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Research Article

The importance of neck circumference to thyromental distance ratio (NC/TM) as a predictor of difficult intubation in obstructive sleep apnea (OSA) patients

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KEYWORDS

Neck circumference;
Thyromental;
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Abstract *Background:* The trial to find a bedside examination that is helpful for foreseeing difficult intubation is quite inspiring. It was reported that thyromental distance (TM), body mass index (BMI), neck circumference (NC) and a Mallampati score >3 were the only helpful bedside test predictors. By using magnetic resonance imaging, it was established that more fat was present in areas around the collapsible parts of the pharynx in OSA patients. So distribution of fat may provide a better suggestion of difficult intubation than neck circumference. The current work studied the neck circumference to thyromental distance ratio as a new predictor of difficult intubation in obstructive sleep apnea (OSA) patients and comparing it to the formally standard Mallampati score.

Patients and methods: After approval of the ethical committee in Kasr Al Ainy University hospital and patients consent 50 ASA class 1 and II OSA patients, 18–60 years of both sexes, undergoing surgery under general anesthesia with tracheal intubation were enrolled in the study. It was a single group study. Body mass index, neck circumference (cm), thyromental distance (cm) and the ratio of the NC to TM (NC/TM) and Mallampati classification were recorded. Difficulty of intubation was assessed using the Intubation Difficulty Scale (IDS). Correlation between all variables and IDS, comparison between NC/TM ratio and Mallampati score as reliable tests for predicting difficult intubation and also measuring sensitivity and specificity of both.

Results: Among the 50 patients, 11 patients experienced difficult intubation according to IDS scale. The Mallampati score and NC/TM were the only statistically significant variables that were

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associated with a difficult intubation. NC/TM ratio was strongly correlated to difficult intubation where P value = 0.01 odds ratio 37.5 with cut-off point is NC/TM $\geqslant$5.15, but the correlation of Mallampati score was weaker P value = 0.05 and odds ratio was 14.5. Moreover, NC/TM ratio showed higher sensitivity (100%) and a negative predictive value (82%), than the Mallampati score sensitivity (90%) and specificity (61%).

Conclusion: Difficult intubation in OSA obese patients was independently associated with a Mallampati score of III or IV, and NC/TM $\geqslant$5.15. Moreover, NC/TM yielded a high sensitivity, specificity and a negative predictive value.

1. Introduction

Obstructive sleep apnea (OSA) is a widespread aliment, and it is characterized by repetitive, partial or complete collapse of the upper airway during sleep, disturbing gaseous exchange and sleep. It is the most common form of sleep disordered breathing (SDB) worldwide as publicized in different epidemiological studies. There is increasing evidence that OSA is an independent risk factor for adverse cardio metabolic profiles. [1]. It was proved that there is no direct relationship between OSA and body mass index (BMI) [2]. Previous studies found that in morbidly obese patients there was no relationship between the existence and severity of OSA, body mass index (BMI), or neck circumference (NC) and difficulty of intubation or laryngoscope grade. Only a Mallampati score of 3–4 or male sex predicted difficult intubation [3]. Furthermore, many authors proved that difficult intubation had been significantly associated with OSA [4].

By the use of ultrasound, the amount of pretracheal soft tissue was the only measure that fully distinguished easy laryngoscopies from difficult ones [5]. This may clarify why some obese patients are easy to intubate and ventilate, while others are not.

By using MRI measurements in obese patients with and without OSA syndrome, Horner et al. demonstrated that more fat was present in areas surrounding the collapsible segments of the pharynx in patients with OSA syndrome [6]. So distribution of fat in specific neck areas, especially the anterior neck, may provide a better suggestion of difficult intubation than neck circumference.

Previous studies also suggested that the significance of screening tests for difficult intubation is restricted when a single test is used [7]. Therefore, combinations of individual tests or risk factors may add some incremental diagnostic value in comparison with the value of each test alone. Several studies have combined risk factors, such as the El-Ganzouri or Wilson scores, which are multivariate risk index systems. However, as these scores include multiple risk factors, they are more time consuming to perform [8–10].

Thus, combining two of the most important risk factors may increase the diagnostic value while not raising the burden of test significantly. Among the predictors of difficult intubation, NC and TM distance showed higher sensitivity and a negative predictive value than the Mallampati score or Wilson score [11].

