ORIGINAL ARTICLE

Which test best predicts difficult endotracheal intubation? A prospective cohort study

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ABSTRACT

BACKGROUND: It is critical to identify patients whose intubation will be difficult to ensure that necessary precautions are taken. In this study, we aimed to show the power of almost all tests used to predict difficult endotracheal intubation (DEI), and to determine which test are more accurate for this purpose.

METHODS: This observational study conducted between May 2015 and January 2016 at department of anesthesiology of a tertiary hospital in Turkey (n=501). A total of 25 parameters and 22 tests used for DEI were compared according to groups formed according to the Cormack-Lehane classification (gold standard).

RESULTS: The mean age was 49.83±14.00 years, and 259 (51.70%) patients were males. We found difficult intubation frequency to be 7.58%. Mallampati classification, atlanto-occipital joint movement test (AOJMT), upper lip bite test, mandibulohyoid distance (MHD), maxillopharyngeal angle, height-to-thyromental distance ratio, and mask ventilation test were independently associated with difficult intubation.

CONCLUSION: Despite comparing 22 tests, the results obtained in this study cannot definitively identify any single test that predicts difficult intubation. Nonetheless, our results show that MHD (high sensitivity and negative predictive value) and AOJMT (high specificity and positive predictive value) are the most useful tests to predict difficult intubation.

Keywords: Atlanto-occipital joint movement test; difficult endotracheal intubation; height-to-thyromental distance ratio; mallampati classification; mandibulohyoid distance; mask ventilation test; maxillopharyngeal angle; predictor tests; upper lip bite test.

INTRODUCTION

Tracheal intubation is an integral part of anesthesia practice and airway management is one of the most important responsibilities of an anesthesiologist. In some cases, tracheal intubation is difficult and is still a major cause of morbidity and mortality in anesthesiology.[1] Difficult endotracheal intubation (DEI) frequency was found to be 0.16–20% in various studies.[2,3] Reports also indicate that one major airway complication occurs for every 22,000 general anesthesia procedures with a death frequency of 1/118,372 anesthesia procedures (0.0008%).[4,5] Although DEI rarely occurs, it has been described as the primary cause of 25% of deaths from anesthesia.[6] Therefore, accurately identifying patients likely to experience DEI is crucial for anesthesiologists.

A number of rapid bedside tests have been used to identify patients at risk for DEI, but their sensitivity remains uncertain.[2] It was shown that bedside screening tests for DEI prediction had limited positive and negative predictive power when used alone, and that predictive capabilities increased when tests are used in combination; however, accuracies are still inadequate.[7] In a systematic review evaluating various airway screening tests used for DEI detection, it was shown that the most commonly used tests were the Mallampati classification (MC), measurement of thyro-mental distance

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(TMD), upper lip bite test (ULBT), inter-incisor gap (IIG), and sterno-mental distance (SMD), but demonstrated that these tests had limited discriminative capacity, sensitivity, specificity, and positive likelihood ratios, regardless of whether they were used alone or in combination. It was also noted that most studies are characterized by a high risk of bias and feasibility concerns.[8] In another review, unlike the two studies mentioned, it was reported that some existing tests, especially a high score on ULBT and presence of short hyomental distance (HMD) were able to predict DEI, but their absence did not exclude it.[9]

In relation with conflicting results and the limitations in comparisons between clinical tests used for this purpose, we aimed to apply a battery of tests comprised of almost all tests known to be used for the purpose of predicting DEI (n=22) to determine which test or tests are more accurate in this context, and to identify tests that showed independent relationships with DEI presence.

MATERIALS AND METHODS

Study Design

This was a prospective, observational, and single-center study conducted between May 2015 and January 2016 at the Department of Anesthesiology, Faculty of Medicine, Karadeniz Technical University, Trabzon, Turkey. The study was initiated with the approval of the Ethics Committee of Karadeniz Technical University Faculty of Medicine and written informed consent was obtained from each of the patients included in the study.

Patients and Data Collection

A total of 501 patients who were scheduled for elective surgery with endotracheal intubation for general anesthesia by the Neurosurgery Department were included in the study. All patients included in the study were classified in the 1–3 group A of the American Society of Anesthesiologists Score (ASA), aged between 18 and 85 years, and had undergone preoperative lateral cervical radiography (ordered by neurosurgery for diagnosis or follow-up). Patients aged <18 and >85, those who were unconscious, unoriented and/or uncooperative, subjects in which fast or awake endotracheal intubation was required, patients with a history of difficult airway and tracheostomy, obstetric patients, and individuals without lateral cervical X-ray images were excluded from the study.

