

Study comparing different airway assessment tests in predicting difficult laryngoscopy: A prospective study in geriatric patients

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ABSTRACT

Background and Aims: Limited studies are available comparing diagnostic accuracy of various airway predictors in geriatric patients. We conducted this study with primary aim to evaluate and validate the predictive value of 'standard airway predictors' like modified Mallampati test, thyromental distance (TMD), sternomental distance, neck movement (NM), mouth opening (MO), dentition and 'new airway predictors' like upper lip bite test (ULBT), ratio of height to thyromental distance and thyromental height test (TMHT) for predicting difficult laryngoscopy in geriatric patients. **Methods:** This prospective, observational study was conducted on 140 patients above 65 years of age of either sex, scheduled for elective surgery under general anaesthesia requiring endotracheal intubation. The age, weight, height, body mass index (BMI) and airway parameters were recorded. The laryngoscopic view was assessed by modified Cormack-Lehane scale. Standard formulae were used to calculate validity indexes. **Results:** The incidence of difficult laryngoscopy found in our study was 25%. The mean age of our study population was 69.37 ± 4.23 years. TMD exhibited the highest sensitivity (80%) and negative predictive value (NPV) (91.86%) as compared to other studied airway predictors. The positive predictive value (PPV) of ULBT was 100%. Moreover, ULBT exhibited highest accuracy (82.14%) and odds ratio (86.88) and high specificity (91.30%) for predicting difficult laryngoscopy in geriatric patients. NM and TMHT also exhibited high accuracy (77.85%, 77.14%) and PPV (59.09%, 52.94%). **Conclusions:** TMD and ULBT both showed good predictive value in diagnosing difficult laryngoscopy in geriatric patients. Furthermore, NM and TMHT also exhibited higher diagnostic accuracy in predicting difficult airway in these patients.

Key words: Difficult airway, edentulous, elderly, geriatric, thyromental height test, upper lip bite test

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INTRODUCTION

To evaluate and validate various preoperative airway assessment tests in geriatric patients is of paramount importance because, firstly, the elderly population has been increasing tremendously since last few decades and is considered as the fastest growing group of the population in many parts of the world.^[1,2] It has been observed that more than 50% of this increasing elderly group need one or two surgeries in their life time.^[3,4] Secondly, airway of geriatric patients is expected to be difficult because of various age-related degenerative changes in

airway anatomy such as dental attrition and loss, atrophy of alveolar bone, osteoarthritis and rigidity of head and neck joints.^[5,6] However, very limited

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studies are available comparing various predictors of airway to predict difficult laryngoscopy in geriatric patients. Thirdly, it is reported that of all the anaesthetic deaths in all age groups, 30– 40% are attributed to inability to manage difficult airway.^[7] Moreover, geriatric patients are vulnerable to airway associated complications such as aspiration, oxygen desaturation, haemodynamic instability because of decreased functional reserve.^[8] Hence, it is imperative to predict difficult laryngoscopy and intubation accurately in this age group. However, the age-related changes in anatomy and its implications on difficult airway are not explored enough to avoid unanticipated difficult airway in geriatric patients.

So, we conducted this prospective study with primary aim to evaluate and validate the predictive value of 'standard airway predictors' like modified Mallampati test (MMT), thyromental distance (TMD), sternomental distance (SMD), neck movement (NM), mouth opening (MO), dentition and 'new airway predictors' like upper lip bite test (ULBT), ratio of height to thyromental distance (RHTMD) and thyromental height test (TMHT) for predicting difficult laryngoscopy in geriatric patients.

METHODS

This prospective, single blinded, observational study was conducted after obtaining institutional ethical committee approval at a university hospital. One hundred and forty patients above 65 years of age, either sex, belonging to American Society of Anesthesiologists (ASA) physical status I and II, scheduled for elective surgery under general anaesthesia requiring endotracheal intubation were recruited for this study. Written informed consent was taken from all the patients. The exclusion criteria included patients with obvious airway malformation, unstable cervical spine and those who required awake and emergency intubation. Non-cooperative patients were also excluded from the study.

During pre-anaesthesia check-up, the patient's age, sex, weight, height, ASA physical status and body mass index (BMI) were recorded. The airway assessment was done by two anaesthesiologists, involved in the study to avoid inter-observer variability. The airway was assessed after removing the dentures, if present. MMT, TMD, SMD, RHTMD and ULBT were measured by the standard methods. The other airway predictors were assessed as:

MO: It is the distance between the upper and lower incisors (inter-gingival distance in edentulous patients) with mouth maximally open, measured with a graduated scale.