Aim of work: In this study we analyzed the ability of NC/TM ratio to predict difficult intubation in OSA patients. We measured the correlation between difficult intubation determined using the Intubation Difficulty Scale (IDS $\geqslant$5) and the NC/TM ratio and its importance in predicting difficulty comparing it to the previously recognized Mallampati score.

2. Patients and methods

This prospective observational study is a single group study which was carried out in Kasr El Ainy Teaching Hospital. After the approval of the ethical committees, a written informed consent was obtained from the patient. 50 patients were involved in the study according to the:

Inclusion criteria: Age 18–60 years, patients of both sexes are included in the study, obstructive sleep apnea patients, patients undergoing surgery under general anesthesia with tracheal intubation with ASA class I and II.

Exclusion criteria: Age >60 years or <18 years, patients undergoing general anesthesia without tracheal intubation, patients with upper airway pathology such as maxillofacial fractures, upper airway tumors or cervical spine fracture, ASA class III or IV or patient refusal.

Diagnosis: Patients were diagnosed clinically, they give history of snoring or cessation of breathing during sleep, and then referred to ENT clinic, where they were diagnosed as OSA and scheduled for surgery. No one was taking continues positive pressure therapy.

Preoperative assessment: Patients were assessed preoperatively through history taking, clinical examination, and routine investigations. In addition, these specific points are recorded:

1. Body mass index which is the ratio between weight (kg) and the square of height (meter).
2. Neck circumference (cm) at the level of cricoid cartilage.
3. Thyromental distance (cm) which is the distance from thyroid notch to the mentum, it was measured with the neck fully extended.
4. The ratio of the NC to TM (NC/TM) was calculated from these measurements.
5. Modified Mallampati classification without phonation: see Fig. 1.
   Class I: Soft palate, fauces, uvula, and pillars visible.
   Class II: Soft palate, fauces, and uvula visible.
   Class III: Soft palate and the base of uvula visible.
   Class IV: Soft palate not visible.

Intraoperative management: Basic monitoring was applied (ECG, Pulse oximetry, non invasive blood pressure, et CO2 analyzer) An intravenous access was obtained and premedication in the form of Atropine (0.1 mg/kg up to the usual adult dose of 0.4–0.6 mg) IV, preoxygenated with 100% oxygen by

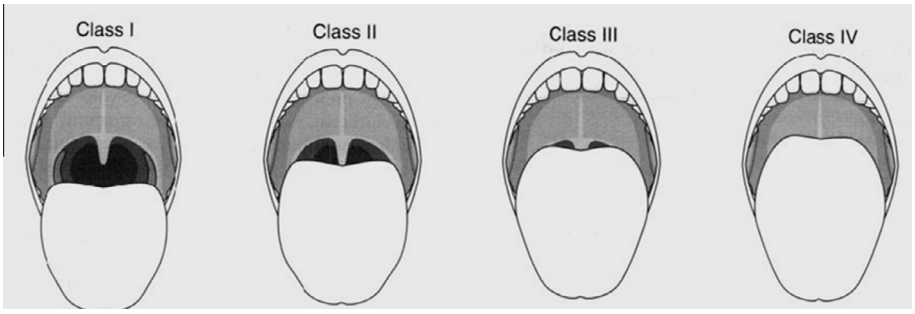

Figure 1 Mallampati grading [12].

face mask for 3 min, followed by intravenous induction using Propofol (2 mg/kg) IV and Fentanyl (2 μg/kg) IV, and neuromuscular blockade achieved with Rocuronium (0.9 mg/kg) IV. Difficulty of intubation was assessed using the Intubation Difficulty Scale (IDS), which was recorded by a senior anesthetist (at least 3 years practicing anesthesia).

The Intubation Difficulty Score (IDS) [12] graded as follows:

N1, number of additional intubation attempts.
N2, number of additional operators.
N3, number of alternative intubation techniques used.
N4, laryngoscopic view as defined by Cormack and Lehane.

Grade 1: N4 = 0.
Grade 2: N4 = 1.
Grade 3: N4 = 2.
Grade 4, N4 = 3.

N5, lifting force applied during laryngoscope.

N5 = 0 if inconsiderable.
N5 = 1 if considerable.

N6, needed to apply external laryngeal pressure for optimized glottic exposure.

