Original Article

The predictive value of the ratio of neck circumference to thyromental distance in comparison with four predictive tests for difficult laryngoscopy in obstetric patients scheduled for caesarean delivery

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Abstract

Background: Preoperative assessment of anatomical landmarks andclinical factors help detect potentially difficult laryngoscopies. The aim of the present study was to compare the ability to predict difficult visualization of the larynx from thefollowing preoperative airway predictive indices, in isolation and combination: Neck circumference to thyromental distance (NC/TMD), neck circumference (NC), modified Mallampatitest (MMT), the ratio of height to thyromental distance (RHTMD), and the upper-lip-bite test (ULBT).

Materials and Methods: We collected data on657 consecutive patients scheduled for elective caesarean delivery under general anesthesia requiring endotracheal intubation and then evaluated all five factors before caesarean. An experienced anesthesiologist, not informed of the recorded preoperative airway evaluation, performed the laryngoscopy and grading (as per Cormack and Lehane's classification). Sensitivity, specificity, and positive and negative predictive values for each airway predictor in isolation and in combination were determined.

Results: Difficult laryngoscopy (Grade 3 or 4) occurred in 53 (8.06%) patients. There were significant differences in thyromental distance (TMD), RHTMD, NC, and NC/TMD between difficult visualization of larynx and easy visualization of larynx patients ($P < 0.05$).The main end-point area under curve (AUC) of the receiver-operating characteristic (ROC) was lower for MMT (AUC = 0.497; 95% Confidence Interval = CI,0.045-0.536) and ULBT (AUC = 0.500, 95% CI, 0.461-0.539) compared to RHTMD, NC, TMD, and NC/TMD score ([AUC = 0.627, 95% CI, 0.589-0.664], [AUC = 0.691; 95% CI, 0.654-0.726], [AUC = 0.606; 95% CI, 0.567-0.643], [AUC = 0.689;95% CI, 0.625-0.724], respectively), and the differences of six ROC curves were statistically significant ($P < 0.05$).

Conclusion: The NC/TM Discomparable with NC, RHTMD, and ULBT for the prediction of difficult laryngoscopy in caes are an delivery.

Key Words: Caesarean delivery, difficult laryngoscopy, modified Mallampati test, neck circumference, neck circumference to thyromental distance, ratio of height to thyromental distance, upper-lip-bite test

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INTRODUCTION

Although the use of general anesthesia for cesarean delivery has declined in these decades in parturient, it is still inevitable for management in several situations such as maternal hemorrhage, overt coagulopathy, fetal compromise (which is life-threatening), and patient refusal for regional anesthesia.[1] Unanticipated difficulties with tracheal intubation in obstetrics remain a true challenge for anesthesiologists. Complications from general anesthesia for cesarean delivery are a leading cause of anesthesia-related mortality.[2] The incidence of difficult larygoscopy or endothracheal intubation varies from 1.5% to 13% in patients undergoing general anesthesia.[2-7]

Most airway difficulties occur when they are not recognized before induction of anesthesia. Therefore, anesthesiologists must use their clinical skills to determine which patient will present difficulties with airway management.[8] Many investigations have explained prediction criteria by applying single or multifactorial indexes.[9-13]

Recently, Gonzalez *et al*.[14] have demonstrated that the assessment of neck circumference (NC) preoperatively is defined as an important predicting factor for difficult intubation that measured the level of thyroid cartilage. Moreover, upper-lip-bite test (ULBT), which evaluates the possibility of a patient to cover the mucosa of the upper lip with the lower incisors, is an acceptable option for predicting difficult intubation as a simple, single test.[15-19]

Another test for difficult laryngoscopy is the ratio of height to thyromental distance (RHTMD = Height [cm]/TMD[cm]). RHTMD measurement has high sensitivity than other tests and is sufficiently sensitive to detect possible difficulties with laryngoscopy and intubation.[20,21]

The Mallampati classification of mouth opening and the Samsoon and Young modified system[22] have been shown to change during pregnancy. A pre-pregnancy classification of I-II may advance one or two classes due to changes in pregnancy.[23] In addition, Savva[23] showed that), modified Mallampatitest (MMT) was neither sensitive nor specific enough as a single test in predicting difficult intubation in parturient patients.

Another study by Kim *et al*.[24] has demonstrated that the ratio of neck circumference to thyromental distance (NC/TMD) was a better indicator than the other established methods for predicting difficult laryngoscopy in obese patients.