NM: It was assessed by keeping a pencil vertically on forehead with patient head and neck in full extension. The orientation of the pencil was adjusted in a way that it was parallel to a distant window frame. Then, while the pencil was held firmly in position, the head and neck were fully flexed and the pencil was sighted against the horizontal of the window frame to judge if it had moved through 90°. This criterion was graded into three levels: <80° ; near 90° (90° ± 10°); >100°.^[9]

ULCT (in edentulous patients): Patient was asked to roll the lower lip over the upper lip as far as possible and graded as – class zero: The lower lip rolling over the upper lip reaching as high as the columella; class I: The lower lip catching the upper lip, completely above the vermilion line fully covering and passing past the vermilion reaching a point midway between the vermilion and the columella; class II: The lower lip catches the upper lip at the level of the vermilion line or positioning itself just above it (2 mm); class III: The lower lip just caresses the upper lip, but falls short of obliterating the vermilion line.^[10]

TMHT: Height between the anterior border of the thyroid cartilage and the anterior border of the mentum, with head in neutral position keeping his/her mouth closed. The height was measured with the help of depth gauze (Kriestel, 1503 DG 1).^[11]

Dentition: To determine dental status, the existence of irregular dentition and lost or protruding maxilla incisors and canines were examined and classified as grade 1: A dental condition with normal dentition and total anodontia, grade 2: indicates the existence of one of the dental conditions, grade 3: indicates the existence of two of the dental conditions.^[12]

In the operating room, after taking baseline vitals and preoxygenation with 100% oxygen for 5 minutes, general anaesthesia was induced with fentanyl 2 µg/kg and propofol 2-3 mg/kg. Muscle relaxation was achieved by vecuronium 0.1 mg/kg or succinyl choline (2 mg/kg), decided by in charge anaesthesiologists according to preoperative assessment of the airway. Bag-mask ventilation was then performed for three minutes (inj. vecuronium) or one minute (inj. succinyl choline). Laryngoscopy

was performed in sniffing position by an experienced anaesthesiologist (more than 10 years experience), not involved in airway assessment, using Macintosh #3, 4 blades. Sniffing position for laryngoscopy was achieved by placing a pillow (height – 8 cm) under the patient's head.^[13] The laryngeal view was assessed by using modified Cormack and Lehane system (MCLS) as: grade 1: full glottic exposure, grade 2a: partial view of the glottis, grade 2b: only the arytenoids or the very posterior origin of the cords visible, grade 3: only epiglottis visible, grade 4: neither glottis nor epiglottis visible.^[14] The MCLS grade 2b, 3 and 4 were considered as difficult laryngoscopy. External laryngeal pressure (ELP) was applied to obtain optimal laryngeal view for intubation, whenever required. However, ELP was not used for the reporting of laryngeal view. The patient's trachea was then intubated and confirmed by bilateral auscultation over the lung fields and capnography.

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 22 (SPSS Inc., Chicago, IL, USA). The sample size was calculated to be 138 patients with a 95% confidence interval and 5% precision rate, assuming the incidence of difficult laryngoscopy to be 10% based on previous studies. After rounding off to the nearest value, the sample size was taken as 140 patients. Data were presented as mean \pm standard deviation or numbers (%). Area under the Receiver Operating Characteristic (ROC) curve and Area under the curve (AUC) were used to calculate the optimal predictive cut off point for TMD, SMD, RHTMD and TMHT. The preoperative airway assessment data and the findings during intubation were used to calculate the validity indexes. Fisher exact test was used for statistical comparison. Additionally, Cohen's kappa (K) values were also calculated for comparing C-L grades with airway predictors. 95% confidence interval (CI) was calculated and a *P* value of 0.05 (two-tailed) was defined as statistically significant.

RESULTS

A total of 140 patients were enrolled in the study. The characteristics of all patients are shown in Table 1. There were no significant differences in weight, height and BMI between patients with easy intubation and patients with difficult intubation. The mean age of our study population was 69.37 ± 4.23 years. Out of 140 patients, 58 (48.42%) were male, 82 (58.57%) were female and 18 patients (12.8%) were edentulous.

The incidence of difficult laryngoscopy was 25% (35 patients). All the difficult intubations were managed by using external laryngeal pressure and with the help of stylet or bougie. There were no failed intubations. However, in one patient the loosened tooth was got dislodged into the oral cavity during laryngoscopy.

