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Evaluation of Neck Circumference to Thyromental Distance Ratio as A Predictor of Difficult Tracheal Intubation - An Observational Study

[1]Dr Pranab Kalita, [2]Dr. Ratindra Kumar Barman, [3]Dr. Trinayan Mili, [4]Dr Nibedita Das

[1]Assistant Professor, Dept. of Anesthesiology, Guwahati Medical Collegeand Hospital, Guwahati, Assam, India

[2]Associate professor, Dept. of Anesthesiology, Dhubri Medical College and Hospital. Guwahati, Assam, India

[3]Assistant Professor, Dept. of Obstetrics and Gynaecology, Lakhimpur Medical College and Hospital, Assam, India

[4]Consultant Anesthesiologist, Downtown Hospital, Guwahati, Assam, India

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Corresponding Author: Dr. Ratindra Kumar Barman, Associate professor, Dept. of Anesthesiology, Dhubri Medical College and Hospital. Guwahati, Assam, India

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ABSTRACT

Background and Aims

Prior to general anesthesia, airway screening is necessary for efficient anesthesia delivery. A study was conducted to assess the neck circumference / thyromental distance ratio as a predictor of difficult tracheal intubation.

Methods

After the Hospital Ethics Committee's approval, 450 adult patients were included in this study. Neck circumference/thyromental distance (NC/TMD), modified Mallampati class (MMT), Sternomental distance (SMD), and inter-incisor distance (IID) were evaluated preoperatively by our anesthesiologist. Intubation Difficulty Scale (IDS) as a reference to predict difficult intubation and IDS>5 was regarded as difficult intubation. Laryngoscopy was done by our senior anesthesiologists who were blinded to the results of the airway predictors under evaluation. The primary outcome was the predictive performance of NC/TMD as a predictor of difficult intubation. Comparing IDS>5 with MMT, SMD, and IID were secondary objectives.

Results

IDS>5 was observed in 9 patients (2%). We observed that sensitivity, specificity, Positive predictive value (PPV), Negative predictive value (NPV), and Area under the Curve (AUC) (95% CI) of ROC of NC/TMD was 88.89 % (51.75%-99.72%), 85.71 %(82.10%-88.84%), 11.27 %(8.40%-14.95%), 99.74 %(98.35%- 99.96%) and 0.901respectively. The AUC of NC/TMD was found to be better than MMT, SMD, and IID.

Conclusion

NC/TMD (≥0.5) is a good predictor of IDS>5.

Keywords

Intubation Difficulty Scale, Neck circumference/ thyromental distance, anesthesia, intubation.

INTRODUCTION

Securing the airway is of utmost importance for an anesthesiologist while providing general anesthesia to a patient. Failure or delayed protection of the airway in an anesthetized patient may increase the morbidity and mortality of patients. The scenario can be even more detrimental and catastrophic in the event of a patient having a low cardio-respiratory reserve. In the context of a closed claims study, 17% presented with difficult or impossible intubation. [1] And of all the anesthesia-related deaths, 30% to 40% were due to the inability to manage a difficult airway. [2] Accurate assessment of the airway should always be performed beforehand to provide appropriate planning and management of difficult intubation and thus limit any unexpected casualties. The incidence of difficult laryngoscopy and tracheal intubation varies widely from 0.1 to 20.2% based on the criteria used to define difficult intubation and different study populations. [3] Therefore, proper assessment of the airway to predict difficult laryngoscopy or intubation should be done as a component of pre-anesthetic check-ups. Anesthesiologists trained in airway management use different screening tests or predictors to determine airway difficulties. The American Society of Anesthesiologists (ASA) defines difficult endotracheal intubation as 3 attempts at intubation with conventional laryngoscopy or when endotracheal intubation takes 10 mins or more. [3] Recently, there is an increasing trend to use Intubation Difficulty Scale (IDS) as a reference to predict difficult intubation. [4] IDS > 5 is regarded as difficult intubation and its incidence has not been reported in our population. [4] The incidence of difficult visualization of the larynx in our institute is 3.6% as reported by Rajkhowa et al. [5]