N6 = 0 if no external pressure or only the Sellick maneuver was applied.
N6 = 1 if external laryngeal pressure was used.

N7, position of the vocal cords at intubation.

N7 = 0 if abducted or not visible.
N7 = 1 if adducted.

The IDS score is the sum of N1–N7. A score of 0 indicated intubation under ideal conditions. Patients were classified further according to the IDS score. Those with an IDS score of $\geqslant 5$ and < 5 were defined as the difficult intubation and easy intubation groups, respectively.

To optimize the laryngoscopic view, patients were placed in the "ramped" position in the operating room. This was attained by pilling blankets behind the patient's back, resulting in elevation of the head, upper body, and shoulders significantly above the chest as a result, the external auditory meatus was horizontal with the sternal notch, and this was assessed by a trained viewer in each patient. The observer recorded the IDS on first laryngoscopy without external laryngeal manipulation. Additional trials at intubation were counted maximum two attempts. A size 3 or 4 Macintosh laryngoscope blade was used. All tracheal intubations were performed by two anesthetists with more than 3 years of experience.

If SpO2 decreased to 90% during the intubation period, the event was recorded as a hypoxic episode and the patient was ventilated either manually or by laryngeal mask airway to optimize SpO2 around 100%.

The laryngoscopic view was graded according to Cormack and Lehane's scale: see Fig. 2.

Grade 1: the vocal cords were completely visible.
Grade 2: only the arytenoids were visible.
Grade 3: only the epiglottis was visible.
Grade 4, the epiglottis was not visible.

Data to be compared:

1. Correlation between Mallampati score and IDS, if it is statistically significant or not.
2. Correlation between NC/TM ratio and IDS, if it is statistically significant or not.
3. Comparison between NC/TM ratio and Mallampati score as reliable tests for predicting difficult intubation.
4. Measuring sensitivity and specificity of NC/TM ratio and Mallampati score as predictors of difficult intubation.

3. Statistics

Data were analyzed using SPSS software (version 16.0, SPSS Inc., USA). The measured variables are expressed as mean (standard deviation). Differences between both sexes were analyzed using Chi square test. Differences between the difficult intubation and easy intubation groups were analyzed using a binary univariate logistic regression model to determine the significant risk factors for difficult intubation. The different variables compared were the following: age, height, weight, body mass index, Mallampati score, and NC/TM ratio.

In the second step, all the significant variables from a previous step were entered in a binary multivariate logistic regression (forward-Wald) model to determine the independent risk factors for difficult intubation. The only significant variable compared were Mallampati score, NC/TM ratio. The diagnostic performance of the significant risk factors was also assessed using the receiver-operating characteristic (ROC) curves. After identifying the adequate cut-off points by selecting the maximum specificity while sensitivity $\geqslant 80\%$, the continuous variables were transformed into binary variables to compare the accuracy of the tests. P value of 0.05 was considered significant.

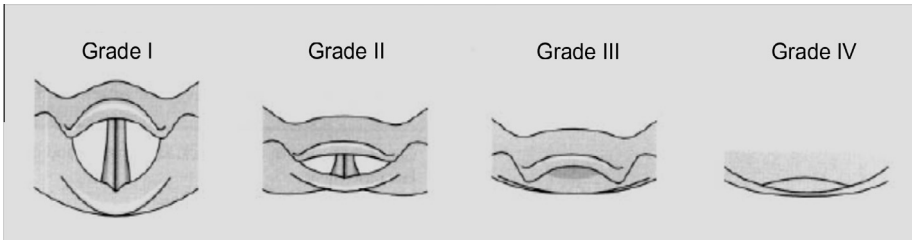

Figure 2 Cormack and Lehane grading of direct laryngoscopy [12].

4. Results

In this research, data from 50 adult obstructive sleep apnea patients scheduled for different elective operation under general anesthesia with tracheal intubation were collected. Their demographic data were shown in Table 1.

Among the 50 patients included in our study 11 patients experienced difficult intubation according to IDS scale. The incidence of difficult intubation among 50 OSA patients was 22%.

Patients were divided into two groups according to IDS: (easy intubation group) with an IDS score of <5 compared with those with an IDS score of $\geqslant 5$ (difficult intubation group) as shown in Table 1. Different variables recorded as age, height, weight, body mass index, Mallampati score and NC/TM ratio were related to an IDS of $\geqslant 5$ (difficult intubation) through binary univariate logistic regression analysis (this test is used to differentiate between significant variables and non significant variables affecting outcome).