According to the ROC curve, the cut off values for TMD, SMD, TMHT and RHTMD were 8.1 cm, 14.2 cm, 5.5 cm and 20.9 cm, respectively [Table 2]. All studied airway predictors except MO showed significant (*P* < 0.05) correlation with modified C-L grades [Table 3]. Validity Indexes for 'standard airway predictors' and 'new airway predictors' to predict the occurrence of difficult laryngoscopy according to the modified C-L classification are shown in Table 4.

The highest sensitivity (80%) and negative predictive value (NPV) (91.86%) was observed with TMD as compared to other studied airway predictors. Furthermore, TMD also exhibited high odds ratio. The positive predictive value of ULBT was 100%. Moreover, ULBT exhibited highest accuracy (82.14%) and odds ratio (86.88) and high specificity (91.30%) for predicting difficult laryngoscopy in geriatric patients [Table 5].

MO exhibited the highest specificity (96.19%) as compared to all other tests evaluated in this study. However, it showed the least sensitivity, NPV and odds ratio. Furthermore, the RHTMD was the least specific test (77.37%) with minimum positive predictive value (PPV) and accuracy as compared to other tests. Nevertheless, assessment of dentition as a preoperative difficult airway predictor showed good PPV, accuracy and specificity.

DISCUSSION

It is very important to validate the diagnostic accuracy of various airway predictors in elderly patients as they have different anatomy as compared to young adults because of degenerative changes (decreased strength of airway muscles, head and neck joint changes, atrophy of alveolar bone, osteoarthritis) which may result in unanticipated difficult airway.^[15,16] These progressive changes in anatomy of geriatric patients warranted us to calculate the optimal cut-off point of TMD, SMD, RHTMD and TMHT for prediction of difficult laryngoscopy by using Receiver Operating Curves (ROC). Previous studies performed in young

Table 1: Demographic characteristics of patients

Variables	Range	Easy Laryngoscopy (n=105)	Difficult Laryngoscopy (n=35)	P
Age (years)	66-88	69.47±4.61	69.08±2.86	0.638
Weight (kg)	29-80	53.04±7.99	57.80±13.25	0.051
Height (cm)	126-178	153.61±10.58	155.63±11.88	0.345
BMI (kg/m ²)	16-39.7	22.88±4.39	23.61±3.88	0.382
Gender (M/F)		40/65	19/16	0.092
Edentulous		18	0	

Data are presented as mean±SD or number of patients. BMI-Body mass index

Table 2: Predictors of difficult laryngoscopy and modified Cormack-Lehane Grade

Variables	Mean±SD	Cut-off values
TMD (cm)	8.07±1.17	≤8.1
SMD (cm)	14.24±1.33	≤14.2
MO (cm)	4.2±1.62	≤3.5
RHTMD	20.12±3.21	≤20.9
TMHT (cm)	5.51±0.85	≤5.5
MMT (I/II/III/IV)	58/53/29/0	III, IV
ULBT (I/II/III)	77/53/10	III
ULCT (zero/I/II/III)	4/11/3/0	II, III
NM (>100°/90°±10°/<80°)	72/46/22	≤80°
Dentition (1/2/3)	73/37/30	Grade 3
MCLS (1/2a/2b/3/4)	65/40/11/22/2	2b, 3, 4

Data are given as mean±SD or number of patients; MMT-Modified Mallampati Test; TMD-Thyromental Distance; SMD-Sternomental Distance; NM-Neck Movement; MO-Mouth Opening; ULBT-Upper Lip Bite Test; RHTMD-Ratio of Height to Thyromental Distance; TMHT-Thyromental Height Test

adults recommended to calculate cut-off values for these airway parameters to predict direct laryngoscopy in different population as cut-off values can vary with ethnicity, race, age and gender.^[17,18]

The ideal airway predictor should have high sensitivity and specificity with low false NPV. In the present study, TMD showed the highest sensitivity and NPV as compared to all evaluated 'standard airway predictors' and 'new airway predictors'. This is comparable to the study by Mostafa *et al.* where TMD exhibited highest sensitivity and high NPV as compared to MMT, SMD and TMHT.^[19] Moreover, TMD also exhibited higher accuracy and PPV in our study. False negative prediction of difficult airway could be catastrophic specially in geriatric patients who have decreased physiological reserve, thus making them more vulnerable for respiratory and cardiovascular complications while managing unanticipated difficult airway.

In our study, neck movement showed the highest accuracy and PPV and also higher specificity among the 'standard airway predictors' in predicting difficult laryngoscopy in geriatric patients. The reason for high false negative prediction in the present study was that the patients with midline neck swelling, scar due to radiation or previous surgery were already excluded

from the study which is very common in this age group. Arthritis, neurological disorder, systemic diseases, variable activity level and other surgical factors (tumour surgery, radiation) more common in geriatric population may result in restricted neck movement in these patients.^[20]

MMT is considered as the gold standard test for the prediction of difficult airway. The study conducted by Moon *et al.* found that the common reason for difficult endotracheal intubation in the old age group was a high Mallampati score.^[16] However, in our study, we found poor sensitivity, PPV and NPV of MMT. This may be attributed to anthropometric differences among the population.

