BARIATRIC SURGICAL PRACTICE AND PATIENT CARE
Volume 19, Number 3, 2024
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DOI: 10.1089/bari.2024.0006

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Ultrasonographic Evaluation of Difficult Airway in Obese Patients: A Prospective Study

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Background: The management of the airway is difficult in obese patients owing to their anatomical and physiological attributes. This study aims to assess the ultrasonographic measurements of anterior neck soft tissue thickness in diagnosing difficult mask ventilation (DMV) and difficult laryngoscopy (DL) among obese patients.
Methods: Patients of age 18–65 years and body–mass index (BMI) >30 scheduled to undergo general anesthesia for elective surgery were included in the study. Ultrasonography-guided measurements of soft tissue distances were performed in the preoperative evaluation room. The distance between the hyoid bone and skin, distance between vocal chord anterior commissure and skin, distance between the trachea and the skin at the level of the suprasternal notch, distance between the thyroid isthmus and skin, and distance between epiglottis and skin were measured. The degree of DMV and DL was quantified.
Results: A total of 128 patients (30 men and 98 women) were enrolled. The average patient age, BMI, and neck circumference were recorded as 50.4 ± 12.2 years, 38.0 ± 5.19 kg/m^2, and 41.3 ± 4.05 cm, respectively. The incidence of DMV and DL was 11.7% and 10.9%, respectively. DMV exhibited a significant correlation with neck circumference ($p = 0.02$), whereas difficult airways did not demonstrate any association with anterior neck soft tissue ultrasonography measurements.
Conclusion: Anterior neck soft tissue measurements may not be predictive of DL and DMV in obese patients. Further studies might be helpful in developing new predictors for difficult airway in obese patients.

Keywords: ultrasonography, airway management, difficult mask ventilation, difficult laryngoscopy

Introduction

Obesity is characterized by an abnormal and excessive accumulation of adipose tissue within the body and can lead to increased perioperative mortality and morbidity because of comorbidities, including alterations in cardiopulmonary physiology, obstructive sleep apnea, and coronary artery disease.[1,2] The World Health Organization defines obesity as a body–mass index (BMI) of ≥30 kg/m^2. In the United States, the prevalence of obesity among adults in 2015–2016 was 39.8%.[2–4] With the increasing incidence of obesity, the number of emergency and elective surgical procedures involving this patient population has also continued to increase.

Unexpectedly, difficult airways require elective surgery or present with life-threatening conditions in critical situations.[5] Difficult mask ventilation (DMV) is a major indicator of difficult airways, and DMV may be associated with increased mortality and morbidity resulting from hypoxia associated with inadequate ventilation.[6] Excessive adipose tissue on the neck and face has a negative effect on airway accessibility, and fat accumulation on the pharyngeal wall anatomically contributes to airway obstruction.[7–9] The functional residual capacity has been shown to decrease exponentially with an increasing BMI ratio.[4,10] These patients may show rapid and deep apnea–induced desaturation despite receiving adequate preoxygenation; therefore, optimal preoperative airway management is important in this population.[11,12] Although predictive tests are recommended for difficult airways, these tests show low sensitivity and high variability.[5]

Ultrasonography (USG) has been increasingly used to predict difficult laryngoscopy (DL), and to date, several studies have been published to find an effective ultrasonography indicator.[5] However, research regarding DMV in conjunction with DL in

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obese patients is extremely limited. The role of USG in measurement of anterior neck soft tissue remains debatable.[7,8]

The primary objective of this study is to evaluate the effectiveness of USG measurements of anterior neck soft tissue thickness in the diagnosis of DMV, and second, evaluate DL in obese patients undergoing elective tracheal intubation for general anesthesia.

