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ORIGINAL ARTICLE **Open Access**

Sternomental displacement and neck circumference: a new look for the neck as a difficult airway predictor in obese surgical patients—a cohort study

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Abstract

Background Sternomental displacement (SMDD) is a surrogate indicator for cervical spine (C-spine) mobility. SMDD revealed good potential to predict difficult airway, but its validity in obese patients is not evident. Therefore, this study assessed the performance of SMDD with neck circumference (NC) in predicting difficult airway in obese surgical patients. The study involved 135 adult patients with body mass index (BMI) ≥ 35 kg/m^2 scheduled for elective surgeries under general anesthesia with endotracheal tubes (ETT) inserted using Macintosh laryngoscopes. The airway was assessed using SMDD, NC, and modified Mallampati test (MMT). Difficult laryngoscopy view (DLV) was defined as Cormack–Lehane (C-L) grade ≥ 3. The accuracy of the SMDD in predicting DLV was set as the primary endpoint, while the accuracy of the SMDD compared to that of NC, MMT, and NC/SMDD ratio in predicting difficult airway was set as the secondary endpoint.

Results The DLV cases were 28 of 135 (20.7%), with a mean BMI of 41.1 ± 3.3 kg/m^2. SMDD < 5cm and NC > 43 cm could predict DLV with an area under the receiver operating characteristic curve (AUROC) of 0.97 and 0.83 respectively. SMDD and NC had a good negative correlation ($r = -0.6$; 95% CI = 0.7 to 0.4; $p = 0.0001$). The NC/SMDD ratio had the best prediction for DLV (AUROC of 0.98 at a cut-off value > 7.8).

Conclusions In obese surgical patients, SMDD and NC/SMDD ratios are excellent predictors for DLV when the cut-off values are < 5cm and > 7.8, respectively.

Trial registration ClinicalTrials.gov, NCT04524546. Registered in August 2020.

Keywords Difficult laryngoscopy, Difficult intubation, Sternomental displacement, Neck circumference, Obesity

Background

The difficulty securing or maintaining the airway remains a significant cause of anesthesia-related hypoxic brain damage and death. Therefore, identifying situations and patients at risk of airway management problems is the key to optimal care and has been the focus of numerous publications (Apfelbaum et al. 2013).

Major airway complications in intensive care units and operating rooms involving obese patients are 47% and 40%, respectively (Cattano et al. 2013; Cook et al. 2011a, 2011b). Obesity is defined as body mass index (BMI) > 30 kg/m^2. Obesity causes abnormal fat distribution around the cervical region, increasing neck circumference (NC). The short neck in obese patients limits cervical spine (C-spine) mobility. Increased NC

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and limited C-spine mobility were reported to be independent predictors of the difficult airway (Salome et al. 2010; Gonzalez et al. 2008).

Sternomental displacement (SMDD) is a relatively new airway measure that represents the difference between the sternomental distance (SMD) that is measured while the head is extended on the neck (SMD-extension) and while the head is in a neutral position (SMD-neutral). The SMDD is a surrogate indicator of C-spine mobility, and it was proved to be a good objective predictor for difficult laryngoscopy view (DLV) in adult patients, and its predictive ability was increased when combined with NC (Prakash et al. 2017).

To the best of our knowledge, the validity of the SMDD was not previously assessed in obese patients. Therefore, this study hypothesized that SMDD could be a good objective predictor for difficult airway in obese patients undergoing general anesthesia (GA). The accuracy of the SMDD as a predictor for DLV was set as the primary endpoint, and to compare the accuracy of SMDD to that of NC, NC/SMDD ratio, BMI, and modified Mallampati test (MMT), in predicting DLV and difficult intubation (DI), were set as the secondary endpoints.

Methods

This observational cohort study was conducted in Kasr Alainy Hospitals after being approved by the Research Ethics Committee of the Kasr Alainy Faculty of Medicine (ID: MS-141–2020, on May 2020, email: kasralainirec@gmail.com). The study was registered on ClinicalTrials.gov (NCT04524546) in August 2020 before patients' enrollment. Written informed consent was obtained from all patients. The Standards for Accurate Reporting of Diagnostic Tests (STARD) guidelines were followed.