First, the demographic features were recorded in the preoperative evaluation, including age, sex, body mass index (BMI), and the relationships between these parameters and DEI were investigated. Second, the following tests and evaluations were performed on all patients before surgery and results were recorded: MC, loss of teeth, septum deviation (SD), inter-incisal distance (open-mouth; inter-incisal distance [IID]), limitation of temporomandibular joint movement (LTMJM), atlanto-occipital joint movement test (AOJMT), head and neck mobility (HNM), ULBT, aphonia, history of obstructive sleep apnea syndrome (OSAS), TMD, SMD, mandibular protrusion test (MPT), Wilson's difficult intubation score (WDIS), HMD ratio (HMDR), height-to-thyromental distance ratio (HTMDR), and mask ventilation test (MVT). In addition, we measured mandibulohyoid distance (MHD), atlanto-occipital interval (AOI), hyoid cervical interval (HCI), mandibular angle (MA), and maxillopharyngeal angle (MPA) from lateral cervical radiographs. All airway tests were performed by the same anesthesiologist and all radiological evaluations were done by the same radiologist.

Difficult intubation and easy intubation patient groups were formed separately for each criterion, and the accuracies of these tests in detecting DEI was statistically evaluated with respect to the predefined gold standard test — the Cormack-Lehane classification (CLC). For this evaluation, direct laryngoscopy was performed by an anesthesiologist with at least 3 years of experience who was blinded to the results of preoperative airway assessment. Glottic visualization was determined according to the CLC as follows:

- Grade 1: Complete visualization of vocal cords.
- Grade 2: Visualization of the inferior portion of the glottis.
- Grade 3: Visualization of only the epiglottis.
- Grade 4: Non-visualized epiglottis.

No external laryngeal manipulation was performed during grading. Patients classified as Grade 3 or Grade 4 according to the CLC were recorded as patients with DEI, while the remaining patients were grouped as having easy intubation.[2,3]

Description of DEI Testing Methods

The tests utilized in this study, relevant criteria are detailed below.

MC: All patients were asked to fully open their mouths and extend their tongues out (forward) as much as possible, while they were sitting and facing the examiner with their heads were in a neutral position, without phonation. The visibility of pharyngeal structures was classified as follows:[2,10]

- Mallampati I: Soft palate, uvula, throat, and anterior posterior pillars are visible.
- Mallampati II: Soft palate, uvula, and throat are visible.
- Mallampati III: Soft palate and root of uvula are visible.
- Mallampati IV: Only the hard palate is visible, the soft palate is not visible.[10]

IID: After the patients were placed in a sitting position, the distance between the lower and upper incisors was measured and recorded using a ruler.[2,3]

LTMJM: The patients were asked to open their mouths fully and IIG was measured. Then, we evaluated the presence or absence of subluxation. Subluxation (mandibular protrusion) was defined according to the maximal forward protrusion of the lower incisors beyond the upper incisors. We applied the following classification using these two values.

- Class 1: IIG >50 mm + no subluxation
- Class 2: IIG <50 mm + no subluxation
- Class 3: IIG <50 mm + subluxation present.[11]

AOJMT: Patients were seated with their head held upright and facing forward. They were asked to move their neck upward as much as possible. The angle of the occlusional surface of the upper teeth with respect to the horizontal line was observed and measured, and the AOJ mobility was classified in four grades:

- Grade 1: Angle >35°
- Grade 2: Angle = 22–34°
- Grade 3: Angle = 12–21°
- Grade 4: Angle <12°.[2,12]

ULBT: Patients were asked to protrude their mandible forward and bite their upper lip with their lower incisors. Results were categorized into three classes:

- Class I: Lower incisors bite the upper lip above the vermilion border, mucosa not being visible.
- Class II: Lower incisors bite the upper lip below the vermilion border, mucosa partially visible.
- Class III: Lower incisors fail to bite the upper lip.[3,13]

HNM: The head and neck range of motion was measured by asking the patients to touch their chin to their chest.[14]

