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Predictors of Difficult Airway Intubation A Prospective Observational Study of 202 Patients Undergoing General Anesthesia

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Abstract

Unanticipated difficult tracheal intubation is a significant source of morbidity and mortality in anesthesia practice. Identifying situations and patients at risk for airway management problems is a key to optimal care. This study compares the parameters described to identify a difficult intubation to look for the best predictors or combinations thereof. *Materials and Methods:* The preoperative airway assessment used multiple parameters like Mallampati test, Thyromental Distance, Head and neck Movement, Interincisor Gap, Lahey & McCormick Scale. The results were evaluated on the basis of sensitivity, specificity, positive and negative predictive value of these tests. During intubation a cumulative Intubation Difficulty Scale rating greater than 5 was used to classify a patient as a difficult intubation to validate the scores. *Results:* Amongst all the parameters studied individually, the Upper lip bite test was found to have the highest sensitivity of 48.48% and specificity of 97.3%. When multiple parameters were taken into consideration, the combination of Mallampati score, Upper lip bite test and Neck circumference to thyromental distance ratio was found to have the highest sensitivity of 75.76% and specificity 91.12%. *Conclusion:* Application of multiple predictors can reduce the frequency of unanticipated difficulty and also unnecessary interventions related to over prediction of airway difficulty.

Keywords: Intubation; Difficult airway predictors; Mallampati test; Thyromental distance; Upper lip bite test; Height to thyromental distance ratio; Neck circumference to thyromental distance ratio; Multiple test predictors.

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Introduction

The management of the airway with induction of anesthesia is the primary responsibility of the anesthesiologist.[1]

Unanticipated difficult tracheal intubation is a significant source of morbidity and mortality in anesthesia practice. The incidence of difficult intubation has been reported to range from 1% to 18%.[2,3] The incidence of abandoned/failed intubation is approximately 0.05%–0.35%.[4,5] Approximately 30% of deaths in patients with difficult airway/intubation were caused by hypoxic brain damage secondary to inability to maintain a patent airway.[2] Increases in the incidence of morbid events have also been noted in patients who have undergone difficult tracheal intubation. These events included desaturation, hypertension, oesophageal intubation, pharyngeal trauma,

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dental injury, cancelation of surgery, prolonged hospital stay and increased rate of unexpected ICU admission.[6–8]

Unexpected difficult intubations may be the result of a lack of accurate predictive tests for difficult intubation and inadequate preoperative examinations of the airway.[3] Identifying situations and patients at risk for airway management problems is the key.[8]

Preoperative evaluation of the airway can be accomplished by various measurements of the anatomical landmarks or noninvasive clinical tests performed during physical examinations. Initially the airway assessment was carried out by a single parameter like Mallampati's oropharyngeal classification,[5,9] Thyromental distance,[10] Inter incisor gap, protrusion of the mandible,[11] Head and neck movement[12] etc. But the consideration of multiple parameters is being increasingly recommended.[14–16]

The need for development of a scoring system, which factors in the multiple parameters, to best predict a difficult airway, necessitates an understanding of the relative importance of all the individual parameters.

Aims

Our study aims to identify the relative importance of parameters that predict difficult intubation and combinations thereof.

Objectives

(1) To evaluate the predictors of difficult airway in patients undergoing general anesthesia.
(2) To compare these scores with the Intubation difficulty score obtained in real time in the operation theatre during intubation under General Anesthesia.
(3) To compare the sensitivity, specificity, negative predictive value and positive predictive value of these factors and scoring systems .
(4) To find the most sensitive combination of these factors for use as an optimal predictor for difficult intubation in our tertiary hospital setting.

Materials and Methods

Study Design: Prospective Observational Study;

Place of Study: Department of Anesthesiology, St. John's Medical College and Hospital, Bangalore, India;

Duration of Study: April 2018 to February 2019.

Patient Selection

(A) Inclusion Criteria:

- ASA physical status I and II;
- Patients aged between 18 and 60 years, inclusive of both sexes;
- Patients scheduled to receive general anesthesia requiring endotracheal intubation for elective orthopedic, urologic, ENT, neurological and abdominal surgeries.

(B) Exclusion Criteria:

- Patients younger than 18 years and older than 60 years of age;
- Patients with abnormal head and neck anatomy; those with a laryngeal or Pharyngeal mass; or with a mass in the oral cavity; pregnant women (due to upper airway edema); or those unable to open the mouth, or with limitation of cervical movement;
- Patients requiring a rapid sequence induction or awake intubation;
- Patients posted for emergency surgical procedures.