We enrolled 135 consecutive patients aged > 18 years, ASA physical status II & III, with BMI ≥ 35 kg/m^2, who were scheduled for elective surgeries under GA with endotracheal tubes (ETT) inserted using Macintosh laryngoscopes. Patients with craniofacial abnormalities, lesions or scars in the head and neck, and previous cervical spine surgeries and those who needed awake intubation were excluded.

The airway examination was performed preoperatively by two research team members who had not been involved in assessing the laryngeal view and endotracheal intubation. The following tests were accomplished: SMDD was measured as the difference between SMD-extension and SMD-neutral. SMD-neutral was measured while the patient's head was neutral using tape as the distance between the upper border of the manubrium sterni and the mentum. The SMD extension was measured similarly with the head extended on the neck (Prakash et al. 2017). NC was measured using tape at the level of the thyroid cartilage (Eiamcharoenwit et al. 2017). MMT, during which the proper classification, was recorded while the patient sat in a neutral position (Samsoon 1987). During the statistical analysis, NC/SMDD ratio was calculated.

In the operating room, the patient was positioned in the ramped position (by placing blankets under the patient's upper body and head until a horizontal alignment was achieved between the external auditory meatus and the sternal notch) (Collins et al. 2004). Intravenous access was secured, and the Ringer acetate solution was started. The basic monitors in the form of non-invasive blood pressure, pulse oximeter, and electrocardiogram were connected. The patient was then pre-oxygenated for 3 min using 100% oxygen. Anesthesia was induced intravenously using fentanyl 1 μg/kg, propofol 1.5–2 mg/kg, and succinylcholine 1 mg/kg, depending on the lean body weight. Mask ventilation was maintained until complete muscle relaxation was achieved, guided by a peripheral nerve stimulator. Our team's two most senior investigators assessed the laryngoscopic view and completed the endotracheal intubation using a Macintosh laryngoscope. These investigators were blinded to the preoperative airway examination results. The possible best laryngeal view that was obtained and its grade was recorded using Cormack-Lehane (C-L) grades as grade I: the vocal cords are completely visible, grade II: only the arytenoids are visible, grade III: only the epiglottis is visible, and grade IV: the epiglottis is not visible (Cormack 1984). The external neck manipulation was used to get the best view. In our study, grades I and II were categorized as easy laryngoscopy, and grades III and IV were categorized as DLV. Difficult tracheal intubation (DI) was defined as the proper insertion of the ETT using conventional laryngoscopy that required more than two attempts or more than 10 min. Failed conventional tracheal intubation was defined as intubation requiring an alternative technique to secure the airway (Langeron et al. 2010). The accuracy of the SMDD in predicting DLV with a calculated cut-off value was analyzed as the primary endpoint, while the accuracy of SMDD compared to that of NC, NC/SMDD ratio, BMI, and MMT in predicting DLV and DI were set as secondary endpoints.

Sample size calculation and statistical analysis

The sample size was calculated using MedCalc software to detect the area under the receiver operating characteristic curve (AUROC) for SMDD of 0.7 with a null hypothesis AUROC of 0.5. We considered that the DLV rate in obese patients would be 23% (Brodsky et al. 2002). Therefore, we calculated a minimum number of 122 patients (with at least 28 DLV cases) for a study power of 90% and an alpha error of 0.05. The number was increased to 135 for possible dropouts.

Statistical analysis was performed using the program IBM SPSS version 23 (Chicago, IL, USA). The normality of data distribution was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Continuous quantitative data was expressed for all statistical comparisons as means and standard deviations (SD) or median and range as appropriate, while qualitative categorical data was expressed as percentages or ratios. Normally distributed data were compared using Student's *t*-test, while non-normally distributed data were compared using the Mann–Whitney or Kruskal–Wallis test as appropriate. Spearman's rank correlation coefficient evaluated the possible relationship between SMDD and NC. A *P*-value < 0.05 was considered statistically significant. The MedCalc software was used to construct the receiver operating characteristics (ROC) curve to determine the accuracy of SMDD, NC, MMT, NC, and NC/SMDD for predicting difficult airway (DLV and DI). For this purpose, binary variables were created (easy versus difficult laryngology and easy versus difficult intubation). The ideal cut-off values for all the tested variables were determined using the Youden index. In addition, the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were all calculated. A *P*-value < 0.05 was considered statistically significant.

