grade I and II were assessed and graded for ULBT, RHTMD, TMD, MMT, IIG, and HNM according to standard methods and correlated with the Cormack and Lehane grade.

Results: ULBT and RHTMD had highest sensitivity, specificity, positive predictive value, negative predictive value, likelihood ratio, i.e., 74.63%, 91.53%, 58.82%, 95.7%, 31.765 and 71.64%, 92.01%, 59.26%, 95.24%, 8.96 respectively, compared to TMD, MMT, IIG and HNM.

Conclusions: ULBT is the best predictive test for difficult laryngoscopy in apparently normal patients but RHTMD can also be used as an acceptable alternative.

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

Introduction

An important responsibility of an anesthesiologist is to maintain a patent airway in anesthetized patients. Failure to secure the airway and interruption of gas exchange, for even a few minutes, can result in catastrophic outcome such as brain damage or even death. Closed claim analysis found that under anesthesia the vast majority of the airway-related events, especially inability to maintain patent airway, involve brain damage or death.[1] The incidence of Cormack and Lehane grade II and III requiring multiple attempts or blades or both is relatively high (1-18%). The incidence of failed endotracheal intubation is 0.05-0.35%, whereas the incidence of cannot ventilate, cannot intubate is around 0.0001-0.02%.[2-4]

Several preoperative airway assessment tests [Mouth opening or Inter-Incisor gap (IIG), Head and neck movement (HNM), Modified Mallampatti Test (MMT), Wilson risk score (WS), horizontal length of mandible (HLM), sternomental distance (SMD), thyromental distance (TMD)] may be used to predict difficult intubations but sensitivity and positive predictive value of these individual signs are low (33%-71%) while false positive results are high.[3-7] Research is ongoing to device a simple bedside test, to anticipate difficult tracheal intubation, which has high sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), likelihood ratio (LR) with minimal false positive (FP) and false negative (FN) values. While several studies have evaluated such predictive criteria individually or in arbitrary combinations, there has been no sufficiently powered systematic

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multivariate analysis of readily available clinical variables like upper lip bite test (ULBT), ratio of height to thyromental distance (RHTMD), IIG, MMT, HNM, TMD, studied simultaneously and published in literature, especially those comparing RHTMD with ULBT.

We conducted this study to evaluate sensitivity, specificity, PPV, NPV, Relative risk (RR), Odd ratio (OR) and LR for various screening tests like ULBT, RHTMD, IIG, MMT, TMD and HNM in isolation, with an attempt to determine a more comprehensive and accurate as well as simple and clinically applicable to day to day basis parameter for predicting difficult laryngoscopy.

Materials and Methods

After institutional ethical committee approval this prospective, observational, single blinded evaluation was done on 480 adult patients of more than 18 years age, of either sex, of American Society of Anesthesiologists grade I and II, undergoing elective surgeries under general anesthesia. Patients unable to sit or stand erect, pregnant females, those having obvious malformation of the airway or those requiring awake intubation were excluded from the study.

Following routine pre-anaesthetic check-up by the attending anesthesiologist, informed written consent was taken from each patient. The airway was assessed pre-operatively in the pre-induction room on the day of surgery by the same anesthesiologist in all studied patients to avoid inter-observer error.

Inter-incisor gap (IIG) was assessed by asking each patient to open the mouth as wide as possible. The distance between upper and lower incisor at the midline was measured and graded as per Table 1.[8]

Maximum range of Head and Neck movement (HNM) movement was noted and graded as I ″ 80 degrees or II ≥80 degrees [Table 1].[8] The patient was first asked to extend the head and neck fully, while 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 oropharyngeal view was assessed using a Modified Mallampatti Test (MMT)[9] by asking the patient to open his or her mouth maximally and to protrude the tongue without phonation, while seated [Table 1].

Upper lip bite test (ULBT) was done to assess the range of freedom of the mandibular movement and the architecture of the teeth concurrently.[10] Each patient was asked to bite their upper lip with lower incisor and categorized as [Table 1]:
Class I – Lower incisor can hide mucosa of upper lip
Class II - Lower incisor can partially hide mucosa of upper lip
Class III - Lower incisor unable to touch mucosa of upper lip.