The study was approved by Institutional Ethical Review Board (IERB No.114/2018. date 24*th* March 2018) and written informed consent was obtained from every patient prior to the study. This study included 202 patients, a detailed history and general physical examination was performed in each of them.

The Sample size was estimated based on the study by Cattano et al.[1] using Buderers Formula[17] was 204. Preoperative airway examination was performed using multiple screening tests to predict difficult airway. These tests were performed for all patients by the same anesthesiologist to avoid interobserver variability (Table 1).

These preoperative tests results were recorded and the difficulty of intubation assessed by experienced anesthesiologists in the operation theatre, shows in Table 2, and the results were compared after compilation of the data.

Table 1: Factors studied in each patient

S. No	Factors studied
1.	Weight (kg), height (cm) and age (years).
2.	American Society of Anesthesiologists (ASA) physical status.
3.	Inter-incisor gap (between the central incisors).
4.	Thyromental distance.
5.	Sternomental distance.
6.	Mallampati score.
	Class 1: soft palate, fauces, uvula and pillars visible.
	Class 2: soft palate, fauces and uvula visible.
	Class 3: soft palate and base of uvula visible.
	Class 4: none of the soft palate visible.
7.	Neck movements:[6] This criterion was graded into ≤ 80° or > 80°).
8.	Mandibular length (from the angle of mandible to middle of the chin).
9.	Height to thyromental distance ratio.
10.	Upper lip bite test (biting the upper lip with the lower incisors).
	Grade 1: lower incisors can bite the upper lip above the vermilion line.
	Grade 2: lower incisors can bite the upper lip below the vermilion line.
	Grade 3: lower incisors cannot bite the upper lip.
11.	Neck circumference to thyromental distance ratio (neck circumference measured at the level of cricoid cartilage perpendicular to the long axis of neck).
12.	Difficult of laryngoscopy as per Cormack and Lehane grading.
	Grade 1: Most of the glottis is seen.
	Grade 2: Only the posterior part of the glottis is visible.
	Grade 3: The epiglottis is visible, but none of the glottis can be seen.
	Grade 4: Epiglottis not visible.

Table 2: The criteria for assessing a difficult intubation

Number	Criteria for Assessing a Difficult Intubation
N1	Number of additional intubation attempts;
N2	Number of additional operators;
N3	Number of alternative intubation techniques used;
N4	Laryngoscopy view as defined by Cormack and Lehane.
	(Grade 1, N4 = 0; Grade 2, N4 = 1; Grade 3, N4 = 2; and Grade 4, N4 = 3)
N5	Lifting force applied during laryngoscopy (N5 = 0 if inconsiderable and N5 = 1 if considerable).
N6	Need to apply external laryngeal pressure to improve glottic pressure.
	(N6 = 0 if no external pressure or only the Sellick's manoeuvre was applied and N6 = 1 if external laryngeal pressure was used).
N7	Position of the vocal cords at intubation (N7 = 0 if abducted or not visible and N7 = 1 if adducted).

Intubation Difficulty Scale (IDS) The IDS score is the sum of N1 through N7.

IDS score < 5 (i.e. easy intubation) IDS score ≥ 5 (i.e. difficult intubation).

Results

Demographics of groups

A total of 202 patients were included in this study and preoperative assessment of the airway was done to predict the difficulty in intubation. Based on the Intubation Difficulty Scale (IDS),[18] the study population was divided into two groups for the purpose of comparison into an 'Easy Intubation Group' - Group A (IDS < 5) and a 'Difficult Intubation Group' - Group B (IDS ≥ 5). There were no cases of desaturation or failed intubation in our study. The prevalence of difficult intubation in our study was 16.3% (33 patients). These two groups were also compared on various parameters such as age, American Society of Anesthesiologists (ASA) physical status grading, presence/absence of snoring and dentition issues.

The mean age in Group A was 39.24 years and in Group B was 42.58 years. This difference was not significant. (p = 0.139). Of the 202 patients studied, 112 (55.4%) were males and 90 (44.6%) were females. In Group B, 24 (72.7%) were males and 9 (27.3%) were females and this difference was significant (p = 0.029). The mean BMI of the study population was 26.10kg/m.[2] In Group A, the BMI was 25.57 ± 5.25, which was lower than Group B (28.85 ± 6.10). In Group B, 10 (30.30%) patients had a BMI < 25.0; 7 (21.21%) patients had BMI between 25.0–30.0 and 16 (48.48%) patients had a BMI > 30.0. This difference was statistically significant (p = 0.002).