Results

In this study, 135 patients (76 females and 59 males) met our inclusion criteria and were enrolled and completed the study. Their mean age was 38.6 ± 8.8 years, BMI 41.1 ± 3.3 kg/m^2 with ASA classification II/III was 111/24. The SMDD was 5.5 ± 0.7 cm, and the NC was 42.1 ± 2.3 cm. The cases that encountered DLV were 28/135 (20.7%), while those who met DI were 10/135 (7.4%). No failed endotracheal intubation cases.

The patients were divided according to their laryngoscopic view into the easy laryngoscopy group (n = 107) and the difficult laryngoscopy group (n = 28). The difficult laryngoscopy group revealed a significantly smaller SMDD and a larger NC than that in the easy laryngoscopy group (4.4 ± 0.5 versus 5.7 ± 0.4 cm; p = 0.001 and 41.2 ± 2.2 versus 45.1 ± 3.2 cm; p = 0.001 respectively). The NC/SMDD ratio was significantly higher in the difficult laryngoscopy group than in the easy laryngoscopy group (10.3 ± 1.5 versus 7.2 ± 0.3; p = 0.001, respectively). The MMT was significantly higher in the difficult laryngoscopy group, while the BMI was comparable (Table 1). The patients were then divided according to the intubation condition into easy intubation (n = 125) and difficult intubation (n = 10) groups. The SMDD was significantly smaller, and the NC was significantly larger in patients with difficult intubation compared to those with easy intubation (4.4 ± 0.5 versus 5.5 ± 0.6 cm, p = 0.001, and 45 ± 4 versus 41.8 ± 2.7 cm, p = 0.001 respectively). NC/SMDD ratio was significantly higher in the difficult intubation group than in the easy intubation group (10.5 ± 1.8 versus 7.7 ± 1.4 cm; p = 0.001, respectively). The BMI and MMT were both higher in patients with difficult intubation (Table 1).

The possible correlation between SMDD and NC revealed a good negative correlation (r = −0.6; 95% CI = 0.7 to 0.4; p = 0.0001) (Fig. 1). The BMI, SSMD, NC, NC/SMDD, and MMT were used to construct a ROC curve to assess their ability to predict cases with DLV (Fig. 2). The AUROC curve, sensitivity, specificity, PPV, NPV, and cut-off values for all tested variables are presented in Table 2. The same parameters were used to construct another ROC curve to assess their ability to predict cases with DI (Fig. 3). The AUROC, sensitivity, specificity, PPV, NPP, and cut-off values for all parameters are presented in Table 3. Both SMDD and NC/SMDD showed a very high predictive ability for both DLV and DI.

Table 1 Airway characteristics according to laryngoscopic view and intubation conditions

Airway measure	Laryngoscopic view			Intubation conditions		
	Easy *n* = 107	Difficult *n* = 28	*P* value	Easy *n* = 125	Difficult *n* = 10	*P* value
Age (years)	39.1 ± 9.3	36.9 ± 6.5	0.2	38.6 ± 9.1	39.4 ± 3.6	0.3
BMI (kg/m^2)	40.8 ± 3.4	42.2 ± 2.3	0.3	40.8 ± 3.2	43.1 ± 2.4	0.03
MMT (class)	2 (1–3)	3 (2–4)	0.001	2 (1–4)	3 (2–4)	0.02
SMDD (cm)	5.7 ± 0.4	4.4 ± 0.5	0.001	5.5 ± 0.6	4.4 ± 0.5	0.001
NC (cm)	41.2 ± 2.2	45.1 ± 3.2	0.001	41.8 ± 2.7	45 ± 4	0.001
NC/SMDD ratio	7.2 ± 0.3	10.3 ± 1.5	0.001	7.7 ± 1.4	10.5 ± 1.8	0.001