Methods

This was a prospective, single-blind, observational study. Ethical approval for this study (Decision no: 2020/08) was obtained from the Ethics Committee for Non-Interventional Clinical Research at Eskisehir Osmangazi University. The study protocol was registered in an international database (ClinicalTrials.gov; Registration no.: NCT04289597). Prior to the procedures and data collection, both oral and written informed consent were obtained from all participating patients. This study was conducted between February 2020 and March 2022 at the Eskisehir Osmangazi University of Medicine Hospital in accordance with the principles of the 2013 Declaration of Helsinki. Patients of age 18–65 years, with an American Society of Anesthesiologists physical status classification (ASA) of II–III, and a BMI >30, who were scheduled for elective surgery under general anesthesia, were enrolled in the study.

The preoperative evaluation included assessment of patients' demographic data, airway physical examination results (mouth opening, Mallampati score, thyromental distance, neck circumference from the thyroid cartilage level, and restriction of neck movement), presence of sleep apnea, and STOP-Bang score. Exclusion criteria involved patients with a neck mass, a history of prior neck and thyroid surgery, trauma, arthritis, tooth loss, a documented history of difficult intubation, as well as individuals with beards and pregnant women.

The ultrasonography-guided measurements of soft tissue distances were performed using the Philips Affiniti 50 ultrasonography linear probe (Philips Medical Systems, Seattle, WA, USA) while the patient was in a supine position on the operating table. The distance between the hyoid bone and skin (DSHB), distance between the vocal cord anterior commissure and skin (DSAC), minimum distance between the trachea and the skin at the level of the suprasternal notch (DST), distance between the thyroid isthmus and skin (DSI), and distance between the epiglottis and skin (DSE) were measured and recorded (Fig. 1). After standard monitoring (electrocardiogram, pulse oximetry, and noninvasive blood pressure measurements), intravenous vascular access was established, and aspiration prophylaxis was performed with metoclopramide and ranitidine. Using a face mask, 100% oxygen was administered until the end-tidal oxygen saturation reached 80%. For anesthesia induction, 2–2.5 mg/kg propofol, 0.6 mg/kg rocuronium, and 0.1–0.3 μg/kg remifentanil were administered. Measurements of lean body weight were used to calculate the doses of propofol, remifentanil, and rocuronium. Mask ventilation was performed using disposable plastic masks. DMV was graded using the Han scale as follows: 1, can be ventilated with a mask; 2, can be ventilated with an airway (with or without muscle relaxation); 3, DMV (insufficient, unstable ventilation necessitating the involvement of two practitioners); and 4, cannot be ventilated by a mask. Grades 3–4 were considered to indicate DMV. In cases where patients were unable to be ventilated using a mask, emergency