Table 3 shows the comparison of study variables (ASA Grade, snoring and dentition) between the two study groups. In Group A, ASA Grade I patients had 97 (57.4%) ASA Grade II patients had 12 (36.4%), while in Group B ASA Grade 1 patients had 72 (42.6%) and Grade II patients 21 (63.6%). This difference was significant with p = 0.027. History of snoring was obtained in 7/169 (4.1%) and 3/33 (9.1%) patients in Group A and B respectively (p = insignificant). Patients with Dentition problems were 6/69 in the Easy Intubation Group (3.6%) and 3/33(9.1%) in the Difficult Intubation Group, (p = insignificant). All 108 patients with CL Grade 1 had easy intubation and 60 out of 61 patients with CL Grade 2 had easy intubation. Whereas 29 out of 30 patients with CL Grade 3 had difficult intubation and all 3 patients with CL Grade of 4 had difficult intubation.

Table 3: Comparison of study variables (ASA Grade, Snoring and Dentition) between the two groups (n = 202)

Variables	Group A (n = 169)	Group B (n = 33)	p - value
ASA Grade I	97 (57.4%)	12 (36.4%)	0.027*
ASA Grade II	72 (42.6%)	21 (63.6%)	
Snoring	7 (4.1%)	3 (9.1%)	
Dentition problems	6 (3.6%)	3 (9.1%)	

Table 4 reflects the comparison of predictors of difficult intubation parameters between the two study groups. In Group A there were 87 (51.5%), 73 (43.2%), 9 (5.3%) and 0 patients having Mallampati Class I, II, III and IV respectively. In Group B there were 3 (9.1%), 17 (51.5%), 13 (39.4%) and 0 having Mallampati class I, II, III and IV respectively, (p-value < 0.001 significant). There was only 1 (0.6%) patient with restricted Neck movement < 80° and the intubation was found to be easy. There were 168 (99.4%) patients with Neck movement > 80° whose intubation was easy and 33 (100%) with Neck movement > 80° whose intubation was difficult, (p-value 1, insignificant).

The mean Interincisor Gap was 5.07 ± 3.14 cms in Group A and 4.22 ± 0.56 cm in Group B. (p = 0.126 insignificant). The mean ML in Easy Intubation Group was 11.66 ± 1.00 cm and 12.15 ± 1.19 cm in Difficult Intubation Group, (p = 0.014. significant). The mean values of Thyro Mental Difference (TMD), SMD, HT/TMD and NC/TMD in Group A were found to be 9.86 ± 0.99 cm, 17.98 ± 1.26 cm, 16.43 ± 2.09 and 3.82 ± 0.63 respectively. The mean value in Group B was found to be 8.01 ± 0.90 cm, 14.88 ± 1.45 cm, 20.34 ± 2.38 and 5.10 ± 0.76 respectively, (p < 0.001 significant difference).

Table 4: Comparison of predictors of difficult intubation studied between the two groups (n = 202).

Variables	Group A (n = 169)	Group B (n = 33)	p - value
Mallampati (MP) class			
I	87 (51.5%)	3 (9.1%)	
II	73 (43.2%)	17 (51.5%)	< 0.001
III	9 (5.3%)	13 (39.4%)	
IV	0	0	
Neck Movements (degrees)			
< 80	1 (0.6%)	0 (0%)	1.000
> 80	168 (99.4%)	33 (100%)	
Upper Lip Bite Test (ULBT) Grade			
I	83 (49.1%)	4 (12.1%)	
II	82 (48.5%)	13 (39.4%)	< 0.001
III	4 (2.4%)	16 (48.5%)	

Variables	Group A (n = 169)	Group B (n = 33)	p - value
Interincisor Gap (IIG) in cm	5.07 ± 3.14	4.22 ± 0.56	0.126
TMD (cm)	9.86 ± 0.99	8.01 ± 0.90	< 0.001
ML (cm)	11.66 ± 1.00	12.15 ± 1.19	0.014
SMD (cm)	17.98 ± 1.26	14.88 ± 1.45	< 0.001
HT/TMD	16.43 ± 2.09	20.34 ± 2.38	< 0.001
NC/TMD	3.82 ± 0.63	5.10 ± 0.76	< 0.001

TMD - Thyromental distance; ML- Mandibular length; SMD - Sternomental distance; HT/TMD - Height to Thyromental distance ratio; NC/TMD - Neck Circumference to Thyromental distance ratio in cm.