Among these variables, the Mallampati score and NC/TM were the only statistically significant variables that were associated with a difficult intubation (expressed as IDS) as shown in Table 2.

From this comparison we found that two variables were considered significant as a predictor for difficult intubation. First variable was NC/TM ratio where P value = 0.01 (P value <0.01 is considered highly significant) and odds ratio was 37.5 (the higher this value the more powerful the statistical correlation).

Mallampati score was also statistically correlated to difficult intubation, but this correlation is weaker than the correlation between NC/TM and difficult intubation because P value = 0.05 and odds ratio was 14.5 (in contrast to NC/TM which showed P value 0.01, odds ratio 37.5).

For more accurate results we performed binary multivariate logistic regression (forward-Wald) analysis in each patient group to determine the independent risk factors for difficult intubation in each group. This test is concerned for detection of the power of risk factor (NC/TM, Mallampati score) to independently influence the outcome (here the outcome was the intubation difficulty) as shown in Table 3.

From this table we can state that NC/TM ratio is of more statistical significance as an independent risk factor for difficult intubation than Mallampati score (P value for NC/TM is 0.004 versus 0.039 for Mallampati score). Figs. 3 and 4 illustrate the ROC curves for NC/TM and Mallampati score.

ROC Curve is a statistical graph to represent the sensitivity and specificity of any test and for what extent the test is diagnostic. NC/TM ratio shows higher AUC = 0.95 versus 0.745 for Mallampati score (the more the area the more diagnostic the test).

The cut-off points for difficult intubation were the Mallampati score of 2 or 3 and NC/TM $\geqslant 5.15$. (Cut-off value is the value where the test becomes most sensitive and most specific).

Table 4 provides information on the accuracy of risk factors. NC/TM showed higher sensitivity (100%) and a negative predictive value (82%), than the Mallampati score sensitivity (90%) and specificity (61%).

5. Discussion

Previous studies have suggested that the value of screening tests for difficult intubation is limited when a single test is used. [7–14] Therefore, combinations of individual tests or risk factors may add some increasing diagnostic importance in comparison with the value of each test alone.

The current work studied the neck circumference to thyromental distance ratio as a new predictor of difficult intubation in OSA patients, that is simple and easy to perform with high specificity and sensitivity compared with well-known indices trying to find an effective bedside test for predicting difficult intubation.

Many studies verified that Obesity, short thick neck, nasal occlusion, enlargement of tonsils hypertrophy, narrow

Table 1 Demographic characteristics of the study group: (mean and standard deviation).

	Total OSA patients $n = 50$	Easy intubation (IDS < 5) $n = 39$	Difficult intubation (IDS $\geqslant 5$) $n = 11$
Age (year)	43.8 (1.03)	43.3 (1.02)	45.8 (1.07)
M/F ratio	29/21	23/16	6/5
Weight (kg)	106 (1.3)	104 (1.36)	113 (9.8)
Height (m)	1.69 (8.3)	1.7 (8.6)	1.68 (7.3)
BMI	37 (5.1)	36.19 (5.1)	39.9 (4.3)
NC/TM	5.1 (0.9)	4.81 (0.6)	6.4 (0.87)
Mallampati 3 or 4 (%)	9 (18%)	4 (10%)	5 (45%)

M/F: male/female.

Table 2 Binary univariate regression analysis of factors related to difficult intubation (IDS ⩾ 5).

Variable	Odds ratio	95.0% C.I of odds ratio		*p* Value
		Lower	Upper	
Age	1.061	0.93	1.21	0.37
Weight	0.696	0.21	2.22	0.54
Height	1.598	0.33	7.59	0.55
Body mass index	2.988	.096	92.6	0.53
NC/TM	37.524	2.27	619.5	0.01**
Mallampati score	14.569	0.94	224.8	0.05*

* Significant correlation as *P* value ⩽0.05 C.I: Confidence interval.
** Highly significant correlation as *P* value ⩽0.01.

Table 3 Binary multivariate logistic regression analysis.