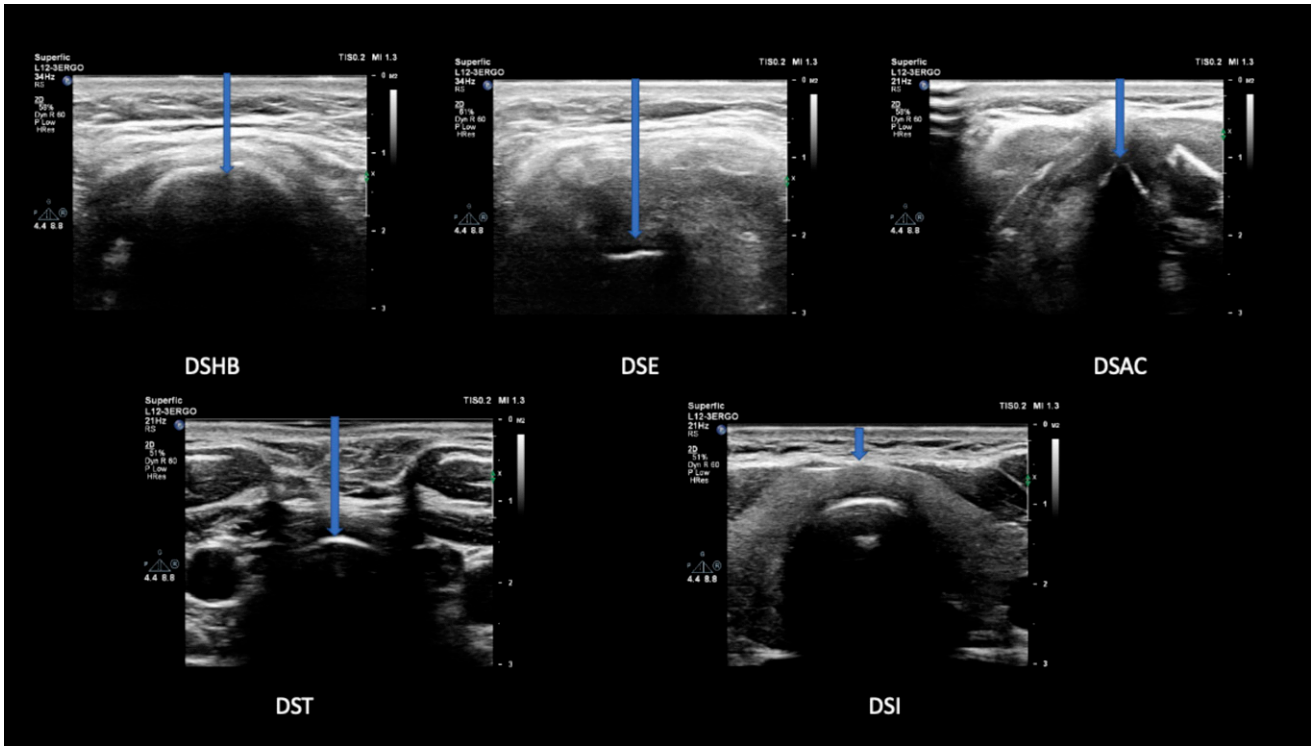


FIG. 1. Ultrasonography distances. DSHB, distance between the hyoid bone and skin; DSAC, distance between the vocal cord anterior commissure and skin; DST, minimum distance between the trachea and the skin at the level of the suprasternal notch; DSI, distance between the thyroid isthmus and skin; DSE, distance between the epiglottis and skin.

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laryngoscopy was scheduled. For patients classified as grades 1, 2, and 3, laryngoscopy was performed following a waiting period corresponding to the duration of action of the administered muscle relaxant. DL was graded using the Cormack–Lehane scale as follows: grade 1: vocal cords visible; grade 2: posterior commissure and epiglottis visible; grade 3: only epiglottis is visible; and grade 4: glottic structures are not visible. Grades 3–4 were considered to indicate DL. Tracheal intubation and mask ventilation were performed with a Macintosh blade by another anesthesiologist who had at least 2 years of experience and was blinded to the ultrasonography measurements.

Patients with Cormack–Lehane scale grades 3–4 underwent direct laryngoscopy with the backward, upward, rightward, pressure (BURP) maneuver, and if the maneuver was unsuccessful, intubation was performed with videolaryngoscopy (Storz's C-Mac 8403 ZX D-blade; Karl Storz, Germany). Patients who could not be ventilated or intubated were scheduled to undergo awake fiberoptic intubation or invasive alternative techniques. The duration of intubation (the time from the first handling of the laryngoscope until the appearance of the capnography trace) and number of intubation attempts were recorded.

Sample size and statistics

Based on the primary endpoint (DMV) and assuming an effect size level of 0.25 (small reference value determined by Cohen's d), 128 patients were included in the study, with a type I error level of 0.05 and a power level of 80%.

Continuous data were presented as mean ± standard deviation. Categorical data were presented as percentages (%). The Shapiro–Wilk test was used to investigate the conformity of data to a normal distribution. In comparisons of two groups, normally distributed groups were compared using an independent-sample *t*-test, whereas the Mann–Whitney *U* test was used for comparisons of groups showing a nonnormal distribution. Pearson's chi-square and Pearson's exact chi-square analyses were used in the analysis of the created cross tables. Backward Wald stepwise logistic regression analysis was used to determine the risk factors. Receiver operating characteristic (ROC) analyses were used to determine the appropriate cutoff point for the independent markers and to calculate the sensitivity and specificity values. Youden index criterion value was used as a reference to determine the optimum cutoff point. IBM SPSS Statistics 21.0 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY) was used for the statistical analyses. A p value < 0.05 was considered to indicate statistical significance.