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 [Table 1].[4]

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

We also assessed height, body weight, and body mass index (BMI). Height of the patient was measured in centimeters from vertex to heel with the patient standing and was rounded to the nearest 1 cm. Then Ratio of Height to Thyromental Distance (RHTMD) was calculated as follows and graded [Table 1].[10]

RHTMD = Height (in cms)/TMD (in cms)

Standardized anaesthetic protocol was followed in all the patients. After establishing venous access and standard monitoring all the patients were administered intravenous (IV) ranitidine 50 mg, ondansetron 4 mg, glycopyrrolate 0.2 mg, midazolam (0.03 mg/kg) and Fentanyl (1-2 mcg/kg). Following preoxygenation, anesthesia was induced with thiopentone sodium (5 mg/kg) IV and rocuronium (0.6 mg/kg) IV was given to facilitate endotracheal intubation. The lungs were ventilated with 100% oxygen with help of a facemask. Laryngoscopy was performed after the loss of the fourth twitch in the train-of-four. With patient's head in the sniffing position, laryngoscopy was performed with a Macintosh # 3 laryngoscope blade by an anesthesiologist (of at least two year experience) who was blinded to the results of preoperative airway assessment. Glottic visualization was assessed using a modified Cormack and Lehane (CL) classification.[4]

Table 1: Grading of various predictive tests

Predictive tests	Grade 1	Grade 2	Grade 3
Inter-incisor gap (IIG)	>4 cm	≤4 cm	
Head and neck movement (HNM)	>80°	≤80°	
Thyromental distance (TMD)	>6.5 cm	6.0-6.5 cm	≤6.0 cm
Oropharyngeal view (MMT)	Class I	Class II	Class III and IV
Upper lip bite test (ULBT)	Class I	Class II	Class III
Ratio of height to thyromental distance (RHTMD)	<23.5	≥23.5	

IIG=Inter-incisor gap; TMD=Thyromental distance; MMT=Modified mallampatti test; ULBT=Upper lip bite test

After evaluation, if needed external laryngeal pressure was permitted for endotracheal tube insertion. Difficult laryngoscopy in this study was set at Cormack and Lehane grade III and IV. After evaluation and endotracheal intubation, surgery was performed under standard anesthesia.

Statistical analysis was carried out using Graph Pad in Stat3 software after collecting patient data as master chart. Demographic data was presented as mean (standard deviation, range) and evaluated using the student's *t*-test. The preoperative data of IIG, MMT, TMD, HNM, ULBT, RHTMD and the laryngoscopic findings were correlated to evaluate the sensitivity, specificity, PPV, and NPV of each test according to standard formulas [Table 2]. We also calculated OR, RR, LR and *P* value for each of the predictive test.

Results

The incidence of difficult laryngoscopy was 13.95% (67 out of 480). Out of the 67 difficult laryngoscopies, 65 had CL grade III and two had CL grade IV. There were no failed tracheal intubations. All the patients were demographically comparable in easy and difficult laryngoscopy group except mean height and mean BMI which was significantly high in difficult laryngoscopy group (*P* value-0.0003 and 0.02437, respectively) [Table 3]. Highest sensitivity, PPV, NPV were observed with ULBT and RHTMD as compared to other predictive test. RR and LR were highest for ULBT, while OR were highest for RHTMD. HNM had lowest PPV, NPV, RR, OR and LR [Table 4, 4a and b].

Discussion

Safe outcome from anesthesia is an important goal for an anesthesiologist. Obvious airway abnormalities initiate a chain of communications and help seeking assistance, however, unrecognized difficult airway may lead to unexpected bad outcomes. Several clinical tests have been proposed for preoperatively identifying patients who may have difficult laryngoscopy but unfortunately, there is still no test or group of tests that can accurately predict difficult laryngoscopy.