No published study has compared NC with ULBT, RHTMD, MMT, and NC/TMD by their sensitivity, specificity, and positive and negative predictive values for prediction of difficult laryngoscopy in pregnant patients.

Therefore, this study was designed to develop predictors for difficult intubation and to compare these indices with established indices in parturient candidates for cesarean delivery.

MATERIALS AND METHODS

This prospective observational study was approved by an institutional Ethics Committee of our university and all patients provided informed and written consent. A total of 657 consecutive American Society of Anesthesiologists (ASA) physical status I and II adult patients who were undergoing cesarean delivery under general anesthesia with tracheal intubation during the 18-month period were enrolled.

Patients with a history of trauma to the airway or cranial, cervical and facial regions, or were edentulous or requiring awake intubation, patients with restricted motility of the neck and mandible (e.g., cervical disc disorders or rheumatoid arthritis) and inability to sit were not included in the study.

Patients' data collected included age, weight, height, and body mass index (BMI). A senior anesthesiologist with at least 8-year experience in anesthesia, who was not informed of the preoperative classes carried out laryngoscopy and evaluated difficulty at intubation.

The subsequent five predictive test measurements were performed on all patients:
- NC: NC was determined at the level of thyroid cartilage in cm[14,22]
- ULBT: ULBT was introduced according to the following criteria: Class I if the incisors can bite the upper lip above the vermilion line, class II if the lower incisors could bite the upper lip below the vermilion line, and class III if the lower incisors could not bite the upper lip[15]
- RHTMD: Thyromental distance (TMD) was measured from the bony point of the mentum while the head was extended completely with closed mouth.[25] Then the ratio of height to TMD was calculated
- MMT: Samsoon and Young's modification of Mallampati test[22] showed oropharyngeal structures visible upon maximal mouth opening. Each patient was asked to open her mouth maximally and to protrude the tongue without

phonation while she was seated.[26] The view was classified as follows: Class I: Good visualization of the soft palate, fauces, uvula, and tonsillar pillars; class II: Pillars obscured by the base of the tongue but soft palate, fauces, and uvula visible; class III: Soft palate and base of uvula visible; and class IV: Soft palate not visible[22]

- NC/TMD: This is a new predictor of difficult intubation in obese patients[24] where in the neck was measured at the level of cricoid cartilage and TMD is the distance from the thyroid notch to the mentum in centimeter.

In the operating theatre, each patient was monitored routinely with an electrocardiogram, noninvasive arterial blood pressure, and peripheral oxygen saturation. Patients breathed high-flow oxygen through a facemask for about 3-5 min or four vital capacity breaths.[27] Anesthesia was then induced with sodium thiopental (5 mg/kg) i.v., and suxamethonium chloride (2 mg/kg) i.v. was administered for facilitating endothracheal intubation. During loss of consciousness, cricoids pressure as described by Sellick[28] was applied to the patients. Whenever the fasciculations disappeared, the parturient head was placed in the 'sniffing position'. All tracheal intubations were performed by an 8-year experienced anesthesiologist who was not informed of the preoperative classes and assessed the difficulty of laryngoscopy at intubation. For the first laryngoscopy in each case, a size three Macintosh laryngoscope blade was used.

The laryngoscopic view was classified according to the Cormack and Lahane scale as follows:[29,30] grade I: Vocal cords were completely visible; grade II: only the arythnoids were visible; grade III: Only the epiglottis was visible; and grade IV: The epiglottis was not visible.

Difficult larygoscopy or difficult visualization of larynx (DVL) has been defined as the visibility of the larynx corresponding to grades III and IV in classification of Cormack and Lahane, and grades I and II on direct laryngoscopy are defined as easy visualization of larynx (EVL). The Sellick maneuver was maintained until the trachea was intubated and the cuff inflated and confirmed successful intubation by bilateral auscultation of lungs and capnography.

A prospective power analysis showed that assuming an incidence of DVL of 5%, 600 patients provided a power of more than 80% to detect an improvement of discriminating power measured by the area under curve (AUC) of the appropriate receiver-operating characteristic (ROC) curve of an absolute value of 15% (e.g. from 50% to 65%) with a type I error of 5% and using a two-sided alternative hypothesis.