TMD: Patients were asked to lie in the supine position with the head in full extension and the mouth closed. The distance between the thyroid prominence and the anterior end of the mandible was measured with a ruler.[2,3]

SMD: With the head of the patients in full extension and the mouth closed, the distance between the upper border of the manubrium sterni and the most extreme point of the mandible was measured using a ruler.[3,15]

HMDR: First, HMD (the distance between the hyoid bone and the tip of the chin) was measured at extreme extension of the head (HMDe) and in the neutral position (HMDn). The HMDe-to-HMDn ratio provided the HMDR value.[16]

HTMDR: We obtained HTMDR values by dividing the patients' height (in cm) by TMD values (in cm).[13]

MPT: Patients were asked to protrude their mandibles as far as possible, and three categorizations were made according to the following criteria:

- Class A: If the patient was able to move the lower incisors in front of the upper incisors.
- Class B: If lower incisors could be advanced only to the level of upper incisors.
- Class C: If the lower incisors could not be advanced to level of the upper incisors.[3,17]

WDIS: This score was calculated based on 5 different dimensions, each of which was graded from 0 to 2 points.

1) Weight: <90 kg (0 points), 90–110 kg (1 point), >110 kg (2 points).
2) Head and neck movement: >90° (0 points), about 90° (±10°) (1 point), <90 degrees (2 points).
3) Jaw movement: IIG ≥5 cm or mandibular protrusion test Class A (0 points), IIG <5 cm and mandibular protrusion test Class B (1 point), IIG <5 cm, and mandibular protrusion test Class B (2 points).
4) Receding mandible: Normal (0 points), moderate (1 point), and severe (2 points).
5) Buck teeth: Normal (0 points), moderate (1 point), and severe (2 points).[3,16]

Mask ventilation test (MVT): Ability to ventilate by mask was graded according to the classification by Han et al.[18] as follows;

- Grade 0: Ventilation by mask not attempted
- Grade 1: Ventilated by mask
- Grade 2: Ventilated by mask with oral airway or another adjuvant
- Grade 3: Difficult mask ventilation (inadequate, unstable, or requiring two practitioners)
- Grade 4: Unable to ventilate in any manner.

Furthermore, patients' lateral cervical X-rays were taken with the head in the neutral position and the mouth closed. The following five parameters were measured by lateral cervical X-ray.

AOI: Measured from the upper margin of the posterior tubercle of atlas vertically upward to the occiput.[19,20]

MA: Assessed by drawing a horizontal line from the intersection of two tangents of the posterior ramus and lower border of the mandible, across to the cervical spine.[19,21]

MHD: Measured from the upper margin of the hyoid bone vertically upward to the lower margin of the mandible in lateral cervical X-rays.[19]

HCI: Was measured linear distance from hyoid bone to point antero-inferior of the third cervical vertebra.[22,23]

MPA: First, the maxillary axis (MA; the line parallel to the hard palate) was determined. Then the pharyngeal axis (PA;

the line passing through the anterior sections of the first and second cervical vertebra) was drawn. The angle between the MA and PA was defined as the MPA.[14]

Statistical Analysis

All statistical analyses were performed with respect to a significance level of 5% alpha error (p<0.05) through the SPSS version 25.0 software (SPSS Inc., IL, USA). Normality of distribution was assessed with Q-Q and histogram plots in continuous variables which were depicted with "mean±standard deviation" or "median (1st quartile - 3rd quartile)" values, as deemed necessary by (non) normality of distribution. Frequency (absolute and percentage) was described for categorical variables. In normally-distributed variables, we utilized the independent samples t-test; whereas the Mann–Whitney U-test was used for non-normally distributed variables. Appropriate Chi-square tests or the Fisher's Exact test were used to compare the distribution of categorical variables between groups. Prediction performances were assessed by use of receiver operating characteristic (ROC) curve analysis. Multiple logistic regression analysis (forward conditional) was performed to determine the factors that were independently associated with DEI.

RESULTS

The mean age of 501 patients included in our study was 49.83±14.00 (min–max: 18–84) years, and 259 (51.70%) patients were male. While 463 patients could be easily intubated (CLC Grade 1 and 2), 38 patients had DEI (CLC Grade 3 and 4), revealing a difficult intubation rate of 7.58%. Patients with difficult and easy intubation according to CLC are shown in Table 1. Comparison of the CLC classification groups are given in Table 2.