Table 5 summarizes the Difficult intubation predictor statistics based on standard cut-off values. Mallampati class 3 or above had a sensitivity of 39.39% and a specificity of 95.81%, with p - value of < 0.001. ULBT Grade 3 showed 48.48% sensitivity and 97.63% specificity. p - value was significant (< 0.001). Neck movements < 80° had 0% sensitivity and 99.41% specificity with a p - value of 1.0. IIG of < 3.5 cms showed sensitivity and specificity of 21.21% and 99.41% respectively with p - value of < 0.001.

Table 5: Difficult intubation predictor statistics based on standard cut-off values (n = 202)

Variables	Standard cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	p - value
MP	3 or above	39.39	95.81	65.00	88.89	86.50	< 0.001
ULBT	Class 3	48.48	97.63	80.00	90.66	89.60	< 0.001
Neck Extension	< 80°	0.00	99.41	0.00	83.58	83.17	1.000
IIG (cm)	< 3.5 cm	21.21	99.41	87.50	86.50	86.63	< 0.001
TMD (cm)	< 6.5 cm	6.06	100.00	100.00	84.50	84.65	0.026
ML(cm)	< 9 cm	0.00	97.63	0.00	83.33	81.68	1.000
SMD (cm)	< 13.5 cm	21.21	99.41	87.50	86.60	86.63	< 0.001
8. HT/TMD	> 23.5	9.1	98.02	60.00	84.77	84.16	0.032
9. NC/TMD	> 5.0	45.45	97.63	78.95	90.16	89.13	< 0.001

MP - Mallampati Grade; ULBT - Upper Lip Bite Test; IIG - Interincisor Gap; TMD - Thyromental Distance; ML - Mandibular Length; SMD - Sternomental Distance; HT/TMD - Height to Thyromental Distance Ratio; NC/TMD - Neck Circumference to Thyromental Distance Ratio.

Standard cut off values of TMD (6.5 cms), ML (<9 cms) and SMD (<13.5 cms) had sensitivity of 6.06%, 0% and 21.21% respectively, specificity of 100%, 97.63% and 99.41% respectively. Their p values were 0.026, 1.0 and <0.001 respectively.

Standard cut-offs values of the ratios of HT/TMD (≥ 23.5) and NC/TMD (> 5.0) showed 9.1% and 45.45% sensitivity respectively with specificity of 98.02% and 97.63% respectively. Amongst all the above parameters, the ratio of NC/TMD >5 had the highest sensitivity of 45.45% and TMD < 6.5 cms had the highest specificity of 100. Table 6 shows, the predictor statistics using the new cut-off values which were derived using the ROC curve to find the optimum sensitivity and specificity of each parameter. IIG with new cut-off value (≤ 4.8 cm) showed a higher sensitivity (87.88%) and a lower specificity (56.55%) as compared to the earlier cut-off (< 3.5 cm) having 39.39% and 95.81% respectively.

Table 6: Diagnostic statistics based on cut-off values using ROC curve analysis, (n = 202)

Variables	New cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	Area under curve	p - value
1. IIG (cm)	≤ 4.8	87.88	56.55	28.43	95.96	61.69	0.771	< 0.001
2. TMD (cm)	≤ 8.5	75.76	92.31	65.79	95.12	89.60	0.915	< 0.001
3. ML (cm)	> 11.5	69.70	49.11	21.10	89.25	52.48	0.614	0.042
4. SMD (cm)	≤ 16.5	87.89	91.72	67.44	97.48	91.09	0.947	< 0.001
5. HT/TMD	> 18.6	75.76	90.53	58.14	95.03	87.25	0.887	< 0.001
6. NC/TMD	> 4.1	96.97	79.29	45.07	99.24	80.20	0.935	< 0.001

Similarly, TMD (≤ 8.5 cm) showed a higher sensitivity and lower specificity as compared to the standard cut-off (< 6.5 cm), 75.76% and 92.31% *v/s* 6.06% and 100% respectively. ML (> 11.5 cm) provided a sensitivity (69.70%) higher than standard cut-off value (0%) and specificity (49.11%) lower than the standard value (97.63%). The sensitivity of the SMD using the new cut-off value (≤ 16.5 cm) was higher (87.89%) as against cut-off value < 13.5 cm (21.21%) but the specificity (91.72%) was found to be lower as compared to 99.41% by using standard cut-off.