Among various predictors, the Modified Mallampati test (MMT), Sternomental distance (SMD), Inter-incisor distance (IID), Neck circumference (NC), thyromental distance (TMD), and thyromental height test (TMHT) are widely used by anesthesiologists. Barring TMHT, these tests were characterized to have low sensitivity and specificity with high false positive rates particularly when a single assessment test was done, which decrease their usefulness. W H Kim et al, in 2011 developed a new index, NC/TMD ratio as a predictor of difficult intubation, assuming that obese patients have large neck circumferences and short necks. [6] However, their study needed further evaluation in the light of apparently normal patients as a useful predictor. It has been proposed that NC/TMD ≥5 is a statistically significant predictive variable of difficult intubation.

The primary objective of our study was to evaluate the incidence of difficult intubation (IDS>5) and the

predictive performance of NC/TMD as a predictor of difficult intubation in non-obese patients requiring endotracheal intubation for the provision of general anesthesia in our institute. The secondary objective was to compare its predictive validity with other established predictors of airway assessment like MMT, SMD, and IID in assessing difficult intubation.

METHODS

It was a prospective observational study conducted in the Department of Anesthesiology and Critical Care in a tertiary center for one year from August 2019 to 30 June 2020 with prior permission and approval from the Institutional Ethics Committee after fulfilling the norms (No. MC/190/2007/PHI- /March 2019/33). Our study included patients of the American Society of Anesthesiologists (ASA) physical status I and II, non-obese, aged between 18 to 65 years old, who were scheduled for elective surgery requiring endotracheal intubation under general anesthesia. Patients having obvious abnormalities of the head, neck, and thorax, obstetrics patients, patients using a cervical collar or having cervical spine pathology, patients having a previous history of head and neck surgery, patients having a history of previous difficult airway, obese patients with BMI>30kg/meter square

DATA COLLECTION

Data collection was done both preoperatively during a pre-anesthetic check-up for demographic and for MMT, SMD, TMD, NC, and IID and intraoperatively for the difficulty of intubation by the same anesthesiologist was trained in airway assessment, but not involved in the study. The pre-anesthetic evaluations of patients were done in the ward the day before surgery. Written and informed consent was taken for the anesthetic technique and study. All patients underwent standard preoperative evaluations and fasting protocols. Intubation was done by different anesthesiologists of our college who had an experience of more than 2 years of clinical anesthesia after passing MD, in anesthesiology.

AIRWAY ASSESSMENT

The patients were evaluated for MMT, SMD, TMD, NC, and IID by using a measuring tape and expressed in centimeters (cm).

NC: Measured at the level of the cricoid cartilage.

TMD: Defined as the distance from the thyroid notch to the mentum when the neck is fully extended.

SMD: The distance from the upper border of the manubrium sterni to the mentum with the head fully extended and mouth closed.

IID: The distance between the upper and lower incisors with the mouth fully open Modified Mallampati test (MMT). [7]

The difficulty of intubation was assessed by filling up the intubation difficulty score (validated IDS score) after intubation. The intubation difficulty score consists of seven variables from N1 to N7. The sum of N1 to N7 gives the total IDS score. [8]

N0	"Ideal" intubation. One performed without effort, on the first attempt, practiced by one operator, using one technique, with full visualization of the laryngeal aperture and vocal cords abducted
N1	Number of additional intubation attempts
N2	Number of additional operators
N3	Number of alternative intubation techniques.
N4	Glottic exposure as defined by Cormack and Lehane (C&L)
N5	Lifting force applied during laryngoscopy (N5=0 if inconsiderable, N5=1 considerable force)
N6	Need to apply external laryngeal pressure to improve glottic view (N6=0 If no external laryngeal press applied or only the Sellick maneuvers applied, N6=1 If external pressure applied)
N7	Position of vocal cords at intubation (N7=0 If abducted or not visible, N7=1 If adducted)

A score ≥5 was considered to be difficult intubation and a score <5 was considered to be easy intubation.

