Original Article

Predictors of difficult airway in the obese are closely related to safe apnea time!

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Abstract

Background and Aims: We aimed to redefine the preoperative factors that may challenge the airway and safe apnea time (SAT) in the obese.

Material and Methods: We analyzed 834 patients with body mass index (BMI) >35 kg/m^2 for their difficult airway score (DASc). DASc is a consolidation of measures of difficult airway like mask ventilation, difficult intubation, change of device, and number of personnel required. DASc varied from "0" no difficulty to "12" serious difficulty and DASc ≥6 was considered difficult. Preoperative parameters – neck circumference (NC), BMI, STOPBANG score, Mallampati score, obstructive sleep apnea grade, and waist circumference– were assessed.

Results: Receiver operating characteristic curve was used to identify risk factors for obese patients at DASc ≥6. The Youden index (for the best threshold, with highest sensitivity and specificity) was BMI 45 kg/m^2 and NC 44.5 cm. Their absence had an 81% negative predictive value to include a difficult airway, while their presence had a positive predictive value of 55%. This further has sensitivity of 66% and specificity of 73%. The mean SAT (256 ± 6 s) was inversely related to DASc ($P < 0.001$).

Conclusion: This study demonstrates that BMI and NC have a strong association with difficult airway in obese patients and are inversely related to SAT. Amongst these NC is the single most important predictor of difficult airway in obese and should be used as a screening tool.

Keywords: Apnea time, bariatric, body mass index, difficult airway, mask ventilation, neck circumference, obese, STOPBANG

Background

Airway management has remained the overriding concern for an anesthesiologist managing an obese patient. Rapidly changing patient demographics are posing newer challenges worldwide. These are unique, for they are not just anatomical but also functional. The role of body mass index (BMI) as a predictor of difficult airway has remained controversial.

Following the onset of apnea, hypoxemia sets in within a significantly shorter time in them than in the non-obese.[1-5] The current guidelines emphasize the need for continuous oxygenation during airway management.[3] It is vital to preoperatively identify and optimize the factors that may challenge the airway, in the setting of limited oxygen reserves. We did not come across any published literature that could highlight how the safe apnea time (SAT) changes during airway management.

Based on previously published data, clinical suggestions, and a pilot study, factors,that might suggest a difficult airway were identified.[4,6] The purpose of this study was to identify preoperative screening parameters variation in SAT during morbidly obese patient with possible difficult airway and to assess in the airway management in these patients.

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Material and Methods

Institutional Ethics Committee approval (October 2017) and written informed consent from all subjects or their legal surrogate was obtained. The study was approved and registered after collection of data. We performed this retrospective analysis of patient's records; 834 consecutive, adult patients with BMI >35 kg/m^2 who underwent laparoscopic bariatric surgery at our center between 2013 and 2015 were enrolled. Patient files and electronic records were analyzed to identify demographics and comorbidities.

Patients with a documented history suggestive of gastroesophageal reflux, pregnancy, limited mouth opening cervical instability, and any severe cardiac or severe pulmonary disease, and any missing reports of mask ventilation (MV) and difficult intubation (DI) were excluded from the study. Our standard records include detailed information concerning MV and intubation difficulty, as assessed by a group of three experienced anesthesiologists. We followed the grading as per Table 1.

The details of techniques and tools (bougie, supra glottic device, video laryngoscope, Aintree catheter) used to manage patients were obtained from patient records filled by anesthesiologist during anesthetic management. Our records contain all information regarding the grading and other airway-related details; the same parameters are graded as per Tables 1 and 2. The determinants of airway difficulty were consolidated into a single number, called the difficult airway score (DASc) as shown in Table 1; the primary variable was DASc and the secondary variable was SAT. The preoperative parameters such as neck circumference (NC), BMI, STOPBANG score, Mallampati score (MPS), obstructive sleep apnea (OSA) grade, and waist circumference (WC) were identified as possible determinants of airway difficulty. All patients were screened using STOPBANG score, which is a clinical scoring system with high correlation with polysomnography.[7] Information on the preoperative parameters (identified from published literatures)[7-16] was obtained from the chart filled by the anesthesiologist at the time of initial interaction and during induction of anesthesia [Table 2]. Entire airway management was executed on the ramp (rapid airway management position or the head elevated laryngoscopy position) on the operation theater table using scale-ampule assembly to keep the tragus and manubrium sterni in line.[17-19]

Anesthesia plan and details of airway management at our previously published article.[10,11] The same was also documented in patient's anesthesia records. The parameters deduced from records were assorted as per Table 1. DASc was graded from 0 (no difficulty) to 12 (serious difficulty). The ease of calculation, a DASc value of 6 was taken as cut-off value. DASc <6 was considered a manageable airway, whereas DASc ≥6 was taken as indication of a difficult airway.