The sensitivity of new HT/TMD ratio here (75.76%) and new NC/TMD ratio here (96.97%) was higher than that given by standard cut-off values (9.1 and 45.5 % respectively) and their specificity (HT/TMD–90.53% *versus* 98.02%, NC/TMD-79.29% *versus* 97.63%) was found to be lower. The p - value of all parameters with new cut-off value was < 0.001 except that of ML (p - value = 0.042). Table 7 summarizes the prediction of difficult intubation of combinations of the above mentioned parameters. The combination of (MP + ULBT + NC/TMD) and (MP + ULBT + TMD + NC/TMD) showed the highest sensitivity (75.76%), specificity (91.12%), PPV (62.50%) and NPV (95.06%). The p - value of all combinations was found to be significant (p < 0.001).

Table 7: Predictor statistics based on combinations of standard cut-off values (n = 202)

Variables	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	*p* - value
1. MP +ULBT	66.67	92.31	62.86	93.41	86.12	<0.001
2. MP+TMD	45.45	94.67	62.50	89.89	86.63	<0.001
3. MP+NC/TMD	60.61	93.49	64.52	92.48	88.12	<0.001
4. ULBT+TMD	54.55	97.63	81.82	91.67	90.58	<0.001
5. ULBT+ NC/TMD	69.70	95.27	74.19	94.15	91.09	<0.001
6. TMD+NC/TMD	45.45	97.63	78.95	90.16	89.11	<0.001
7. MP+ULBT+TMD	72.73	92.31	64.86	94.55	89.11	<0.001
8. MP+ULBT+NC/TMD	75.76	91.12	62.50	95.06	88.61	<0.001
9. MP+TMD+NC/TMD	60.61	93.49	64.52	92.40	88.12	<0.001
10. ULBT+TMD+NC/TMD	69.70	95.27	74.19	94.15	91.09	<0.001
11. MP + ULBT + TMD + NC/TMD	75.76	91.12	62.50	95.06	88.61	<0.001

NC/TMD – 45.45%) and specificity (TMD- 100%) using standard cut off values were used.
Parameters which had the highest individual sensitivities (MP- 39.39%, ULBT -48.48% and
NC/TMD – 45.45%) and specificity (TMD- 100%) using standard cut off values were used.

Discussion

The significance of difficult or failed intubation is very well-recognized as a cause of morbidity and mortality. A test to predict difficult intubation should have high sensitivity, so that, it will identify most patients in whom intubation will truly be difficult. It should also have a high positive predictive value, so that, only a few patients with an airway actually easy to intubate are unnecessarily subjected to the protocol for management of a difficult airway. The ideal model for prediction of difficult intubation would have high sensitivity and specificity. Sensitivity and specificity are dependent on each other, an increase in one of them usually results in a decrease in the other. High specificity may also increase the positive predictive value despite low-sensitivity.

A parameter with high-sensitivity, low-specificity, and low-positive predictive value would incorrectly classify patients as having a difficult airway. However, these may only be a fraction of those that accompany the potentially serious outcome of unanticipated difficult tracheal intubation. Therefore, the sensitivity of a parameter is more important than the specificity.[19]

Defining a good predictive parameter for difficult intubation is challenging because many factors affect visualization of the larynx at intubation, such as the maximum mouth-opening distance, the circumference and length of the neck, and several other characteristics that may be difficult to accurately quantify. These include the compressibility of the tongue and soft tissues of the floor of the mouth and the extent of subluxation of the temporomandibular joint during laryngoscopy.

In addition, the ability of the person performing the intubation, cannot be easily incorporated into a standardized assessment.[1]

The present study, included 202 patients for preoperative assessment of the airway; we found that 16.3% (33 out of 202) of them had difficult intubation. There were no cases of failed intubation. The prevalence of difficult intubation in earlier studies was reported to be 1%–18%[2–5] depending on the criteria used to define it. A total of 33 patients had difficult intubation, out of which 24 were males. The preponderance of males with difficult intubation in our study could be due to the difference in anthropometry, muscularity and laxity of soft tissue in the neck between males and females. Equivocal results are available in literature.[15,17] The mean BMI of patients in Group A was significantly lower (p = 0.002) than that of patients with difficult intubation, which is at variance with other studies in literature[16,22]

In our study, 97 (57.4%) ASA Grade I patients had easy intubation and 12 (36.4%) had difficult intubation. Seventy two (42.6%) patients with ASA Grade II had easy intubation and 21 (63.6%) had difficult intubation. This difference was significant with p - value of 0.027. This too is at variance with other studies in literature. [23] We propose that this can be attributed to the effects of systemic diseases on the airway.