Among the 'new airway predictors', the ULBT showed highest accuracy, PPV and odds ratio as compared to TMHT, RHTMD and also with all other studied standard airway predictors. Furthermore, ULBT exhibited highest specificity as compared to TMHT and RHTMD. This is probably the first ever study assessing the ULBT in elderly patients. However, most of the studies conducted in young adults also found high accuracy, specificity and PPV of ULBT.^[21,22] The ULBT assesses the range and freedom of mandibular movement and the architecture of the teeth simultaneously.^[23] In our study, the ULBT showed zero false positive indicating that once mandibular movement is restricted due to arthritis or because of degenerative changes of muscles and ligaments, a difficult airway is expected. ULCT was used to assess airway of edentulous patients which is also an indicator of mandible subluxability.

Mostafa *et al.* in his study found high accuracy and NPV of TMHT in elderly patients.^[19] In the present study, we also found highest NPV of TMHT as compared to ULBT and RHTMD and comparable to TMD. Moreover, TMHT showed higher sensitivity as compared to the other two new tests. In addition, TMHT is a simple, bedside test that does not depend on head extension of the patient and hence can be easily performed in uncooperative elderly patients.

Table 3: Comparison between modified C-L grades and airway predictors

Test	Modified C-L Grades			K (95% CI)	Significance Fisher Exact Test
	Easy (n=105)	Difficult (n=35)	Total		
MMT					
Easy	90	21	111	0.27 (0.09-0.45)	0.003
Difficult	15	14	29		
TMD					
Easy	79	7	86	0.46 (0.32-0.62)	<0.00001
Difficult	26	28	54		
SMD					
Easy	76	10	86	0.37 (0.22-0.53)	<0.00001
Difficult	29	25	54		
NM					
Easy	96	22	118	0.35 (0.14-0.51)	0.0002
Difficult	9	13	22		
MO					
Easy	101	31	132	0.10 (0.04-0.25)	0.1074
Difficult	4	4	8		
Dentition					
Easy	91	19	110	0.34 (0.16-0.51)	0.0002
Difficult	14	16	30		
ULBT					
Easy	105	25	130	0.37 (0.20-0.55)	<0.00001
Difficult	0	10	10		
TMHT					
Easy	81	8	89	0.47 (0.32-0.62)	<0.00001
Difficult	24	27	51		
RHTMD					
Easy	60	8	68	0.25 (0.12-0.38)	0.0004
Difficult	45	27	72		

MMT-Modified Mallampati Test; TMD-Thyromental Distance; SMD-Sternomental Distance; NM-Neck Movement; MO-Mouth Opening; ULBT-Upper Lip Bite Test; RHTMD-Ratio of Height to Thyromental Distance; TMHT-Thyromental Height Test, C-L: Cormack Lehane

Table 4: Validity indexes for 'standard airway predictors' and 'new airway predictors' to predict the occurrence of difficult laryngoscopy

	MMT	TMD	SMD	NM	MO	Dentition	RHTMD	TMHT	ULBT
TP	14	28	25	13	4	16	27	27	10
FP	15	26	29	9	4	14	45	24	0
FN	21	7	10	22	31	19	8	8	25
TN	90	79	76	96	101	91	60	81	105
Sensitivity	40	80	71.42	37.14	11.42	45.71	77.14	77.14	28.57
Specificity	85.71	75.23	72.38	91.42	96.19	86.66	57.14	77.14	91.30
PPV	48.27	51.55	46.29	59.09	50	53.33	37.5	52.94	100
NPV	81.08	91.86	88.37	81.35	76.51	82.72	88.23	91.01	77.77
Accuracy	74.28	76.42	72.14	77.85	75	76.42	62.14	77.14	82.14
Odds ratio	4	12.15	6.5	6.30	3.15	5.4	4.5	11.3	86.88
LR	2.55	3.23	2.59	4.33	3	3.43	1.8	3.37	3.28
RR	2.8	6.37	3.98	3.26	2.12	3.08	3.18	5.88	5.2

PPV - Positive Predictive Value; NPV - Negative Predictive Value; LR - Likelihood Ratio; RR - Relative Risk; MMT - Modified Mallampati Test; TMD - Thyromental Distance; SMD - Sternomental Distance; NM - Neck Movement; MO - Mouth Opening; ULBT - Upper Lip Bite Test; RHTMD - Ratio of Height to Thyromental Distance; TMHT - Thyromental Height Test