Data are expressed as mean ± SD, or median (range). *Abbreviations*: *BMI* body mass index, *MMT* modified Mallampati test, *SMDD* sternomental displacement, *NC* neck circumference. *P*-value < 0.05 is statistically significant

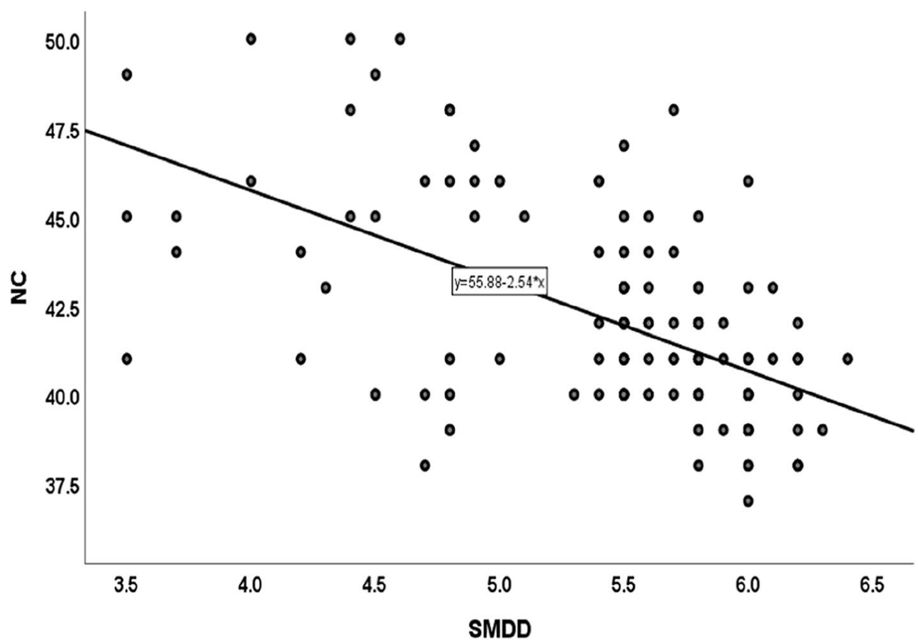

Fig. 1 A scattered plot shows the correlation between NC and SMDD

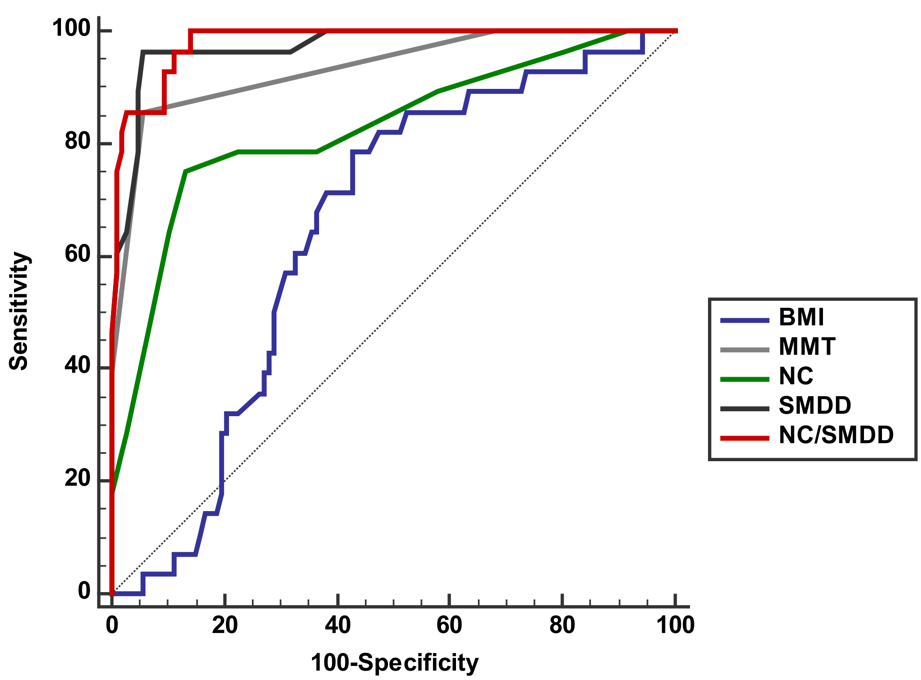

Fig. 2 The area under the receiver operating characteristics (AUROC) curve to assess the ability of the BMI, MMT, SMDD, NC, and NC/SMDD to predict difficult laryngoscopy view in obese patients undergoing general anesthesia. BMI, body mass index; SMDD, sternomental displacement; NC, neck circumference