In the operating room, the patients were positioned with pillows under the head, and the neck extended. Standard monitoring equipment measuring non-invasive blood pressure (NIBP), heart rate (HR), percentage oxygen saturation (SPO2), end-tidal carbon dioxide (ETCO2), and continuous electrocardiography (ECG) were attached, and baseline recordings were taken. Intravenous (IV) access was done and premedicated with an injection of Fentanyl 2 mcg/kg IV and an injection of glycopyrrolate 4 microgram /kg. All patients underwent pre-oxygenation for 3 minutes with 100 % oxygen. Anesthesia was induced with propofol 2 mg/kg. Atracurium 0.6 mg/kg was administered IV for neuromuscular relaxation after mask ventilation. Direct Laryngoscopy and intubation were done by senior anesthesiologists with more than 2 yrs of experience who were blinded to the airway predictors measured. Laryngoscopy was done by Macintosh number 3 and 4 laryngoscope blades. Subsequently, difficulty in performing intubation was evaluated by IDS. The IDS score is the sum of N1 through N7. A score of ≥5 indicates difficult intubation.

A total of 450 patients were included in our study. The sample size was calculated using G-Power 3.1.9.7 statistical software. The sample size required for this study was estimated from a previous study by Rajkhowa et al which demonstrated that the incidence of difficult laryngoscopy in the Indian population is 3.6%. [5] The area under the curve (AUC) of MMT as reported by their study was 0.58. To prove that NC/TMD is a better predictor of difficult intubation, we assume that the AUC for NC/TMD must be higher than AUC for MMT by 0.3. So, considering a power of study of 80% and a level of significance of 5%, 406 patients are required with an allocation ratio of 28. So, considering a dropout ratio of 10%, we intended to include 450 patients in the study population.

STATISTICAL ANALYSIS

The data were entered into MS Excel spreadsheets and analyzed using SPSS (Version: 21.0) statistical package. The description of the data is in the form of mean ± SD for quantitative data while in the form of % proportion for qualitative (categorical) data. Chi-square and Fisher's exact test were used to evaluate the association between categorical variables. Quantitative variables like age, height, and weight; are compared by using a student t-test. The incidence of difficult intubation was determined based on IDS ≥5. Sensitivity, specificity, and positive and negative predictive value were calculated for MMT, SMD, IID, and NC/TMD with a 95% confidence interval (CI). The area under the curve (AUC) was computed for the airway predictors by the receiver operating characteristics curve (ROC). A p-value <.05 is considered significant

Result	Condition Present	Condition Not Present
Test Positive(TP)	True Positive(TP)	False Positive(FP)
Test Negative(TN)	False Negative(FN)	True Negative(TN)

Sensitivity: TP*100÷ (TP+FN)

Specificity: TN*100÷ (TN+FN)

Positive predictive value (PPV): TP*100÷ (TP+FP)

Negative predictive value (NPV): TN*100÷ (TN+FN)

RESULTS

Data presented as mean ±SD or numbers of patients as a percentage (%) were tabulated and analyzed in

Microsoft Excel 7. A total of 545(n=545) patients were assessed for eligibility out of which 95 (n=95) patients were excluded from the study due to not meeting inclusion criteria. A total of 450(n=450) patients were enrolled in our study.

The TP, TN, FP, FN, sensitivity, specificity, PPV, and NPV of NC/TMD ratio MMT, IID, and SMD with respect to the IDS score were determined.

The area under the curve (AUC) was also computed by the receiver operating characteristics curve (ROC) for the airway predictors. A *P* value of< 0.05 was considered significant.