We compared Cormack-Lehane (CL) Grades with difficulty in intubation. None of the 108 patients with C-L Grade 1 had difficult intubation, while 1 out of 61 patients with C-L Grade 2 had difficult intubation. 96.67% (29 out of 30) patients with C-L Grade 3 and all 3 patients with C-L Grade 4 had difficult intubation.

In our study, there was a general increase in difficulty with intubation with increasing MP score 87 out of 90 patients with Malampatti Grade I , 73 out of 90 patients with MP Grade II had easy intubation and 13 out of 22 patients with MP III had difficult intubation. This was statistically significant (p - value < 0.001). There were no patients with MP Grade V in our study.

Sensitivity and Specificity of Individual tests

Mallampati et al.[9] found a significant correlation between preoperative grading and ease of laryngoscopy in their study done on 210 patients, reporting a sensitivity of 50% and specificity of 99% for the MP score. Cattano et al.[1] found the sensitivity, specificity, PPV and NPV of Mallampati score as 35%, 91%, 8% and 98% respectively in their study done on 1956 patients. Sensitivity and specificity in our study was similar, 39.39% and 95.81% respectively. The Positive Predictive Value was found to be higher (65%) and Negative Predictive Value (88.89%) lower. The Mallampati score was accurate in predicting easy intubation but could predict difficult intubation in only 39.39% of cases. Hence, it cannot be considered to be an accurate predictive test of difficult intubation. The is in concordance with the findings of Naquib et al.[20]

The Upper Lip Bite Test (ULBT), when tested initially had the potential to evaluate both jaw movement and buck teeth simultaneously, providing additional support for airway assessment. Khan et al.[11] compared ULBT with modified Mallampati classification in 300 patients and found that ULBT had higher accuracy. It had sensitivity, specificity, PPV and NPV of 76.5%, 88.7%, 28.9% and 98.4% respectively. In our study, it could predict 48.48% of difficult intubations and 97.63% of easy intubations, whereas PPV and NPV was 80% and 90.66% respectively.

Nichol and Zuck[12] suggested atlanto-occipital distance as a major anatomical factor that determines head extension. They stressed the importance of the position of the head and neck in direct laryngoscopy in order to achieve proper alignment of the axes of the oral cavity, pharynx and larynx. Tse et al.[21] found the sensitivity, specificity, PPV and NPV of neck extension ≤ 80° to be 21%, 93%, 18% and 87% respectively. We did not find any patients with difficult neck extension ≤ 80°, thus the sensitivity and PPV was 0.

The sensitivity, specificity, PPV and NPV of thyromental distance (< 6.5 cm) test in our study was found to be 6.06%, 100%, 100% and 84.5% respectively. It successfully predicted all patients with easy intubation. Among all the morphometric measurements, TMD has been studied as a predictor of difficult intubation with equivocal results.[3,22]

Reciever Operating Characteristic curves (ROC) are a graphical method to represent Sensitivity and Specificity of a test and the Area Under the Curve (AUC) is considered a good indicator of the overall efficiency of a test.[23]

When an ROC curve was used to determine a better cut-off for TMD; the sensitivity increased to 75.76% although the specificity decreased to 92.31% with the new cut-off (≤ 8.5 cm). Krobbuaben et al.[22] did not find any significant association between difficult laryngoscopy and Interincisor Gap (IIG ≤ 3.5 cm), unlike in our study (p < 0.001). IIG as a parameter to predict difficult intubation had sensitivity of 21.21%, specificity of 99.41%, PPV of 87.50% and NPV of 86.50% . Using the ROC curve to determine the best cut-off value it was seen that with IIG ≤ 4.8 cm, the sensitivity increased to 87.88% and specificity decreased to 56.55%.

Interestingly, we did not find any correlation between mandibular length (ML< 9 cm) and difficult intubation. Merah et al.[24] also did not find any correlation between ML and difficult intubation but suggested that ML of atleast 9 cm should guarantee easy intubation. Kurtipek et al.[25] concluded that ML if used on its own, does not have much predictive value.