Discussion

The main findings of our study were that in obese patients undergoing GA with ETT inserted using a Macintosh laryngoscope, SMDD was a good predictor of DLV and DI. A large NC was a fair predictor, but the NC/SMDD ratio provided an excellent prediction of DLV and DI. Despite the increased BMI in patients with DLV, BMI showed a weak predictive ability.

Table 2 Predictive ability of BMI, MMT, SMDD, NC, and NC/SMDD ratio for difficult laryngoscopy view (DLV)

	AUROC	95% CI	*P* value	Sensitivity	Specificity	+v predictive	-ve predictive	Cut-off value
BMI	0.65	0.56–0.73	0.005	79%	57%	33%	91%	> 41 kg/m^2
MMT	0.94	0.88–.97	0.001	86%	94%	80%	96%	> 2
SMDD	0.97	0.93–0.99	0.001	96%	95%	82%	99%	< 5cm
NC	0.83	0.75–0.86	0.001	75%	87%	60%	93%	> 43cm
NC/SMDD ratio	0.98	0.94–0.99	0.001	99%	99%	86%	100%	> 7.8

AUROC curve, area under the receiver operating characteristic curve, *BMI* body mass index, *MMT* modified Mallampati test, *SMDD* sternomental displacement, *NC* neck circumference

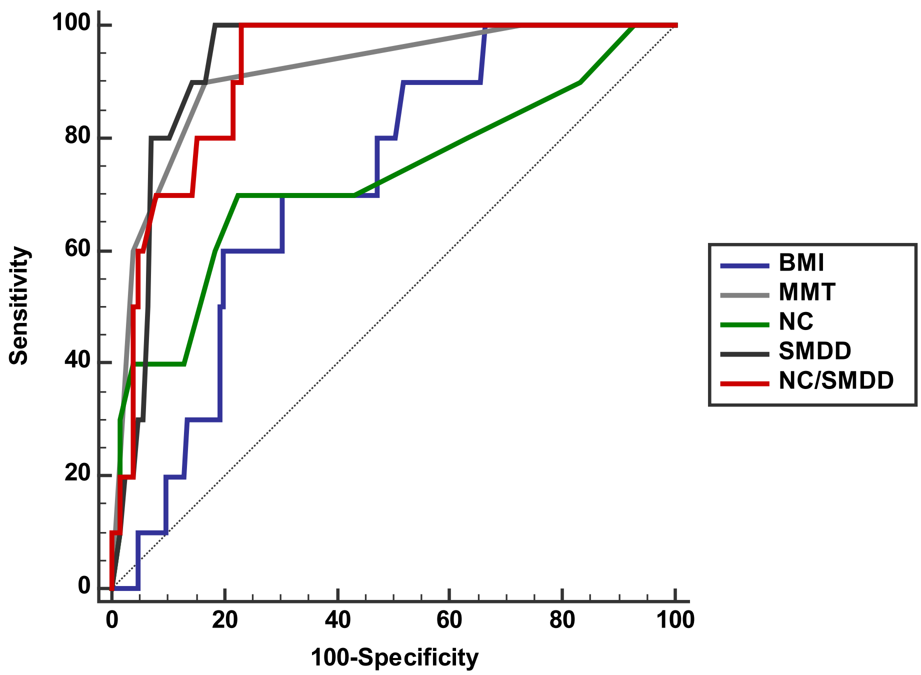

Fig. 3 The area under the receiver operating characteristics (AUROC) curve to assess the ability of the BMI, MMT, SMDD, NC, and NC/SMD to predict difficult intubation in obese patients undergoing general anesthesia. BMI, body mass index; SMDD, sternomental displacement, NC, neck circumference