Variable	Odds ratio	95% C.I for odds ratio		*P* value
		Lower	Upper	
NC/TM ratio	26.73	2.87	248.34	0.004**
Mallampati score	10.33	1.01	95.32	0.039*

* Significant correlation as *P* value ⩽0.05 C.I: Confidence interval.
** Highly significant correlation as *P* value ⩽0.01.

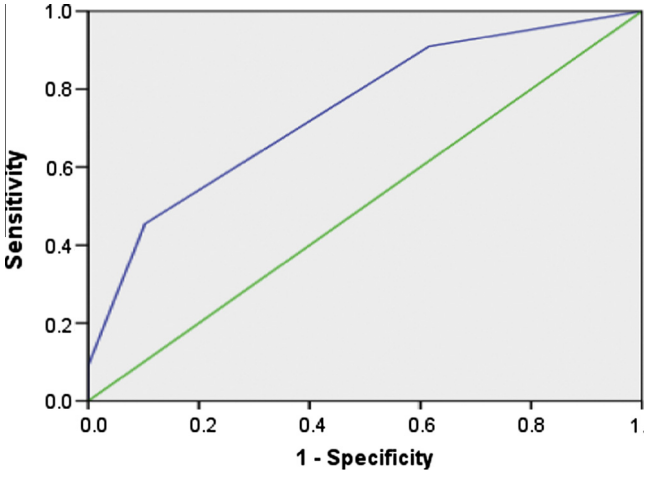

Figure 3 ROC curve for NC/TM ratio. Area under the curve (AUC) = 0.95.

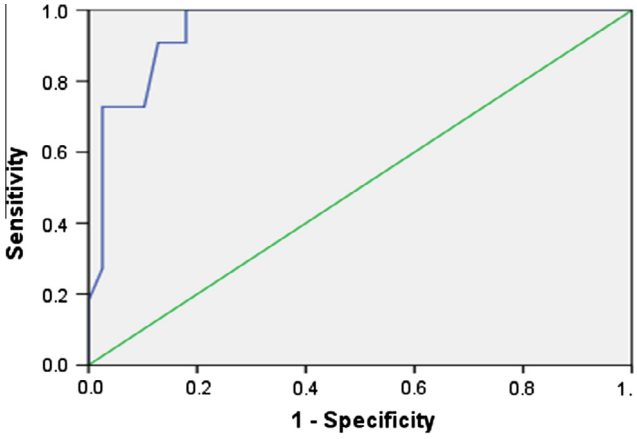

Figure 4 ROC curve for Mallampati score. Area under the curve (AUC) = 0.74.

oropharyngeal space, and retrognathia are distinctive shames of OSA, but these are not the diagnostic criteria of difficult intubation [15]. On the other hand, some patients with OSA reveal no specific predictors on routine examination [16].

However, O'Keeffe t et al. stated that not all OSA patients are obese, and not all morbidly obese patients have OSA. There is no direct relationship between OSA and BMI [2].

Previous studies reported that the NC is an independent risk factor for difficult intubation in obese patients [17,18]. However, the NC alone may not clearly specify the amount of soft tissue at different topographic section within the neck. Also based on using ultrasonography, Ezri and colleagues reported that the amount of pretracheal soft tissue by using ultrasound was the only measure that can differentiate an easy laryngoscopy from a difficult one [5].

Table 4 Cut-off value for NC/TM and Mallampati score.

Cutoff value	Sensitivity (%)	Specificity (%)
NC/TM ratio ⩾5.15	100	82
Mallampati 2 or 3	90	61

In our research, no sedative premedication, as OSA syndrome has sensitivity to central depressant drugs, which may be accompanied by upper airway obstruction or respiratory arrest occurring even with minimal doses.

Perioperative monitoring for apnea, desaturation and dysrhythmia is crucial during anesthetic management of OSA patients. They are at high risk of hypoxemia, and its deleterious consequences of cardiac and cerebral function, in our research, SpO2 values were kept within normal range more than 90%

during induction of anesthesia period in all patients. And no any serious complication developed.

In our OSA patients 22% had difficult intubation and the ratio of the NC/TM was a better method than Mallampati score to predict difficult intubation. Cut-off value for this ratio was 5.15, with higher statistical significance and higher sensitivity and specificity with 0.95 area under the curve on ROC curve which correspond to 100% sensitivity and 82% specificity. In contrast to ROC curve for Mallampati score area under the curve (AUC) = 0.74, corresponds to with sensitivity (90%) and specificity (61%).