A list of these measures is provided in the Appendix together with a short description and instructions on how to perform the calculations. The AUC was used as themain end-point of the study to decide whether the score was clinically useful. An ROC plot was obtained by calculating the sensitivity (true-positive fraction) and specificity (true-negative fraction) of every observed data value (cut-off value), and plotting sensitivity against 1-specificity (false-positive fraction). A value of 0.5 under the ROC curve indicated that the variable performs no better than chance and a value of 1.0 indicates perfect discrimination. A larger area under the ROC curve represents more reliability[31,32] and good discrimination of the scoring system. Differences between the AUC values of all predictive tests were calculated, and a P value of 0.05 was defined as statistically significant.

Patient data were presented as mean ± SD BMI, determined from weight (kg)/height 2(m). Patient data and value of the airway predictors were compared using t-tests for continuous variables and U-test for MMT or ULBT. Sensitivity, specificity, and Positive predictive value PPV were obtained and compared amongst predictors. The data were analyzed using SPSS version 18.0.

RESULTS

A total of 657 parturient patients were included in this study. Patients' age, height, weight, and BMI are shown in Table 1. There were 596 ASA I and 61 ASA II patients. DVL was observed in 53 (8.6%) patients. There was no failed intubation. There were significant differences in weight and BMI between DVL and ELV patients [Table 1].

The distributions of ASA, MMT, ULBT, and the Cormack and Lehane grades are presented in Table 2.

Significant differences were observed in TMD, RHTMD, NC, and NC/TMD between DVL and EVL patients using the U-test [Table 3]. The measures used to explain the predictive properties of the four models are shown in Table 4.

The main end-point of this study, the AUC of the ROC, was lower for MMT (AUC = 0.497; 95% CI,0.045-0.536)

Table 1: Patient characteristics

Variables	Patients (n=657)	ELV (n=604)	DLV (n=53)	P value
Age (year)	27.2±5	27.1±4.9	28.8±5.1	0.013
Height (cm)	161±13	161.0±13.5	161.8±5.5	0.017
Weight (kg)	78.6±18.1	78.1±18.3	84.3±13.7	0.661
BMI (kg/m^2)	30.4±6.7	30.2±6.8	32.2±5.5	0.040

ELV: Easy visualization of the larynx, DLV: Difficult visualization of the larynx, BMI: Body mass index, DVL: Difficult visualization of larynx, EVL: Easy visualization of larynx. Data are presented as mean±SD and ULBT (AUC = 0.500, 95% CI, 0.461-0.539) compared to RHTMD, NC, TMD, and NC/TMD scores ([AUC = 0.627, 95% CI, 0.589-0.664], [AUC = 0.691; 95% CI, 0.654-0.726], [AUC = 0.606; 95% CI, 0.567-0.643], [AUC = 0.689;95% CI, 0.625-0.724], respectively), and the differences of six ROC curves were statistically significant ($P < 0.05$). Predictive values of the six single or combined predictors are shown in Tables 4 and 5.

Table 2: Distribution of American Society of Anesthesiologists, modified mallampati class, upper lip bite test, and laryngoscopic view of all patients

Category patients	Number of patients	%
ASA		
I	596	90.7
II	61	9.3
Mallampati class		
1	174	26.5
2	230	35
3	230	35
4	23	3.5
ULBT		
1	212	32.3
2	443	67.4
3	2	0.3
Laryngoscopic view		
1	416	63.3
2	188	28.6
3	49	7.5
4	4	5.6

ASA: American society of anesthesiologists, MMT: Modified mallampati class, ULBT: Upper lip bite test

Table 3: Demographic data of patients in difficult and easy laryngoscopic view groups

Variable	DVL (*n*=53)	EVL (*n*=604)	*P* value
TMD	6.4±1.1	6.9±0.9	0.001
RHTMD	26±5.4	23.7±3.8	0.000
NC	38.3±2.8	36.4±3.0	0.000
NC/TMD	6.1±1.3	5.3±0.9	0.000

TMD: Thyromental distance, RHTMD: Ratio of height to thyromental distance, NC: Neck circumference, NC/TMD: Neck circumference to thyromental distance ratio, DVL: Difficult visualization of larynx, EVL: Easy visualization of larynx. Data are presented as mean±SD

Using discrimination analysis, MMT grade > I, ULBT ≥ grade 2, RHTMD > 28.83, NC > 39.5, TMD ≥ 5, and NC/TMD > 5.6 were considered as the cut-off points for predicting difficulty in laryngoscopy. The RHTMD was the least sensitive of the single tests with a sensitivity of 26.4%.ULBT and NC/TMD had the highest sensitivities amongst single predictors (100% and 71.1%, respectively). After RHTMD, NC and NC/TMD had the highest accuracy and positive predictive values. The multivariate analysis odds ratio (95% CI) of MMT, ULBT, RHTMD, NC, and NC/TMD were 0.67, (0.36-1.23) 1.01, (0.55-1.84) 6.41, (3.16-13.01) 7.85 (4.32-14.24), and 5.96 (3.20-11.12), respectively.