Table 3 Predictive ability of BMI, MMT, SMDD, NC, and NC/SMDD ratio for difficult intubation (DI)

	AUROC	95% CI	*P* value	Sensitivity	Specificity	+v predictive	-ve predictive	Cut-off value
BMI	0.72	0.64–0.79	0.001	60%	80%	20%	96%	> 43 kg/m^2
MMT	0.91	0.85–0.95	0.001	90%	83%	32%	99%	> 2
SMDD	0.93	0.87–0.97	0.001	99%	86%	37%	99%	< 4.8cm
NC	0.73	0.64–0.80	0.02	70%	78%	20%	97%	> 43cm
NC/SMDD ratio	0.92	0.86–0.96	0.001	90%	83%	30%	99%	> 8.8

AUROC curve, area under the receiver operating characteristic curve, *BMI* body mass index, *MMT* modified Mallampati test, *SMDD* sternomental displacement, *NC* neck circumference

The C-spine mobility is a fundamental component in determining the ease of laryngeal exposure during direct laryngoscopy and endotracheal intubation. During direct laryngoscopy, the C-spine extension occurred mainly at the occipital-Atlanta-axial (OAA) complex with minimal movement at the level of subaxial cervical segments (Takenaka et al. 2007). A patient may be difficult to intubate because the head cannot be sufficiently extended on the neck, as in patients with a cervical spine injury, rheumatoid arthritis, and ankylosing spondylitis. However, it has been demonstrated that even a simple C-spine extension could improve the visualization of the glottic opening, so the sniffing position was shown to effectively improve the laryngeal view primarily due to its ability to facilitate the angulation and extension at the level of the OAA complex (Takenaka et al. 2007). In 2008, a retrospective study was conducted by Mashour et al. (Mashour et al. 2008), including the records of the preoperative airway evaluation of 14053 surgical patients. The authors identified that 8.1% of patients reported having limited C-spine mobility, and the incidences of difficult laryngoscopy and difficult intubation were twice that in normal patients.

The degree of C-spine mobility is expressed either as a full range of neck movement, from maximum flexion to maximum extension, or as the degree of either extension or flexion. Several methods were described to measure the degree of C-spine movement. Wilson et al. (Wilson et al. 1988) have described how to measure the full range of C-spine mobility by using a pencil applied vertically on the forehead that moves from maximum flexion to maximum extension, and they identified three levels of C-spine mobility: < 80°, 80–90°, and > 90°. Difficult laryngoscopy could be expected when the range of C-spine mobility is less than 80°. Some studies used a goniometer or clinometer for their measurements (Chaves et al. 2008; Salimi et al. 2016). A previous study that included 190 patients in whom the clinometer measured neck extension and flexion revealed that difficult laryngoscopy should be expected when the neck extension from the neutral position is ≤ 37.5° (Salimi et al. 2016). The previously mentioned techniques (Wilson et al. 1988; Chaves et al. 2008; Salimi et al. 2016) described C-spine mobility as angles' degrees.

The SMDD is considered a surrogate indicator of C-spine mobility. Prakash et al. in 2017 (Prakash et al. 2017) studied the SMDD in 610 surgical patients with a mean BMI of 23.68 ± 4.87 kg/m^2. SMDD showed a sensitivity of 70% and specificity of 53% for predicting DLV at a cut-off value ≤ 5.25 cm. The authors concluded that SMDD provides a rapid, simple, objective measure for predicting patients at risk of DLV. Another recent study by Kopanaki et al. in 2020 (Kopanaki et al. 2020) included 221 surgical patients with a mean BMI of 27.1 ± 5.1 kg/m^2. The authors measured the SMD ratio (SMDR), representing the ratio between SMD in extension to SMD in neutral neck positions. The authors noticed a negative correlation between the SMDR and the C-L grade. A SMDR below 1.55 was associated with DLV incidence ranging between 33 and 53% (C-L III-IV glottic views), while a SMDR > 1.9 means no likelihood of DLV.