The demographic data of all patients and the measurement of the screening tests were tabulated. MMT III&IV, NC/TMD≥5, SMD≤12.5 and IID≤4 are considered a predictor of difficult intubation. [Table-1]

Out of 450 patients, IDS>5 was encountered in 9 patients (2%) in our study. [Table-2]

There was a statistically significant difference in mean age and weight between IDS<5 and IDS>5 patients. (P-value<0.05). Gender and height were comparable among the patients (p –value>0.05). [Table-2]

Out of the 9 (IDS> 5) patients, MMT could predict 5. Out of the 441 easy intubation, MMT predicted 411. Hence MMT has a sensitivity(95CI) of 55.56% (21.20%-86.30%) and a specificity (95% CI) of 93.20%(90.43%-95.36%) and PPV (95% CI) of14.29%(7.79%-24.73%) and NPV(95% CI) of 99.04%(98.02%- 99.53%).[Table3,Figure1]

Out of 9 (IDS>5) patients, NC/TMD could predict 8. Out of the 441 easy intubation, NC/TMD predicted 378. Hence NC/TMD has a sensitivity(95CI) of 88.89% (51.75%-99.72%) and a specificity (95% CI) of 85.71%(82.10%-88.84%)and PPV (95% CI) of 11.27%(8.40%-14.95%) and NPV(95% CI) of 99.74%(98.35%- 99.96%).[Table3,Figure1]

Out of 9 (IDS>5) patients, IID could predict 5. Out of the 441 easy intubation, IID predicted 372. Hence IID has a sensitivity(95CI) of 55.56% (21.20%-86.30%) and a specificity(95% CI) of 84.35%(80.62%-87.62%), and PPV (95% CI) of 6.76%(3.74%-11.91%) and NPV(95% CI) of 98.94%(97.81%-99.49%).[Table3,Figure1]

Out of 9 (IDS> 5) patients, SMD could predict 4. Out of the 441 easy intubation, SMD predicted 431. Hence SMD has a sensitivity (95CI) of 44.44% (13.70%-78.80%) and a specificity (95% CI) of 97.73%(95.87%-98.91%),and PPV (95% CI) of28.57% (13.36%-50.93%) and NPV (95% CI) of 98.85%(97.96%- 99.36%).[Table3,Figure1]

The area under the ROC curve (AUC) is a measure of how well a parameter can distinguish between two diagnostic groups (DI/EI). The AUC of ROC curves of the airway assessment tests is presented in Table 4 and Figure 2. The AUC of NC/TMD is the highest (0.901) among the predictors.

DISCUSSION

An important cause of morbidity and mortality in anesthesia practice is unexpectedly difficult intubation, which stands out as a significant challenge for the anesthesiologist. Preoperative assessment of difficult airways allows time for optimal preparation, selection of equipment and technique, and participation by the experienced anesthesiologist in mitigating a proper management plan.

This study was conducted to evaluate the incidence of difficult intubation (IDS>5) as well as to detect the predictive performance of NC/TMD and to compare the predictive performance of different airway

predictors in practice, viz, NC/TMD, MMT, SMD, and IID in assessing difficult intubation. Altogether 450 patients of ASA I and II were included in the study population. Difficulty in intubation was assumed as MMT grade III and IV, SMD<=12.5, IID<=4, NC/TMD≥5.

In our study, the incidence of difficult intubation as defined by IDS>5 was found to be 2% which is within the incidence of 1 to 4% as reported by Benumof et al. [9] Bhabani et al. discovered a similar incidence of 2% difficult intubations in their study of the Indian population. [10] The incidence of difficult intubation ranges between 1.5-13%. [11] The major reason for this wide range of variation could be attributed to the different criteria used to define difficult intubation, the type and size of the laryngoscope blade used, and the degree of relaxation achieved. It also depends on the different anthropometric features among populations. The definitions used to define difficult intubation mostly includes Cormack Lehane grade III and IV, ASA criteria of ≥3 attempts at endotracheal intubation, or time taken ≥10 min. In our study, we relied on the IDS scale as it encompasses the number of additional attempts, number of additional operators, number of alternative techniques, glottis exposure as defined by Cormack and Lehane grade, lifting force applied during laryngoscopy, external laryngeal pressure applied and the position of vocal cords.