In the present study RHTMD showed lowest accuracy, specificity and PPV as compared to ULBT, TMHT and all other studied standard airway predictors. The longitudinal decrease in height with aging has been described by many authors. This change in height with aging may be universal, but its incidence may vary considerably within and between groups of

elderly adults depending on their body posture and/or pathological changes in head and neck joints.^[24] This could possibly explain the poor accuracy of RHTMD in elderly patients. In our study, dentition showed higher diagnostic accuracy in predicting difficult laryngoscopy as compared to MMT, SMD and MO. Difficult intubation due to abnormal or poor dentition

Table 5: Comparison of different airway predictors

Criteria	Airway predictors
Sensitivity	TMD>TMHT=RHTMD>SMD>Dentition>MMT>NM>ULBT>MO
Specificity	MO>NM>ULBT>Dentition>MMT>TMHT>TMD>SMD>RHTMD
PPV	ULBT>NM>Dentition>TMHT>TMD>MO>MMT>SMD>RHTMD
NPV	TMD>TMHT>SMD>RHTMD>Dentition>NM>MMT>ULBT>MO
Accuracy	ULBT>NM>TMHT>Dentition>TMD>MO>MMT>SMD>RHTMD
Odds Ratio	ULBT>TMD>TMHT>SMD>NM>Dentition>RHTMD>MMT>MO
Likelihood Ratio	NM>Dentition>TMHT>ULBT>TMD>MO>SMD>MMT>RHTMD
Relative Risk	TMD>TMHT>ULBT>SMD>NM>RHTMD>Dentition>MMT>MO

MMT-Modified Mallampati Test; TMD-Thyromental Distance; SMD-Sternomental Distance; NM-Neck Movement; MO-Mouth Opening; ULBT-Upper Lip Bite Test; RHTMD-Ratio of Height to Thyromental Distance; TMHT-Thyromental Height Test; PPV-Positive Predictive Value; NPV-Negative Predictive Value

has been reported by many studies.^[16,25] Furthermore, Ezri *et al.* found positive associations of increased laryngoscopy grade with increased age, protruding teeth and loose teeth.^[26] However, the presence of loose teeth was not considered in the dentition grading scale used in this study.

In our study, we found easy laryngoscopy (100%) in all edentulous patients which was very close to the finding by Khan *et al.* who found 2% prevalence of difficult laryngoscopy in his study conducted in 588 edentulous patients.^[10] The absence of teeth especially maxillary teeth in edentulous patients, improves the line of vision to the glottis and this could be attributed to easy laryngoscopy in these patients.^[5]

The incidence of difficult laryngoscopy in geriatric patients found in our study was 25%. The higher incidence of difficult laryngoscopy found in our study as compared to previous studies could be attributed to the anthropometric differences among population and secondly, we assessed difficult laryngoscopy by using MCLS as compared to Cormack and Lehane (C-L) grading system used in other studies.^[27] Moreover, there are very limited studies available, assessing the airway of geriatric patients exclusively. However, the reported incidence of difficult laryngoscopy in general population varies from 1.5% to 27%.^[28,29] Furthermore, studies including elderly population as a subset also reported association between difficult laryngoscopy and elderly patients.^[5,10,30]

Limitations of our study were firstly, the diagnostic accuracy of studied airway predictors in elderly

were not compared with young adults. Secondly, medical conditions of the patient (diabetes, rheumatoid arthritis, obstructive sleep apnoea (OSA), osteoarthritis) that might affect the airway were not recorded and analysed. Thirdly, the incidence of difficult endotracheal intubation was not assessed in our study which is the ultimate objective of the airway assessment. In geriatric patients with missing and/or loose teeth, it is difficult to intubate the trachea even with grade I laryngoscopic view.

CONCLUSION

To conclude, TMD showed the highest sensitivity, NPV and odds ratio among the 'standard airway predictors' with higher diagnostic accuracy in geriatric patients. Moreover, ULBT was the most accurate predictor of difficult laryngoscopy with highest odds ratio in elderly patients as compared to all airway predictors evaluated in our study. The more recent airway predictor TMHT also exhibited higher NPV, sensitivity and good diagnostic accuracy in diagnosing difficult laryngoscopy in elderly patients. However, further studies comparing various airway predictors specially 'new airway predictors' in geriatric patients are much needed to validate these parameters and to prevent unanticipated difficult airway in these patients with limited functional reserve.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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