There were no significant differences between the two groups in terms of age (p=0.662), presence or absence of teeth (p=0.185), SD (p=0.208), IID (p=0.081), presence or absence of aphonia (p=0.069), OSAS history (p=0.069), AOI (p=0.148), MA (p=0.158). However, sex (male > female, p=0.048), BMI (p<0.001), MC (p<0.001), LTMJM (p=0.011), AOJMT (p<0.001), HNM (p=0.011), ULBT (p<0.001), TMD (p<0.001), SMD (p<0.001), MPT (p<0.001), WDIS (p<0.001), MHD (p<0.001), HCI (p=0.008), MPA (p<0.001), HMDR (p<0.001), HTMDR (p<0.001), and MVT (p<0.001) were significantly associated with CLC classification. That is, the values for these parameters or their frequencies showed significant differences in the easy and difficult intubation groups (Table 2).

Table 1. Summary of Cormack-Lehane classification

	n	%
Grade 1	292	58.28
Grade 2	171	34.13
Grade 3	25	4.99
Grade 4	13	2.59

Data are given as frequency (percentage).

According to ROC analyses, tests with the highest specificity values were the AOJMT (99.57%) and MPT (99.57%), followed by LTMJM, HNM, aphonia and OSAS history, all of which had a value of 99.14%. The AOJMV was also the test with the highest positive predictive value (PPV) (80.00%) and one of the highest overall accuracy values (93.61%). Other tests with the highest accuracy were found to be the WDIS (93.81%), MVT (93.41%), and MPT (93.21%). The tests with the highest sensitivity were found to be the AOI, MA, and MHD tests with a value of 70.27%. The tests with the highest negative predictive value (NPV) were: HTMDR (95.64%), WDIS (95.57%), ULBT (95.16%), and MC (95.12%). We also calculated the area under curve (AUC) of ROC analyses and 95% confidence intervals (95% CI), and the highest AUC was found for WDIS (cut-off: 1 point), with a value of 0.810 (Table 3).

We performed multiple logistic regression analysis to determine the best predictive factors associated with difficult intubation. MC (Class 3 and 4), AOJMT (Grade 3 and 4), ULBT (Class 2 and 3), MHD (>20), MPA (<105), HTMDR (>23.5), and MVT (hard) were found to be significant factors associated with difficult intubation. Other variables included in the model, age (p=0.092), sex (p=0.655), BMI (p=0.225), TMD (p=0.093), SMD (p=0.399), WDIS (p=0.244), HCI (p=0.464), and HMDR (p=0.898) were non-significant (Table 4). The ROC curves of the variables in the multiple logistic regression model are shown in Figure 1.

DISCUSSION

According to the results of the present study, the most sensitive tests in detecting DEI were MC, AOJMT, ULBT, MHD, MPA, HTMDR, and MVT; however, of note, the highest sensitivity value was 70.27%. Of note, we did not find a significant relationship between DEI and age, gender and BMI.

An ideal bedside test that can be used to predict difficult intubation should be easy to perform, have high sensitivity, specificity, and accuracy, as well as minimal interobserver variation. The most important of these values can be accepted to be sensitivity (i.e., the ability to accurately predict true positives). This enables the anesthesiologist to ensure the security of the airway and avoid unexpected serious airway consequences.

In our study, MC was shown to be an important predictive test for DEI, consistent with previous studies. It was found that patients with MC class 3 and class 4 were significantly more likely to have DEI. In a comprehensive meta-analysis, in

Table 2. Summary of patient characteristics and intubation assessment results with regard to intubation groups according to the Cormack-Lehane classification