Results

Data of 128 patients (30 men and 98 women) were analyzed in this study. Demographic data and preoperative airway parameters of the patients are presented in Table 1. The evaluations for DMV indicated the following distribution among patients: DMV grade I was observed in 69.5% ($n = 89$) of individuals, grade II in 18.7% ($n = 24$), and grade III in 11.7% ($n = 15$). None of the patients exhibited DMV grade IV. The rates of patients showing Cormack–Lehane grades I, II, and III were 46.8% ($n = 60$), 42.1% ($n = 54$), and 10.9% ($n = 14$), respectively, whereas none of the patients showed Cormack–Lehane grade IV.

Table 1. Patient Demographic Data and Preoperative Airway Parameters

Parameters	*All (n: 128)*
Age (year)	50.4 ± 12.2
Gender	
Male	30 (23.4 %)
Female	98 (76.6 %)
ASA physical status	
II	72 (56.3 %)
III	56 (43.8 %)
Weight (kg)	102 ± 17.3
Height (m)	1.64 ± 0.08)
BMI (kg/m^2)	38.0 ± 5.19
Mallampati scores	
1	20 (15.6 %)
2	56 (43.8 %)
3	33 (25.8 %)
4	19 (14.8 %)
Thyromental distance (cm)	
>6	2 (1.6 %)
<6	126 (98.4 %)
Mouth opening inter-incisor distance (cm)	
<3	1 (0.8 %)
>3	127 (99.2 %)
Neck circumference (cm)	41.3 ± 4.05
Neck movement limitation	
Yes	7 (5.5 %)
No	121 (94.5 %)
Stop bang scoring	
Low	26 (20.3 %)
Medium	59 (46.1 %)
High	43 (33.6 %)
Surgery	
Abdominal surgery	57 (44.6 %)
Gynecological surgery	8 (6.3 %)
Ear nose throat	2 (1.6 %)
Breast surgery	10 (7.8 %)
Obesity surgery	21 (16.4 %)
Orthopedic surgery	7 (5.5 %)
Spinal surgery	5 (3.9 %)
Urological surgery	18 (14.1 %)

Data are expressed as n (%) or mean ± SD. ASA, American Society of Anesthesiologists; BMI, body–mass index.

The relationship between DMV and DL and the ultrasonography measurement distances is presented in Table 2. The BURP maneuver was applied in patients with Cormack–Lehane grades II ($n = 1$) and III ($n = 13$). A video laryngoscope was used in patients with DL. The intubation time was 30.5 ± 5.76 in patients with easy laryngoscopy and 42.0 ± 10.0 in the patients with DL ($p < 0.001$). DMV showed a significant relationship with neck circumference ($p = 0.02$), age ($p = 0.04$), male sex ($p = 0.004$), and the STOP-Bang score ($p = 0.014$). DL showed a significant relationship with mouth opening ($p = 0.004$) and neck movement limitation ($p = 0.005$).

In the charts obtained with the ROC analysis (for the charts on the top line), similar results were obtained when determining the cutoff point of the Han scale of the measured distances. The areas under the curve (AUC) were determined (DSHB = 0.580, DSAC = 0.580, DST = 0.568, DSI = 0.526, and DSE = 0.582), and a comparison of the AUC

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Table 2. Ultrasonography Distance Graded for DMV and DL

		DMV Han scale		*DL-modified Cormack–Lehane scale*	
	Total, n*: 128*	*Easy,* n*: 113*	*Difficult,* n*: 15*	*Easy,* n*: 114*	*Difficult,* n*: 14*
DSHB	0.74 (0.26)	0.73 (0.25)	0.84 (0.34)	0.73 (0.26)	0.84 (0.32)
DSE	2.29 (0.34)	2.28 (0.34)	2.38 (0.32)	2.30 (0.33)	2.20 (0.35)
DSAC	0.99 (0.26)	0.98 (0.25)	1.09 (0.31)	0.99 (0.25)	1.04 (0.34)
DST	1.55 (0.32)	1.56 (0.31)	1.48 (0.39)	1.55 (0.32)	1.53 (0.30)
DSI	0.86 (0.20)	0.87 (0.19)	0.86 (0.28)	0.86 (0.20)	0.86 (0.23)

All pairwise comparison analysis results were calculated as $p > 0.05$.