Sternomental Distance (SMD) can be a predictor of head and neck mobility; Ramdhani et al.[26] studied this parameter and found it to be superior to other tests in predicting difficult intubation. However, the patient group in their study was limited to women of childbearing age only. We found SMD (< 13.5 cm) to have sensitivity of 21.21%, specificity of 99.41%, PPV of 87.50% and NPV of 86.63%. The ROC curve showed a sensitivity of 87.89% and specificity of 91.72%, when new cut-off was taken as ≤ 16.5 cm.

Krobbuaben et al.[21] in their study found HT/TMD ≥ 23.5 was a determining factor for predicting a poor laryngeal view among Thai patients, with sensitivity, specificity, PPV and NPV of 77%, 66%, 24% and 95% respectively. HT/TMD (≥ 23.5) in our study showed low-sensitivity of 9.1%, specificity of 98.02%, PPV of 60% and NPV of 84.77%. ROC curve analysis was used to determine a new cut-off value (> 18.6), and it was found that the sensitivity increased to 75.76% and specificity decreased to 90.53%. This discrepancy may be due to the difference in morphologic charachteristics of Indian population.

Neck circumference to thyromental distance ratio (NC/TMD) was studied by Kim et al.[15] and evaluated as a new index on the assumption that obese patients with both a large neck circumference and a short-neck, might be more difficult to intubate than patients with a large-neck circumference or a short-neck alone. They found NC/TMD > 5 to have sensitivity, specificity, PPV and NPV of 88.2%, 83%, 45.5% and 97.8% respectively. This parameter showed a high-sensitivity (45.45%) in our study. Specificity, PPV and NPV was found to be 97.63%, 78.95% and 90.16%. The new cut-off, NC/TMD > 4.1 (as determined by the ROC curve) had higher-sensitivity (96.97%) but lower-specificity (79.29%).

It is evident from the discussion on individual clinical parameters that each of these tests are based on different anatomical factors of the airway and hence, combinations of individual tests may have higher predictive value in comparison with the value of each test alone. Several authors have combined predictive parameters and devised multivariate risk-index systems such as the El-Ganzouri or Wilson scores.[6–8] These scores contain multiple risk-factors, they are more time consuming to perform. All combination analysis showed a dramatic improvement in predictive values. Combining Mallampati test and Upper lip bite test improved the sensitivity to 66.67% and specificity to 92.3% and it has a better predictive value (PPV and NPV of 62.86% and 93.41% respectively) which is of definite significance.

Combination of ULBT and NC/TMD ratio gives indices of: sensitivity 69.70%, specificity 95.27%, PPV 74.19% and NPV-94.15%. This combination could predict more number of difficult intubations than any other two parameters combined together. Mallampati test and thyromental distance help in determining the relationship of the tongue with oral cavity and to determine the anterior mandibular space respectively. This combination had a sensitivity of 45.45%, specificity of 94.67%, PPV of 62.5% and NPV of 89.89%. Mallampati test and NC/TMD ratio when combined together could predict 60.61% of the difficult intubation and 93.49% of the easy intubation. It had 64.52% PPV and NPV of 92.48%.

We selected a total of four parameters, as suggested by Rudin Domi,[27] which had the highest-sensitivity or specificity individually (MP - sensitivity of 39.39%, ULBT - sensitivity of 48.48%, NC/TMD - sensitivity of 45.45%, TMD - specificity 100%) from our study. When MP class, ULBT and NC/TMD ratio were combined together, it could predict difficult intubation in 75.76% and easy intubation in 91.12%. It had a PPV of 62.50% and NPV of 95.06%. This combination provided the best sensitivity of predicting difficult intubation. We are in the process of developing a scoring system based on these findings and which is undergoing validation.

Conclusion

We studied various parameters like Mallampati class, Neck movements, Upper lip bite test, Interincisor gap, thyromental distance, mandibular length, sternomental distance, Height to thyromental distance ratio and Neck circumference to thyromental distance ratio to predict difficult intubation. Amongst them, Upper lip bite test was found to predict highest number of difficult intubation (48.48%). A combination of Mallampati class, upper lip bite test, neck circumference to thyromental distance ratio, had the highest predictive value (sensitivity - 75.76%, specificity - 91.12%, Postive Predictive Value - 62.5% and Negative Predictive Value - 95.06%). We suggest that if the ROC of a parameter were used, it would give a more precise estimate of sensitivity and specificity.

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