	Intubation			p
	Total (n=501)	**Easy (n=463)**	**Difficult (n=38)**	
Age	49.83±14.00	49.75±14.14	50.79±12.33	0.662
Sex, n (%)				
Male	259 (51.70)	233 (50.32)	26 (68.42)	0.048
Female	242 (48.30)	230 (49.68)	12 (31.58)	
Body mass index	26 (26–27)	26 (25.5–27)	27.25 (26–29)	<0.001
Mallampati classification, n (%)				
Class 1	272 (54.29)	260 (56.16)	12 (31.58)	<0.001
Class 2	199 (39.72)	188 (40.60)	11 (28.95)	
Class 3	26 (5.19)	12 (2.59)	14 (36.84)	
Class 4	4 (0.80)	3 (0.65)	1 (2.63)	
Loss of teeth, n (%)				
Absent	443 (88.42)	412 (88.98)	31 (81.58)	0.185
Present	58 (11.58)	51 (11.02)	7 (18.42)	
Septum deviation, n (%)				
Absent	480 (95.81)	445 (96.11)	35 (92.11)	0.208
Present	21 (4.19)	18 (3.89)	3 (7.89)	
Inter-incisal distance	5 (5–5.5)	5 (5–5.5)	5 (5–5.5)	0.081
Limitation of TMJ movement, n (%)				
Absent	494 (98.60)	459 (99.14)	35 (92.11)	0.011
Present	7 (1.40%)	4 (0.86)	3 (7.89)	
AOJ movement test, n (%)				
Grade 1	480 (95.81)	451 (97.41)	29 (76.32)	<0.001
Grade 2	11 (2.20)	10 (2.16)	1 (2.63)	
Grade 3	8 (1.60)	2 (0.43)	6 (15.79)	
Grade 4	2 (0.40)	0 (0.00)	2 (5.26)	
Head-neck mobility, n (%)				
Normal	494 (98.60)	459 (99.14)	35 (92.11)	0.011
Limited	7 (1.40)	4 (0.86)	3 (7.89)	
Upper lip bite test, n (%)				
Class I	475 (94.81)	452 (97.62)	23 (60.53)	<0.001
Class II	17 (3.39)	9 (1.94)	8 (21.05)	
Class III	9 (1.80)	2 (0.43)	7 (18.42)	
Aphonia, n (%)				
Absent	495 (98.80)	459 (99.14)	36 (94.74)	0.069
Present	6 (1.20)	4 (0.86)	2 (5.26)	
OSAS history, n (%)				
Absent	495 (98.80)	459 (99.14)	36 (94.74)	0.069
Present	6 (1.20)	4 (0.86)	2 (5.26)	
Thyromental distance	8 (7.5–8)	8 (7.5–8)	7.4 (6.5–8)	<0.001
Sternomental distance	13.5 (13–14)	13.5 (13–14)	13 (12–13.5)	<0.001
Mandibular protrusion test, n (%)				
Class A	493 (98.40)	461 (99.57)	32 (84.21)	<0.001
Class B	6 (1.20)	2 (0.43)	4 (10.53)	
Class C	2 (0.40)	0 (0.00)	2 (5.26)	

Table 2. Summary of patient characteristics and intubation assessment results with regard to intubation groups according to the Cormack-Lehane classification *(continue)*

	Intubation			p
	Total (n=501)	Easy (n=463)	Difficult (n=38)	
Wilson's difficult intubation score, n (%)				
0	433 (86.43)	421 (90.93)	12 (31.58)	<0.001
1	41 (8.18)	32 (6.91)	9 (23.68)	
2	17 (3.39)	7 (1.51)	10 (26.32)	
3	8 (1.60)	3 (0.65)	5 (13.16)	
4	2 (0.40)	0 (0.00)	2 (5.26)	
Atlanto-occipital interval	6.63±3.17	6.69±3.20	5.91±2.80	0.148
Mandibular angle	121.49±7.54	121.63±7.44	119.81±8.60	0.158
Mandibulohyoid distance	17 (12–22)	16 (12–22)	24 (19–30)	<0.001
Hyoid cervical interval	44.80±6.85	44.56±6.81	47.68±6.72	0.008
Maxillopharyngeal angle	102.81±9.80	102.35±9.59	108.50±10.65	<0.001
Hyomental distance ratio	1.3 (1.3–1.3)	1.3 (1.3–1.3)	1.25 (1.2–1.3)	<0.001
Height-to-thyromental distance ratio	22 (21–22)	22 (21–22)	23.05 (22–25)	<0.001
Mask ventilation test, n (%)				
Easy	486 (97.01)	458 (98.92)	28 (73.68)	<0.001
Hard	15 (2.99)	5 (1.08)	10 (26.32)	

Data are given as mean±standard deviation or median (1st quartile - 3rd quartile) for continuous variables according to normality of distribution and as frequency (percentage) for categorical variables. TMJ: Temporomandibular joint; AOJ: Atlanto-occipital joint; OSAS: Obstructive sleep apnea syndrome.