DISCUSSION

In this study, the incidence of DVL was found to be 8.6%. Honarmand *et al*.[20] showed a similar incidence of DVL in obstetrics (8.7%). In another recent literature by Boutonnet *et al*.,[6] performed to evaluate the anesthetic practices in obstetrics, the incidence of difficult intubation was found to be 3.3%. Another study by Merah *et al*.[5] showed an incidence of 10% in difficult laryngoscopy in a Nigerian parturient. We can describe this variation in incidence of DVL to factors such as different anthropometric features among the population, cricoids pressure application, head position, or degree of muscle relaxation.[33] In parturient patients, because of the gaining weight associated with pregnancy, the visibility of observing the larynx reduces.[34] This fact is supported by our finding of a relation between reduced laryngoscopic view and weight and NC.

Failed tracheal intubation with inability to maintain an open airway and adequate oxygenation is one of the main and most frequent causes of anesthesia-related maternal mortality and morbidity.[4] Thus, studies for predictive test that has accuracy and applicability for prediction difficult intubation continue. Not only RHTMD, but also NC and NC/TMD seem to have these quality factors and they are easy to perform as a bedside test.

Table 4: Predictive value for modified mallampati test, upper lip bite test, ratio of height to thyromental distance, neck circumference, and neck circumference to thyromental distance to predict the occurrence of a grade 3 or 4 intubation according to the modified cormack-lehane classification

Test	True+	False+	True-	False-	Accuracy (%)	Sensitivity (%)	Specificity (%)	Positive predictive value(%)	Negative predictive value(%)	Likelihood ratio (positive test)	Odds ratio/ relative risk	AUC of ROC curve
MMT	6.3	93.6	90.8	9.1	58.3	83.2	27.32	9.1	94.8	1.14	0.670/1.443	0.497
ULBT	8.1	90.6	9.1	7.9	35.1	100	0.33	8.1	100	1	1.01/0.991	0.5
RHTMMD	30.4	69.6	93.6	6.4	89.2	26.42	95.2	32.6	93.6	5.5	6.41/0.210	0.627
NC	28.2	71.7	90.2	4.8	85.8	49.06	89.07	28.3	95.2	4.49	7.8/0.169	0.691
NC/TMD	17.4	96.6	82.5	3.4	70.3	71.7	70.2	17.4	96.6	2.41	5.967/0.196	0.685

MMT: Modified Mallampati test, ULBT: Upper lip bite test, RHTMD: Ratio of height to thyromental distance, NC: Neck circumference, NC/TMD: Neck circumference to thyromental distance, AUC: Area under curve, ROC: Receiver-operating characteristic. Data are number of patients or derived data

Table 5: Comparison of receiver-operating characteristic curves

Item	Difference between areas	*P* value
MMT~NC	0.194	<0.001
MMT~NC/TMD	0.192	0.001
MMT~RHTMD	0.131	0.025
MMT~ULBT	0.003	0.953
NC~NC/TMD	0.002	0.973
NC~RHTMD	0.063	0.256
NC~ULBT	0.191	<0.001
NC/TMD~RHTMD	0.062	0.008
NC/TMD~ULBT	0.189	0.001
RHTMD~ULBT	0.127	0.015

MMT: Modified mallampati test, ULBT: Upper lip bite test, RHTMD: Ratio of height to thyromental distance, NC: Neck circumference, NC/TMD: Neck circumference to thyromental distance

Analysis of our data showed that the AUC of ROC for RHTMD, NC, and NC/TMD were 0.627, 0.691, and 0.689, respectively, whereas the AUC for MMT and ULBT were only 0.497 and 0.500, respectively. The accuracy of NC and NC/TMD for preoperative prediction of difficult laryngoscopy in non-obstetric patients was documented by Gonzalez[14] and Kim *et al*.,[24] studies. In this study, we found that RHTMD, NC, and NC/TMD were the most useful predictors with specificities of 95.2, 89.07, and 70.2 and accuracies of 89.2, 85.8, and 70.3, respectively. The advantage of NC/TMD is its higher sensitivity than the other two tests, thus minimizing false-negative (3.4%) predictions. Because difficult laryngoscopy is infrequent, the incidence of false negative is also small.