The SMDD and SMDR are easier to measure, and the calculated difference or ratio between two straight lengths might be more accurate than angles' degrees. Another privilege of both SMDD and SMDR is to avoid using the absolute values of the SMD, which revealed a wide range of cut-off values for predicting DLV as 12.5cm, (Savva 1994) 13.5cm, (Al Ramadhani et al. 1996), and 15cm (Liaskou et al. 2014) due to the anthropometric differences among the population. Our study is the first to assess the performance of SMDD as a predictor of difficult airway in the obese population, with promising results for predicting both DLV and DI. Furthermore, the high specificity (95%) and high NPV (99%) for predicting DLV means that 99% of tested cases would be easy to intubate if the test was negative.

The role of neck circumference in predicting DLV and DI is still debatable (Gonzalez et al. 2008; Eiamcharoenwit et al. 2017). Our results revealed a good predictive ability of the NC for DLV with an AUROC of 83%, 75% sensitivity, and 87% specificity when the cut-off value is > 43cm. This ability was reduced for predicting DI with an AUROC of 73%, 70% sensitivity, and 78%sepcificty at the same cut-off value. In a study by Gonzalez et al. (Gonzalez et al. 2008), the NC was correlated with DI at a cut-off value > 43cm, with 92% sensitivity and 84% specificity. In another study by Eiamcharoenwit et al. (Eiamcharoenwit et al. 2017), the predictive ability of the NC was deficient, as the AUROC for DL was 56% in their study population with MBI 43.1 ± 3m kg/m^2 and mean NC of 38.0 ± 3.0 cm. Both studies (Gonzalez et al. 2008; Eiamcharoenwit et al. 2017) defined the DI according to the difficult intubation score (DIS). Other studies revealed a positive correlation between NC and the incidence of DLV and DI. The highest ability of NC to predict DLV and DI was achieved at a cut-off value > 50cm (Abrahams et al. 2010; Shiga et al. 2005).

It was previously concluded that when a single airway test is used, the value of screening for DLV or DI is restricted, and combining individual tests can provide some incremental diagnostic benefits (Kim et al. 2011). Our study assumed that obese patients with both large NC and impaired neck mobility would be more difficult to intubate when compared with patients with large NC or impaired neck mobility alone. The new predictor, NC/SMDD ratio, provided an excellent predictive ability for DLV and DI. The NC/SMDD ratio revealed an AUROC of 98% with 99% sensitivity and 99% specificity at a cut-off value > 7.8 for predicting DLV and an AUROC of 92% with 90% sensitivity and 83% specificity at a cut-off value > 8.8 for predicting DI. A study by Kim et al. (Kim et al. 2011) assumed that NC and thyromental (TMD) could represent thick and short neck characters, respectively; therefore, the authors provided NC/TMD ratio as a new predictor for DI with a better predictive ability compared to other established indices.

Our study has limitations; we included patients scheduled for elective surgeries, so our results cannot be extrapolated to the emergency, obstetric, or ICU setting. In addition, the influence of age and gender was not considered.

Conclusions

In obese surgical patients, the SMDD as a surrogate for neck extension and the NC/SMDD ratio for both NC and extension provide strong DLV and DI predictive abilities.

Abbreviations

SMDD	Sternomental displacement
NC	Neck circumference
MMT	Modified Mallampati test
C-spine	Cervical spine
BMI	Body mass index
DL	Difficult laryngoscopy
DI	Difficult intubation
C-L Grade	Cormack–Lehane grade
AUROC	Area under the receiver operating characteristic curve

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Authors' contributions

AG: This author helped with the clinical work, data collection, and writing the manuscript. AA: This author helped with the conception and design of the study, analysis of the data, and writing the manuscript. MA: This author helped with the clinical work and data collection and writing the manuscript. NM: This author helped with the clinical work, writing, and revising of the manuscript. WS: This author helped with writing and revising the manuscript. HN: This author helped with writing and revising the manuscript. All authors have read, revised, and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the Research Ethics Committee of the Kasr Alainy Faculty of Medicine (ID: MS-141–2020, on May 2020, email: kasralainirec@gmail.com). The study was registered on ClinicalTrials.gov (NCT04524546) in August 2020 before patients' enrollment. Written informed consent was obtained from all patients.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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