Table 3. Performance of the variables to predict difficult intubation

	Cut-off	Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV (%)	NPV (%)	AUC (95.0% CI)	p
Mallampati classification	Class 3 & 4	39.47	96.76	92.42	50.00	95.12	0.697 (0.595–0.800)	<0.001
Loss of teeth	Present	18.42	88.98	83.63	12.07	93.00	0.537 (0.438–0.636)	0.448
Septum deviation	Present	7.89	96.11	89.42	14.29	92.71	0.520 (0.422–0.618)	0.681
Inter-incisal distance	≤4.5	18.42	96.33	90.42	29.17	93.50	0.578 (0.484–0.672)	0.109
Limitation of TMJ movement	Present	7.89	99.14	92.22	42.86	92.91	0.535 (0.435–0.636)	0.471
AOJ movement test	Grade 3 & 4	21.05	99.57	93.61	80.00	93.89	0.608 (0.502–0.714)	0.027
Head-neck mobility	Limited	7.89	99.14	92.22	42.86	92.91	0.535 (0.435–0.636)	0.471
Upper lip bite test	Class 2 & 3	39.47	97.62	93.21	57.69	95.16	0.687 (0.581–0.793)	<0.001
Aphonia	Present	5.26	99.14	92.02	33.33	92.73	0.522 (0.423–0.621)	0.652
OSAS history	Present	5.26	99.14	92.02	33.33	92.73	0.522 (0.423–0.621)	0.652
Thyromental distance	≤6.5	26.32	97.84	92.42	50.00	94.18	0.739 (0.653–0.825)	<0.001
Sternomental distance	≤12.5	31.58	94.38	89.62	31.58	94.38	0.699 (0.608–0.789)	<0.001
Mandibular protrusion test	Class B & C	15.79	99.57	93.21	75.00	93.51	0.577 (0.472–0.681)	0.115
Wilson's difficult intubation score	>1	44.74	97.84	93.81	62.96	95.57	0.810 (0.719–0.902)	<0.001
Atlanto-occipital interval	≤6.5	70.27	51.35	52.80	10.70	95.42	0.578 (0.490–0.665)	0.117
Mandibular angle	≤120	70.27	53.79	55.05	11.16	95.63	0.564 (0.468–0.661)	0.193
Mandibulohyoid distance	>20	70.27	71.05	70.99	16.67	96.67	0.762 (0.692–0.831)	<0.001
Hyoid cervical interval	>45	59.46	61.25	61.11	11.22	94.83	0.628 (0.540–0.716)	0.010
Maxillopharyngeal angle	<105	63.89	65.09	65.00	12.92	95.70	0.662 (0.568–0.756)	0.001
Hyomental distance ratio	≤1.2	26.32	96.75	91.38	40.00	94.09	0.710 (0.612–0.808)	<0.001
Height-to-thyromental distance ratio	>23.5	47.37	94.82	91.22	42.86	95.64	0.780 (0.695–0.865)	<0.001
Mask ventilation test	Hard	26.32	98.92	93.41	66.67	94.24	0.626 (0.519–0.733)	0.010

PPV: Positive predictive value; NPV: Negative predictive value; AUC: Area under ROC curve; CI: Confidence intervals.

Table 4. Significant predictive factors associated with difficult intubation, multiple logistic regression analysis

	β coefficient	Standard Error	p	Exp(β)	95.0% CI for Exp(β)	
Mallampati classification, Class 3 & 4	2.118	0.691	0.002	8.313	2.147	32.186
AOJ movement test, Grade 3 & 4	2.742	1.088	0.012	15.511	1.840	130.768
Upper lip bite test, Class 2 & 3	1.318	0.671	0.049	3.737	1.003	13.920
Mandibulohyoid distance, >20	1.279	0.503	0.011	3.593	1.341	9.623
Maxillopharyngeal angle, >105	1.146	0.502	0.022	3.144	1.176	8.408
Height-to-thyromental distance ratio, >23.5	1.677	0.549	0.002	5.347	1.823	15.688
Mask ventilation test, Hard	2.154	0.806	0.008	8.615	1.776	41.793
Constant	-4.818	0.509	<0.001	0.008		

Dependent variable: Hard intubation; Nagelkerke R^2=0.515; Correct prediction=95.42%. CI: Confidence interval.