That was in same line with the study of Kim et al. who studied this NC/TM ratio in obese patients and compared it to Mallampati score. They found that the ratio of the NC/TM was a better technique than Mallampati score to foretell difficult intubation. Cut-off value for this ratio was 5. With 0.86 area under the curve on ROC curve which correspond to 88.2% sensitivity and 83.0% specificity in relation to ROC curve for Mallampati score area under the curve (AUC) = 0.72 which correspond to 58.8% sensitivity and 88.6% specificity, meaning means that obese patients who have 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 [11]. They verified that NC/TM is a superior indicator than either the NC or TM alone.

In a previous study, other variables using NC, the NC/BMI and NC/sternomental distance(SM) were also assessed. However, multivariate analysis revealed that the NC/BMI and NC/SM did not show a positive connection with difficult intubation [9].

In our results regarding Mallampati score, we found that only 45% of difficult intubation patients (IDS > 5) were Mallampati grade 3 or 4, and these patients were obese (BMI = 39.9(4.3)). That is consistent with the study of Gonzalez et al. who conducted a research on obese patients and concluded that thyromental distance, BMI, large neck perimeter, and higher Mallampati score were the only predictors of potential intubation problems in obese patients [17]. Furthermore Neligan et al. found that there was no connection between the existence and severity of OSA, BMI, or NC and difficulty of intubation or laryngoscopy grade. Only a Mallampati score of 3 or 4 or male sex predicted difficult intubation in obese patients [3]. We could not prove the point of male gender as a risk factor in our study as the number of our study sample is small.

While in non obese, Anna Lee et al. who studied the ability of Mallampati score to predict difficult intubation in non obese patients and concluded that the Mallampati tests have limited accuracy for predicting the difficulty airway and thus are not valuable screening tests [19]. Also, Elganzouri et al. concluded that improved risk stratification for difficulty with intubation can be obtained by use of a simplified preoperative multivariate airway risk index, with better accuracy compared to Mallampati classification at both low- and high-risk levels [10].

In the current work we did not include the relation between the grade of severity of OSA according to AHI and the occurrence of difficulty in intubation. Previously, Hiremath et al. found that difficult intubation and OSA are related significantly and they share anatomical features [4]. Furthermore, Lee et al. investigated the connection of difficult intubation between age, height, weight, BMI and AHI in OSA patients. They determined that a high AHI and large neck circumference can predict difficult intubation [20]. In contrast, Siyam et al. revealed that there was no relationship between the severity of obstructive sleep apnea and the occurrence of difficult intubation [21]. So this could be verified in further studies.

Previously, it was proved by a study done by of Krobbuaban et al. that height/thyromental distance ratio is valuable screening test for difficult laryngyscopy [22], in our study we used NC/TM ratio instead of height/TM ratio as a predictor of difficult intubation and we found that NC/TM index is sensitive and specific test. The similarity in results could be because the denominator (TM) is the same.

From our results, in OSA patients NC/TM proved to be a better indicator for difficult intubation(IDS > 5) and cut-off value for this ratio was 5.15 with high sensitivity and specificity and higher area under the curve on the ROC curve, which correspond to 100% sensitivity and 82% specificity, than the Mallampati score with sensitivity 90% and specificity 61%. Moreover NC/TM ratio is of more statistical significance as an independent risk factor for difficult intubation than Mallampati score.

6. Conclusion

Difficult intubation in OSA obese patients was independently associated with the Mallampati score of 3 or 4, and NC/TM $\geqslant$5.0 produced a high sensitivity, specificity, and a negative predictive value. So, we consider a preoperative value of NC/TM $\geqslant$5.15 to be a good predictor of difficult intubation in OSA obese patients.

7. Limitation of the study

The number of study population (50 patients) is considered relatively small compared to other studies made. We also choose patients according to clinical diagnosis made by ENT clinic and did not apply a formal questionnaire in our inclusion criteria. AHI scores were not graduated. Therefore, correlation with AHI scores and DI was not researched.

8. Recommendation

We recommend that further studies will be needed comparing the importance of NC/TM ratio in obese with OSA versus obese without OSA to confirm our results. Also the grading of severity of OSA in relation to difficult intubation and NC/TM ratio significance could be researched among larger population.

Conflict of interest

We don't have conflict of interest.

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