Numerical data are expressed as mean (SD) (in centimeters). DL, difficult laryngoscopy; DMV, difficult mask ventilation; DSAC, distance from skin to anterior commissure of the vocal cords; DSE, distance from skin to epiglottis midway; DSHB, distance from the hyoid bone to skin surface; DSI, distance from the thyroid isthmus to skin surface; DST, distance from skin to trachea at jugular notch; SD, standard deviation.

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revealed that all pairwise comparisons showed no significant differences ($p > 0.05$).

In the charts obtained in the ROC analysis (regarding charts on the bottom line), similar results were observed in determining the cutoff point of the Cormack–Lehane scale of the measured distances. The AUC (DSHB = 0.585, DSAC = 0.541, DST = 0.508, DSI = 0.505, and DSE = 0.583) was determined, and all pairwise comparisons showed no significant differences ($p > 0.05$) (Fig. 2).

Discussion

The outcomes of this prospective study demonstrated that while there were positive differences in DSHB, DSAC, and DSE concerning increased tissue thickness in cases of DMV, these differences were not statistically significant. Therefore, USG measurements of anterior neck soft tissue (DSHB, DSAC, DST, DSI, and DSE) may not predictive of DMV and DL in obese patients.

The American Society of Anesthesiologists Practice Guidelines for the management of difficult airway define DMV as a condition where adequate ventilation cannot be provided because of one or more of the following problems: insufficient mask seal, excessive gas leak, or excessive resistance to the ingress or egress of gas.[13] The most concerning scenario in cases involving airway management is when patients cannot be ventilated or intubated.[13] Inadequate ventilation, including DMV, and difficult or unsuccessful tracheal intubation are the most important causes of anesthesia-related mortality and morbidity.[14] Difficult airways characterized by both DMV and DL are common in patients with obesity.[15] In many studies, neck circumference has been shown to be predictive of DMV in obese patients.[11,14,15] Additionally, Neligan et al. and Brodskly et al. reported that neck circumference had no relationship with BMI in patients with morbid obesity and that increased neck circumference was associated with DL.[16,17] In our study, although neck circumference exhibited predictive capability for DMV, its predictive value for DL was found to be nonsignificant.

In a study conducted by Özdilek et al. on patients with morbid obesity (BMI ≥ 40 kg/m^2), the rate of DMV was 3.6% in women, 13.5% in men, and 6.6% in total. Neck circumference and BMI were not considered predictive for either sex. The DL rates were 4.8% in women, 10.8% in men, and 6.67% in total. A Mallampati score of >2 in both sexes was predictive for DL.[7] In the current study, the incidence of DMV was more commonly observed in males, and this observation was similar to the findings reported in