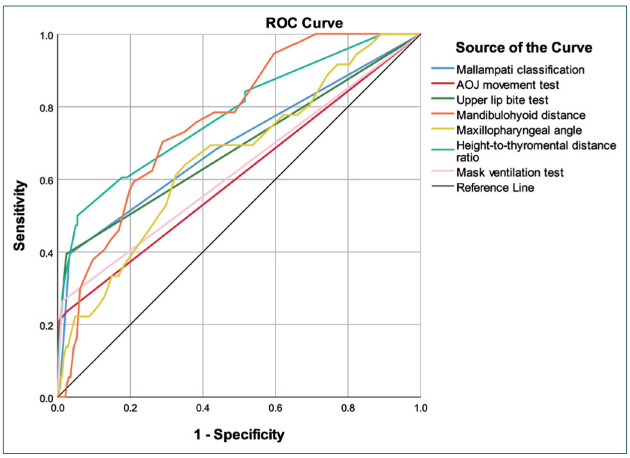

Figure 1. Receiver operating characteristic curve of the variables in the multiple logistic regression model.

which the predictive power of MC was investigated, attention was drawn to the importance of MC in predicting DEI among many other parameters.[7] Basunia et al.[12] reported that MC had the highest PPV, specificity (93.4%), and NPV (94.1%) when used alone. However, in this study, sensitivity (62%) of MC was found to be lower than several other methods, a finding similar to a study by Lundstrøm et al.[24] In our study, the specificity, accuracy and NPV of MC in predicting difficult intubation were found to be high, while its sensitivity and PPV were found to be low. In our study, tests were performed by the same practitioner, thus avoiding inter-observer variability. Similar results demonstrating the importance of the MC have been confirmed by other studies.[3,9]

In a few studies, a significant relationship was found between limited AOJ movement (determined by the Delikan test) which is one of the tests measuring the mobility of the AOJ, and has been associated with difficult intubation. Saraf et al.[25] and Basunia et al.[12] demonstrated that intubation is more difficult in patients with reduced AOJ movement. Saraf et al.[25] found the sensitivity of the Delikan test to be 31.17%, specificity to be 96.88%, PPV to be 85.71%, and NPV to be 70.05%. Notably, overall accuracy was 72.19%. The AOJMT was determined to be the test with the highest specificity, accuracy, and PPV compared to the other tests in our study, but it was also one of the tests with the lowest sensitivity.

There are many studies investigating the power of ULBT to predict difficult intubation, and most of them have argued that ULBT can be an important bedside test for pre-assessment of DEI.[9,13,26] For example, Shobha et al.[13] showed that ULBT had the highest sensitivity and specificity (96.64% and 82.35%, respectively) in this regard, and higher PPV and NPV when compared to other tests. Likewise, Mehta et al.[27] found that ULBT had high sensitivity, specificity, PPV, NPV, accuracy, and AUC values when used alone or in combination with other tests. In our study, we found that the specificity, accuracy, and NPV of the ULBT test was high, while the sensitivity value and PPV were low. Considering our findings and prior results, we also believe that ULBT is a useful test that can predict DEI.

Some parameters measured in lateral cervical X-ray are also frequently used in the estimation of DEI. Several studies showed a significant relationship between MHD,[19,28,29] MPA,[14,30,31] and DEI. We found MHD to be the test with the highest sensitivity and NPV in estimating DEI. However, MHD's specificity, accuracy, and PPV were lower than many other tests. We determined MPA as the second test with the highest sensitivity and NPV. However, we found the specificity and PPV to be relatively low compared to other tests.

According to Badheka et al.[26] and Prakash et al.,[3] the power of HTMDR test in predicting DEI is higher than TMD alone. In the study by Badheka et al.,[26] HTMDR was reported as the test with the second highest sensitivity, specificity, PPV, and NPV values, and it was emphasized that HTMDR could be an alternative method to assess DEI presence. We found similar results in our study. Although we did not find HTMDR to be the test with the highest predictive power, we found it to be among the tests with high specificity, accuracy, NPV, and AUC. In fact, HTMDR had the second highest AUC value (95%) among the tests evaluated. We also found that HTMDR is a stronger predictor than TMD when used alone.