Moreover, the likelihood ratio (LR+) for a positive test result may be a useful measure to judge the usefulness of a predictive tool in practice.[33] This measure is the number of times more likely that a patient with a positive test result will present with difficult intubation. The LR+ was 5.5 for RHTMD, 4.49 for NC, and 2.41 for NC/TMD, whereas it was 1.14 and 1 for MMT and ULBT, respectively.

Using the multivariate analysis, we found that NC, RHTMD, and NC/TMD have the highest odds ratio for prediction of difficult laryngoscopy. We found that NC > 39.5, RHTMD > 28.83, and NC/TMD > 5.6 were determining factors in predicting a poor laryngeal view for parturient patients. Our result confirms the Gonzalez[14] and Brodsky[34] study that NC at the level of thyroid cartilage is a valuable predictor of difficult laryngoscopy in obese patients, as shown in the parturient in our study. Gonzalez[14] showed NC > 43 is an important predicting factor for determining difficult intubation in obese patients (males and females); our results showed NC >39.5 to be an indicator of difficult larygoscopy in obstetrics. This difference in our study is because patients BMI that BMI = 46 ± 12 in defined for obese patients with intubation difficulty scale (IDS >5); however, in our study, BMI = 32.2 ± 5.5 was defined for DVL in obstetrics (*P* = 0.017).

RHTMD > 28.83 (sensitivity = 26.42%, specificity = 95.2%) was considered as a predictor for difficult intubation in our study; however, in Honarmand's[20] study it was considered to be >21.24 (sensitivity = 71.4, specificity = 98.1%). This difference can be due to the RHTMD calculation on accurate measurement of patients' TMD and height made by variation in observers.[10]

This study was designed to develop a predictor for difficult intubation that is simple and easy to use at the bedside compared with established indices; we found that NC/TMD >5.6 (sensitivity = 71.7%, specificity = 70.2%) showed a moderate to fair sensitivity, specificity, negative predictive value, and a relatively large AUC on the ROC curve, which revealed that NC/TMD is highly predictive. A study by Kim *et al*.[24] found NC/TMD ≥5 to be a good predictor of difficult intubation; however, their study had some limitations. We included only elective surgical patients while excluding emergency cases in our study. Moreover, our conclusion is not applicable to all subgroups of the general population, such as obeseor tooth less patients.

CONCLUSION

We found that difficult intubation was associated with TMD, increasing NC, RHTMD, and the ratio of NC/TMD. This study supports the use of assessing NC/TMD preoperatively to predict a potentially difficult intubation as an easy and simple test.

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APPENDIX

STATISTICAL TERMS AND DEFINITIONS

- True positive: A difficult laryngoscopy that had been predicted to be difficult (A)
- False positive: An easy laryngoscopy that had been predicted to be difficult (B)
- True negative: An easy laryngoscopy that had been predicted to be easy (D)
- False negative: A difficult laryngoscopy that had been predicted to be easy (C)
- Sensitivity: The percentage of correctly predicted difficult laryngoscopies as a proportion of all laryngoscopies that were truly difficult (A/(A + C))
- Specificity: The percentage of correctly predicted easy laryngoscopies as a proportion of all laryngoscopies that were truly easy (D/(B + D)
- Positive predictive value: The percentage of correctly predicted difficult laryngoscopies as a proportion of all predicted difficult laryngoscopies (A/(A + B))
- Negative predictive value: The percentage of correctly predicted easy laryngoscopies as a proportion of all predicted easy laryngoscopies (D/(C + D))

- Accuracy: The percentage of correctly predicted easy or difficult laryngoscopies as a proportion of all laryngoscopies (A + D)/(A + B + C + D)
- Likelihood ratio of a positive test result (LR+): The number of times more likely that a patient with positive test result will have a difficult airway; it is calculated by sensitivity divided by 1-specificity.'

AUC of an ROC-curve (area under a receiver operating characteristic curve): The probability of the correct classification using the test in a sample pair of two patients (one with an easy airway, one with a difficult airway). In this specialized case the AUC= (sensitivity* (1-specificity)/2) + (sensitivity* specificity) + ((1-sensitivity)* specificity/2)