Preoperative airway assessment test should be highly sensitive to predict maximum number of patients of difficult laryngoscopy correctly, and highly specific to predict easy laryngoscopy correctly. Test should also have a high PPV (so that only a few patients with easy laryngoscopy are subjected to the protocols for difficult intubation) with few negative predictions (to avoid deleterious and even life threatening consequences). Likelihood ratio for a positive test result may be a useful measure to judge the efficacy of a predictive tool in daily practice [Table 2].

Table 2: Standard formula for different test for data analysis

Sensitivity	No. of difficult intubation correctly predicted No. of difficult intubation	TP TP+FP
Specificity	No. of easy intubation correctly predicted No. of easy intubation	TN TN+FP
PPV	No. of difficult intubation correctly predicted No. of intubation predicted be difficult	TP TP+FP
NPV	No. of easy intubation correctly predicted No. of intubation predicted to be easy	TN TN+FN
RR	Probability of difficult intubation in anticipated difficult airway (Pa) Probability of difficult intubation in unanticipated difficult airway (Pb)	TP/TP+FP FN/FN+TN
OR	Compare the probability of difficult intubation in anticipated and unanticipated difficult intubation	Pa/(1-Pa) Pb/(1-Pb)
LR+	Sensitivity/(1−Specificity)	
LR-	(1−Sensitivity)/Specificity	

TP=True positive; FP=False positive; TN=True negative; FN=False negative

Table 3: Demographic data based on Cormack and Lehane's laryngoscopy grading (mean±SD)

Variable	Laryngoscopy assessment		*P* value
	Easy (CL I and II)	Difficult (CL III and IV)	
Age (in yrs)	41.0±12.8	46.7±13	0.8329
Weight (in kg)	64.5±10.1	71.4±10.7	0.5038
Height (in cm)	162.5±8.2	170.5±5.6	0.0003
BMI (in kg/m^2)	23.7±3.7	26.6±4.1	0.02437
Sex-male/female	198/215	41/26	

Table 4: Distribution of various predictive tests based on Cormack and Lehane's laryngoscopy grading

Factors	Grade	Total no. of cases	CL I	CL II	CL III	CL IV
IIG	Grade I	464	343	63	56	2
	Grade II	016	5	2	9	0
HNM	Grade I	450	328	60	60	2
	Grade II	030	20	5	5	0
MMT	Class I	160	130	20	10	0
	Class II	112	90	12	9	1
	Class III	158	104	26	38	0
	Class IV	050	24	7	9	1
TMD	>6.5 cm	425	327	55	43	0
	6-6.5 cm	042	15	8	18	1
	≤6 cm	013	6	2	4	1
RHTMD	<23.5	399	334	46	18	1
	≥23.5	081	14	19	47	1
ULBT	Class I	256	204	40	12	0
	Class II	139	100	34	4	1
	Class III	085	20	15	49	1

IIG=Inter-incisor gap; HNM=Head and neck movement; MMT=Modified mallampatti test; TMD=Thyromental distance; RHTMD=Ratio of height to thyromental distance; ULBT=Upper lip bite test

Table 4a: Comparison of various predictive tests

Variable	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Odds ratio	Relative risk	Likelihood ratio	*P* value
IIG	13.43	98.31	56.25	87.50	9.000	4.500	7.925	<0.0001
HNM	07.46	93.95	16.67	86.22	1.233	1.210	1.252	<0.5920
MMT	70.15	61.02	22.60	92.65	3.678	3.073	1.799	<0.0001
TMD	07.46	98.06	38.46	86.72	4.083	2.897	3.853	<0.0240
RHTMD	71.64	92.01	59.26	95.24	29.01	12.444	8.966	<0.0001
ULBT	74.63	91.53	58.82	95.70	8.806	13.668	31.765	<0.0001

IIG=Inter-incisor gap; HNM=Head and neck movement; MMT=Modified mallampatti test; TMD=Thyromental distance; RHTMD=Ratio of height to thyromental distance; ULBT=Upper lip bite test