The sensitivity and specificity of NC/TMD in our study are 88.89% and 85.71% respectively, which is similar to the study conducted by Kim et al. (88.2% and 83%). their study used the same criteria IDS defined difficult intubation as in our study. [6] The study by Abdel et al. found the highest sensitivity of 100% which was done on obese patients with obstructive sleep apnea (OSA). [12] This high sensitivity could be attributed to the small population considered in their study. However, the study done by Anahita et al. found a low sensitivity of 71.7%. [13] The probable reason for this low sensitivity could be due to the inclusion of the obstetric population in the study group. The PPV and NPV in our study for NC/TMD are 11.27% and 99.74% which is comparable to the study by Khanooja et al. (11.26% and 99.8%). [14] The high sensitivity and specificity of NC/TMD in our study imply that this predictor has a high probability of predicting difficult intubation. Moreover, it is a reliable predictor of easy intubation as evidenced by its high NPV.

The sensitivity of MMT in our study is 55.56% which is quite similar to that reported by Khanooja et al. and Kim et al. of 55% and 58.8% respectively. [6, 14] The study conducted by Bhavdip et al. found a low sensitivity of MMT of 28.6%. [15] The specificity of MMT in our study was 93.20% which is similar to that study conducted by Bhavdip et al. (93%). [15] However, the study by Abdel Naim et al. found the specificity of MMT as 61%95. [12] The wide variation in the range of sensitivity and specificity of MMT can be due to the differences in the evaluator's assessment of the oral structures and the position of the patient while performing the test. MMT is also influenced by the patient's ethnicity and physiological changes during pregnancy. PPV and NPV of MMT in our study were 14.29% and 99.04% respectively which is comparable to the results of the study by Patel B et al. (18.03% and 96.04%). [15] Thus, in our study, MMT shows to have a high specificity and NPV which implies that MMT could predict easy intubation rather than predicting difficult intubation.

The sensitivity and the specificity of IID in our study are 55.56 % and 84.35% respectively which is nearly similar to the study conducted by Foroosh et al. and Srinivasa et al. [16,22]

The study by Gupta et al. however found the sensitivity of IID for difficult intubation to be very low (18.8%). [17] The discrepancies in the observed results may be because there occurs substantial inter-observer variability concerning their measurements. The PPV and NPV in our study are 6.76% and 98.94% respectively which is similar to the study done on the Kashmiri population by Gupta et al. (6.6% and 98.1%). Decreased mouth opening has been demonstrated to be a significant predictor of difficult intubation by Wilson et al., Rose DK, and Cohen et al. in their studies. [18, 19] However, there are also studies by Savva and Krobbuaban that found no correlation between IID and difficult intubation. [20, 21] Similarly we can infer from our study that IID is not a useful predictor of difficult intubation.

The sensitivity of SMD as concluded by our study is 44.44% which is comparable to the study by Srinivasa et al. of 57.14% with a cut-off value for SMD considered as 12.5cm for both studies. [22] In contrast, the studies by Bhavdip et al. found the sensitivity of SMD to be 91% for difficult intubation. [15] This increased sensitivity could be probably due to the small study population in their context. The specificity and NPV of SMD in our study are 97.73% and 98.85% respectively which is close to that found by Aswini et al. of 93.9% and 98%91. [23] The PPV of SMD in our study is 28.57% which is comparable to the study by Savva et al. 26.3%. [20] The study by Ramdhani et al. found sensitivity, specificity, and PPV of SMD as 66.7%, 71.1%, and 7.6% respectively which is different from our study. [24] This difference could be due to the assumption of the different cut-off values for SMD 13.5 cm for difficult intubation in their study. Savva et al in their study found SMD to be a reliable predictor of difficult intubation. However, the study by Prakash et al. concludes that SMD is not a useful predictor of difficult intubation. [20, 25] Our study also concludes that SMD is not a reliable predictor of difficult intubation owing to its low sensitivity. Moreover, there is no standard cut-off value of the airway parameters under evaluation quoted in the literature for review in our study population. This may be a reason for the difference in the predictive index of the parameters in different studies.