Difficult ventilation is estimated to be seen in 5% of the general population. Oliver Langeron et al.[32] reported a statistically significant relationship between DEI and difficult ventilation. El-Orbany et al.[33] emphasized that the risk of DEI is higher in patients who had difficult mask ventilation, and therefore, clinicians should be prepared for DEI when faced with a patient that demonstrates difficult (or impossible) mask ventilation. The results of our study also support this hypothesis. In this study, MVT was the test with the second highest specificity and PPV; additionally, it had accuracy, NPV and AUC values that were higher than many other tests.

There are some limitations of our study. First, the low number of patients identified to have DEI in some tests may have caused misleading results. Second, in applications to predict DEI, the degree of difficulty would be more appropriate to use combined factors rather than using a single factor. In our study, we evaluated the tests one by one. The best test to predict DEI is likely to be a combination of several tests, or a new and novel method that is yet to be identified. Also, OSAS diagnosis in the patients was questioned by history and testing for OSAS confirmation was not performed; thus, recall bias or lack of pertaining knowledge may have influenced results in this respect. Furthermore, although the number of patients included in this study was respectable, the rarity of DEI might necessitate the enrollment of larger groups to ensure that each of the tests utilized can obtain sufficient data (regarding DEI diagnosis) suitable for comparison purposes.

Conclusion

The results, we obtained in this study consisting of the evaluation of 25 parameters, are not sufficient to definitively identify which test predicts difficult intubation the best. However, the comparative results and demonstration of comparisons are critical aspects of the study which can be guiding for future studies aiming to identify novel methods for DEI diagnosis. We found MC Class 3 and 4, AOJMT Grade 3 and 4, ULBT Class 2 and 3, MHD (>20), MPA (<105), HTMDR (>23.5), hard MVT were independently associated with difficult intubation determined via the gold standard CLC results. Among these, we think that the MHD (due to highest sensitivity and NPV) and the AOJMT (due to highest specificity and PPV) are the most useful tests that can be used to predict difficult intubation. In fact, combining these tests could be valuable to increase overall accuracy, but it should be kept in mind that greater sensitivity is a highly desired attribute due to the possible severity of outcomes associated with DEI.

Ethics Committee Approval: This study was approved by the Karadeniz Technical University Faculty of Medicine Clinical Research Ethics Committee (Date: 07.09.2015, Decision No: 7).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Zor endotrakeal entübasyonu hangi test en iyi tahmin eder? İleriye yönelik bir kohort çalışması

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AMAÇ: Entübasyonu zor olacak hastaların belirlenmesi, gerekli önlemlerin alındığından emin olmak çok önemlidir. Bu çalışmada, zor endotrakeal entübasyonu (DEI) öngörmede kullanılan hemen hemen tüm testlerin gücünü göstermeyi ve bu amaçla hangi testlerin daha doğru olduğunu belirlemeyi amaçladık.
GEREÇ VE YÖNTEM: Bu gözlemsel çalışma, Mayıs 2015 ile Ocak 2016 tarihleri arasında Türkiye'de üçüncü basamak bir hastanenin anesteziyoloji bölümünde yapıldı (n=501). DEI için kullanılan toplam 25 parametre ve 22 test Cormack-Lehane sınıflamasına (altın standart) göre oluşturulan gruplara göre karşılaştırıldı.
BULGULAR: Ortalama yaş 49.83±14.00 yıldı ve 259 (%51.70) hasta erkekti. DEI sıklığını %7.58 olarak bulduk. Mallampati sınıflaması, atlanto-oksipital eklem hareket testi (AOJMT), üst dudak ısırma testi, mandibulohyoid mesafe (MHD), maksillofaringeal açı, tiromental mesafe yükseklik oranı testi ve maske ventilasyon testi bağımsız olarak zor entübasyon ile ilişkiliydi.
TARTIŞMA: Bu çalışmada 22 testin karşılaştırılmasına rağmen, elde edilen sonuçlar zor entübasyonu öngören tek bir testi kesin olarak tanımlayamamaktadır. Bununla birlikte, sonuçlarımız MHD (yüksek duyarlılık ve negatif prediktif değer) ve AOJMT'nin (yüksek özgüllük ve pozitif prediktif değer) zor entübasyonu öngörmede en faydalı testler olduğunu göstermektedir.
Anahtar sözcükler: Atlanto-oksipital eklem hareketi testi; maksillofaringeal açı; mallampati sınıflandırması; mandibulohyoid mesafe; tahmin edici testler; tiromental mesafe yükseklik oranı testi; üst dudak ısırma testi, zor endotrakeal entübasyon.

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