Table 4b: Comparison of various tests

Criteria	Order of various airway assessment tests
Sensitivity	ULBT>RHTMD>MMT>IIG>HNM>TMD
Specificity	IIG>TMD>HNM>RHTMD>ULBT>MMT
PPV	RHTMD>ULBT>IIG>TMD>MMT>IIG
NPV	ULBT>RHTMD>MMT>IIG>TMD>HNM
Odds ratio	RHTMD>IIG>ULBT>TMD>MMT>HNM
Relative risk	ULBT>RHTMD>IIG>MMT>TMD>HNM
Likelihood ratio	ULBT>RHTMD>IIG>TMD>MMT>HNM

The reported incidence of difficult airway varies from 1.3 to 18% in general population. The incidence of difficult laryngoscopy was 13.95% in our study which is comparable to that observed by earlier studies.[5,8,11] However, the incidence was higher than observations of some authors[7,12,13,14] and lower as compared to Allahyray's study on obstetric patients. This difference could have resulted from anthropometric differences in our population.

The demographic variables like mean age and weight were comparable between patients with easy and difficult laryngoscopy. However, mean height and BMI were statistically high in difficult laryngoscopy group. This may be due to excessive soft tissues in the velopalate, retropharynx and submandibular region in obese patients[5] and varied length of neck and mandible as well as volume of tongue and soft tissues according to size and proportion of the body in tall patients.[10]

Khan *et al.* introduced ULBT as a simple and effective method for predicting difficult intubations in 2003.[12] Our study also revealed ULBT as the best predicting test with highest sensitivity, NPV, RR and LR. Specificity, PPV and OR were also relatively high compared to other predictive tests [Tables 4a and b]. The results were comparable to the studies by Khan *et al.* and Eberhart *et al.*[12,13] The sensitivity and PPV of ULBT was higher, but specificity and NPV was lesser than the observations of other authors.[15,16] The variations in statistical data could be due to population differences.

The second best test in present study was RHTMD with higher sensitivity, specificity, PPV, NPV, LR, OR and RR ($P < 0.0001$) [Table 4a]. RHTMD, introduced by Schmitt *et al.*, has better predictive value for predicting difficult laryngoscopy than TMD as it allows for individual's body proportions which are not allowed in TMD.[10] Krobbuaban *et al.*, and Krishna *et al.*, assumed RHTMD ≥ 23.5 cm as risk factor for predicting difficult laryngoscopy with high sensitivity, specificity and NPV and observed variable results.[11,17] Although the different statistical values in our study varied from other studies, the conclusion was comparable.

TMD alone had been advocated as a screening test for predicting difficult laryngoscopy by Patil *et al.*[18] A wide range of cut-off values are quoted for TMD ranging from 5.5-7 cm. A number of studies defined TMD < 7 cm to predict difficult intubation.[5] In spite of higher cut-off, these studies observed low sensitivity, specificity and PPV of TMD. In the present study, TMD showed high specificity but at the cost of very low sensitivity which is unacceptable.

Though Mallampati scoring system based on oropharyngeal structures has been in use for more than two decades, over the years many of its limitations have been pointed out by various trials. The absence of a definite demarcation between class II and III and between class III and IV, the effect of phonation and patient's cooperation leads to high inter-observer variability and decreased reliability.[19] In our evaluation, MMT had a low sensitivity, specificity and PPV, with an acceptable NPV [Table 4a]. Although, other studies on MMT had represented different reports of sensitivity, specificity and positive predictive value,[20,21] we observed poor sensitivity of IIG and HNM, which is unacceptable in clinical practice [Table 4a].

To conclude, our study demonstrates that the upper lip bite test (ULBT) is the best predictive test for difficult laryngoscopy out of all the six predictive tests evaluated. Ratio of height to Thyromental distance (RHTMD) can be used as an acceptable alternative with a decent predictability. Since the etiology of difficult airway is multifactorial, integration of ULBT and RHTMD with other commonly used predictive test would be helpful to improve prediction of difficult airway.

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