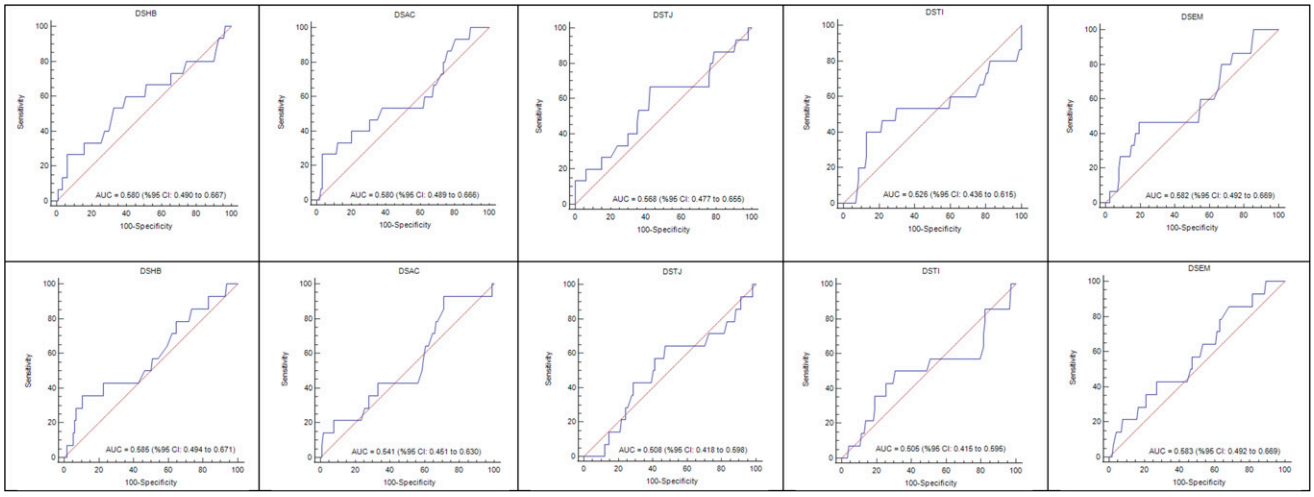


FIG. 2. Charts obtained with the ROC analysis of the five ultrasonography measurements and Han scale (for the charts on the top line) and Cormack–Lehane. DSAC, distance from skin to anterior commissure of the vocal cords; DSEM, distance from skin to epiglottis midway; DSHB, distance from the hyoid bone to skin surface; DSI, distance from the thyroid isthmus to skin surface; DST, distance from skin to trachea at suprasternal notch; ROC, receiver operating characteristic.

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the literature. Although a significant relationship was observed with increased neck circumference, no relationship was observed with BMI. The incidence of DL was 10.9%, and the Mallampati score showed predictive value for DL.

For morbidly obese patients, placing the patient in a ramp position reportedly improves laryngeal visibility and facilitates ventilation and oxygenation in comparison with the sniffing position.[18,19] In the study conducted by Özdilek et al.,[7] patients were positioned on a ramp; however, in our study, laryngoscopy was conducted with patients in the supine sniffing position. This difference in positioning might account for the elevated occurrence of DL observed in our present study.

According to the results of a recent meta-analysis, DSE is the most frequently studied parameter, despite the lack of definitive evidence for USG measurements of the anterior soft tissues of the neck.[20] DSE has been reported to be predictive of DL using a single measurement.[8,21] However, studies that aimed to define difficult airways showed high heterogeneity and were limited in number.[20] Our study is important in this context, as we specifically evaluated measurements of anterior neck soft tissues within a group with a risk factor for a difficult airway, namely, obesity.

In the study by Wu et al., measurements were taken at three levels (DSHB, DSAC, and DSE) within the anterior soft tissue of the neck in general population. The study revealed AUC values exceeding 0.7, indicating that these three parameters were predictive for DL.[22] Alessandri et al. assessed the predictive value of increased DSHB for DMV while conducting measurements of neck anterior soft tissues (DSHB, DSAC, DST, DSI, and DSE). Their study revealed a positive correlation between increased soft tissue thickness and both DL and DMV.[23] In our study, measurements were recorded at five distinct levels; however, no discernible differences were identified among the measured parameters, such as BMI and DSHB, concerning a difficult airway.

The anterior soft tissue thickness of the neck, measured at the hyoid bone, thyrohyoid membrane, and anterior commissure levels in the Chinese population, and pretracheal USG results at the vocal cord level in individuals with morbid obesity in Israel, have been documented as reliable predictors of DL.[22,24] However, in a similar study conducted in the United States on patients with morbid obesity, soft tissue thickness of the neck was not a significant predictor of DL.[25] In these three studies, the incidence of DL was 13.7%, 18%, and 31%, respectively, whereas in our study, the corresponding value was 10.9%. These figures suggest the presence of interstudy disparities regarding the occurrence of DL.[21] These different results suggest that the failure to predict DL in obese people in our society may be attributable to race, sex, or body shape differences, as in other studies.