In our study, age and increased weight were found to be statistically significant predictors of difficult intubation with a p-value <0.05. This is similar to the study by Rose and Cohen et al. which stated that difficult intubation increases with increasing age due to bone and joint changes and also poor dental condition. [18]

The AUC for NC/TMD, MMT, SMD, and IID were 0.901, 0.691, 0.67, and 0.717 respectively and NC/TMD had a statistically significant difference (p-value<.05) when compared with the other tests. Our study results were consistent with the study by Abdel Naim et al. who studied the importance of NC/TMD as a predictor of difficult intubation in OSA patients.

Vrishali R et al. in their study found the AUC under ROC for NC/TMD and MMT to be 0.73 and 0.66 respectively, thereby concluding that NC/TMD is a better predictor of difficult intubation as compared to MMT. [26] The area under the ROC curve for NC/TMD is significantly greater than MMT, SMD, and IID in our study. Thus, in our study, NC/TMD is

found to be a reliable predictor of difficult intubation in comparison to other airway predictors like SMD, IID, and MMT. However, no studies are comparing NC/TMD with SMD and IID. Hence more studies are needed to evaluate these factors in a normal population.

LIMITATIONS OF THE STUDY

All patients were not intubated by the same anesthesiologists; the C&L score and IDS score vary with the experience and expertise of the anesthesiologists. The degree of relaxation achieved may be different for different cases. We did not evaluate a combination of different airway predictors. Our study aimed to detect the predictive performance of an NC/TMD. The predictive performance of a combination of tests to detect IDS scores will be considered in the upcoming days. This study, therefore, needs more input in the light of a greater study population encompassing patients of all categories like obstetrics and pediatrics age groups. Our study result needs to be interpreted and extrapolated to a population with different morphological characteristics.

CONCLUSION

NC/TMD is a better predictor of difficult intubation with a sensitivity of 88.89% and an area under a ROC curve of 0.9 as well as a better predictor of easy intubation with a high NPV of 99.74%. NC/TMD is a better predictor of difficult intubation in comparison to MMT, SMD, and IID.

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TABLES

Table 1: Demographic variables and predictors of difficult intubation…

Variable	Mean(±SD)
Age(years)	38.29±11.63
Weight(kg)	57.25±7.77
Height(cm)	155.71±6.354
BMI (kg/m^2)	23.38±2.81
	M=156(34.7%)
Gender	F=294(65.3%)
	I&II=415(92.2%)
MMT I&II/III&IV	III&IV=35(7.8%)
	>5=71(15.8%)
NC/TMD	<5=379984.2%)
	>12.5=436(96.89%)
SMD (cm)	≤12.5=14(3.1%)
	>4=376(83.6%)
IID (cm)	<=4=74(16.4%)

SD: standard deviation; **BMI:** body mass index; **MMT:** modified mallampati test; **NC:** neck circumference; **TMD:** thyromental distance; **SMD:** Sternomental distance; **IID:** inter incisor distance