Bianchini et al. evaluated the predictive value of upper airway USG for DMV and reported that tongue base thickness (cutoff = 50 mm) was predictive in elderly, male, and overweight patients, both pre- and postcurarization. Other sonographic measurements (hyoid bone, epiglottis, and thickness of the soft tissues anterior to the arytenoid) did not show statistically significant relationships. Furthermore, the thickness of the base of the tongue was associated with upper airway obstruction in patients lying supine as a result of tone loss after curarization under anesthesia.[5] The increased deposition of fat in the pharynx among obese individuals contributes to the collapse of the soft-tissue oropharynx between the uvula and epiglottis as a result of relaxation of upper respiratory tract muscles, consequently elevating the risk of DMV.[11] The incidence of DMV was 2.8 times higher in the patients in our study than that in the normal population.[23] Conversely, the incidence of DL was 1.8 times lower. Hence, in obese patients, DMV poses a greater risk than DL. As a result, tongue base thickness may be more significance in obese patients; however, further prospective studies are necessary to substantiate this assertion.

Langeron et al. reported a DMV rate of 5% in the adult population. According to their study, BMI > 26 kg/m^2, age > 55 years, missing teeth, presence of a beard, and history of snoring were considered independent risk factors for DMV.[6] The incidence of DMV increases with increasing obesity. Leoni et al. and Cattano et al. reported DMV rates of 8.8% and 14%, respectively, in patients with BMI > 30. Neck circumference, Mallampati classification, limited chin protrusion, and male sex were also found to be important risk factors for DMV in obese patients. However, obstructive sleep apnea syndrome (OSAS) was not defined as a risk factor. Male sex may be associated with an increased risk because of differences in adipose tissue deposition, pharyngeal length, and neck circumference.[11,14] In the general population, OSAS has been found to be an independent risk factor for DMV, and individuals with high BMI have a high risk of OSAS.[14,26] Individuals with a high STOP-Bang score of 5–8 show a high probability of moderate or severe OSAS.[27] In our study, the incidence of DMV was 11.7%, and male sex, neck circumference, and the STOP-Bang score were predictive of DMV. OSAS progresses with a thick neck anatomy and limited chin protrusion, and unlike the present study, its association with DMV was considered acceptable as a study result.

Our study had some limitations. First, it was conducted at a single center and involved only our society. The utilization of the Han scale for assessing mask ventilation, while recognized for its objectivity in defining DMV, introduced certain complexities. Factors such as airway anatomy, the impact of air on ultrasonography transmission, and the proficiency of the practitioner could complicate the assessment of glottic structures. For instance, men tend to have a more prominent thyroid cartilage, often referred to as the "Adam's apple," with greater ossification compared with women. In our study, male sex emerged as predictive of DMV; however, the male-to-female ratio was low (M/F: 23.4%). This observation was attributed to the cross-sectional design of the study.

Prediction of difficult airways is important for effective and safe airway management. The growing interest in USG for defining airway management may facilitate the definition of a number of predictive values for DMV and DL. As per the findings of our study, it appears that anterior neck soft tissue measurements (DSHB, DSAC, DST, DSI, and DSE) might not serve as predictive indicators for DMV and DL in obese patients. However, randomized controlled studies are needed in the future, as the results of the studies conducted thus far are heterogeneous and indicate the need for more experience.

Authors' Contributions

Concept—M.O.; design—M.O., G.E.K.; data collection and/or processing—M.O, S.S.B, and Y.K.; analysis and/or interpretation—M.B.; writing—M.O.; critical review—B.Y. and M.S.G.

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Author Disclosure Statement

No competing financial interests exist.

Funding Information

This work was supported by the Eskisehir Osmangazi University Scientific Research Projects Coordination Unit (Grant number: TSG-2021-1714). This study was registered with ClinicalTrials.gov (NCT04289597).

Presentation

Oral presentation, 6th World Congress on Regional Anesthesia & Pian Medicine, 6–9 September 2023, Paris, France.

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