Table 1: Showing variables affecting IDS

IDS			
Variables affecting intubation	**<5(n=441)**	**>5(n=9)**	**p-value**
Age (years)	38±11.62	46.56±9.57	0.031
Weight (kg)	57.15±7.69	62.44±10.58	0.043
Height (cm)	155.71±6.38	155.67±5.41	0.983
BMI (kg/m^2)	23.37±2.83	23.14±2.47	0.413
Gender	M=151, F=290	M=4, F=5	0.1835
NC/TMD	4.66±0.46	5.34±0.35	<0.0001
SMD (cm)	15.74±1.35	14.41±2.2	0.004
IID (cm)	4.14±0.33	3.87±0.42	0.015
MMT	Easy-411, difficult-30	Easy-4, difficult-5	<0.0001

IDS: Intubation Difficulty Scale; **BMI:** body mass index; **MMT:** modified mallampati test; **NC:** neck circumference; **TMD:** thyromental distance; **SMD:** Sternomental distance; **IID:** inter incisor distance

Table 2: Univariate analysis of variable affecting IDS

Airway assessment test				
Variables	MMT≥III	NC/TMD>=5	IID≤4	SMD≤12.5
True positive	5	8	5	4
False-negative	4	1	4	5
True negative	411	378	372	431
False positive	30	63	69	10
sensitivity (95%CI)	55.56%	88.89%	55.56%	44.44%
specificity(95%CI)	93.20%	85.71%	84.35%	97.73%
PPV (95% CI)	14.29%	11.27%	6.76%	28.57%
NPV (95% CI)	99.04%	99.74%	98.94%	98.85%

MMT: modified mallampati test; **NC:** neck circumference; **TMD:** thyromental distance; **SMD:** Sternomental distance; **IID:** inter incisor distance; **PPV:** Positive predictive value; **NPV:** negative predictive value

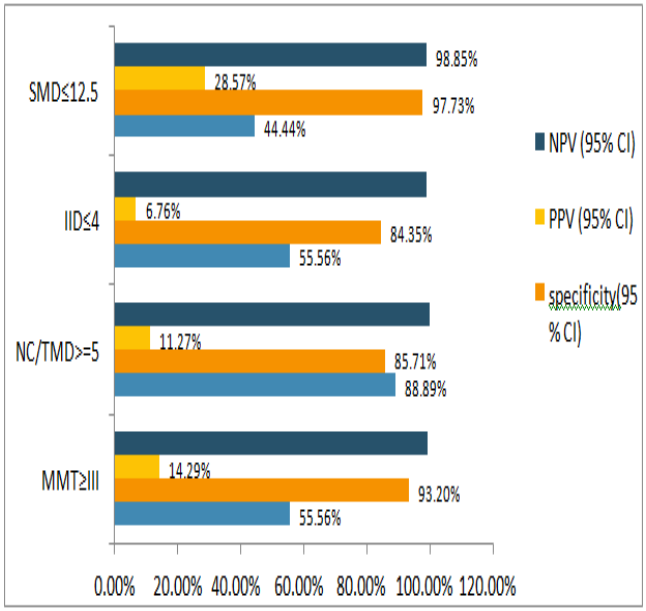
Table 4: Area under the curve of ROC of predictors

Area Under the Curve					
				Asymptotic 95% Confidence	
Test Result Variable(s)		Std.	Asymptotic	Interval	
Test Result Variable(s)	Area	Error	Significance	Lower Bound	Upper Bound
NC/TMD	0.901	0.032	<0.0001	0.838	0.964
MMT	0.691	0.124	0.05	0.449	0.933
SMD	0.67	0.122	0.081	0.431	0.908
IID	0.717	0.093	0.025	0.534	0.9

ROC: receiver operating characteristic curve; **MMT:** modified mallampati test; **NC:** neck circumference; **TMD:** thyromental distance; **SMD:** Sternomental distance; **IID:** inter incisor distance.

Figure

Figure 1: NPV, PPV, specificity, and sensitivity of predictors



SMD: Sternomental distance; **IID:** inter incisor distance; **IID:** inter incisor distance; **NC:** neck circumference; **TMD:** thyromental distance; **MMT:** modified mallampati test.

Figure 2: ROC curve of NC/TMD, MMT, and SMD/IID