As a standard protocol, hypoxia was defined as SpO_2 of <90%, and time elapsed between onset of apnea to SpO_2 90% was taken as the SAT. MV was reinstituted when SpO_2 dropped to 90%. In patients with no difficulty in intubation, the tube was left *in situ* and time to achieve SpO_2 90% was noted. This was followed by resumption of mechanical ventilation. The time to achieve an SpO_2 of 100% was recorded as the recovery period. Minimum SpO_2 was also documented.

This article adheres to the applicable Equator guidelines.

Statistical analysis

Statistical analysis was performed using SPSS 20. Values for preoperative variables were reported as mean standard deviation (SD) for continuous variables and frequency (percentage) for categorical variables. To compare patients with DASc <6 and ≥6, Student's *t*-test was performed for quantitative variables and Chi-square test for categorical variables. Levene's test was selected for equality of variances; in cases where the variance was found to be unequal, Welch's test was applied. Preoperative quantitative factors such as BMI and NC were divided into two categories at optimal cut-off obtained by Youden index after receiver operating characteristic (ROC) curve analysis for DASc categories. An area of (0.5 <area >0.8) under the ROC curve was considered significant. Simple linear regression was done for exploring relationship between preoperative and quantitative measurements with actual DASc score without categories. Preoperative categorical factors were analyzed with analysis of variance (ANOVA) for DASc score. Tukey's test was used to locate the group with statistical significance. A P value <0.05 was considered statistically significant. DASc was divided

Table 1: Difficult airway score (DASc)

Points	MV grade	Attempts	Additional devices	CL
Each parameter scores 0	I	1	0	I, II
Each parameter scores 1	2	2	1	III
Each parameter scores 2	3	3	2	IV
Each parameter scores 3	3P	Could not be intubated	3 or (SGD_AIC)	Not visualized

DASc varies from 0 (no difficulty) to 12 (serious difficulty); score 6 being at midpoint was taken as cut-off; DASc <6 is manageable airway, DASc ≥6 is indication of difficult airway; MV: 1 when one anesthesiologist can mask ventilate unassisted, MV: 2 one anesthesiologist protrudes and holds the jaw and the other one holds mask and ventilates; MV: 3 when one additional anesthesiologist to ventilate; MV: 3P indicates mask ventilation facilitated by a supraglottic device; MV: Mask ventilation; CL: Cormach and Lehanne grading; SGD_AIC indicates intubation facilitated by supraglottic device and Aintree catheter as <6 and ≥6 and logistic regression was performed on all the preoperative factors to find which, if any, is a significant contributor. Adjusted odds ratios and their confidence intervals were computed. ROC curve was done only for those factors that were significant in multivariable analysis.

The power of the study for mean difference and SD between subjects with DASc <6 and DASc ≥6 is nearly 100%.

Results

A total of 834 adult patients undergoing laparoscopic bariatric surgery were included in the study. Patient characteristics are as shown in Table 2. Based on univariate regression analysis of preoperative parameters, BMI, WC, NC, MPS, STOPBANG, and OSA were found to have statistically significant effect on DASc (P < 0.001) [Table 3]. Furthermore, the STOPBANG score was directly related to DASc [Figure 1a]. Tukey's test revealed that severe OSA group had a significantly different mean DASc; P < 0.001. However, mild and moderate OSA groups did not have a statistically significant effect on DASc; P > 0.05. The prevalence of severe OSA was found to be 50% in this cohort.

The mean DASc changed significantly (P = 0.001) as MPS increased from grade 1 to grade IV. However, it lost its statistical significance for DASc ≥6 when all preoperative parameters were analyzed together. Gender, age, and the group "others" were not found to have statistically significant influence on DASc in the univariate setup.

ROC curve was run for the preoperative quantitative factors to evaluate the predictive model of DASc (with DASc <6 and ≥6). Factors BMI and NC were identified as significantly contributing to DASc. The area under the curve for BMI = 0.63; confidence interval (CI) 0.58–0.68; P < 0.001 and for NC was 0.64; CI 0.59–0.69; P < 0.001. The Yuoden index (for the best threshold, with highest sensitivity and specificity) was found to be 45 kg/m^2 for BMI and 44.5 cm for NC.

The univariate analysis of our study also demonstrated WC to have possible association with DASc, which could be due to probable association of WC with OSA.[18,19] When all preoperative factors were considered together in ANOVA setup, only NC was found to have significant (P < 0.001) effect on mean DASc, and others became not significant [Table 3].

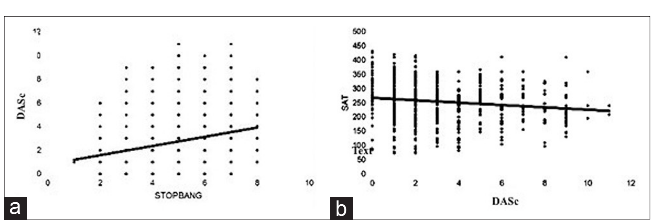

Figure 1: (a) Simple linear regression of difficult airway score (DASc) on STOPBANG depicting that DASc directly correlates with increasing STOPBANG. (b) Simple linear regression of safe apnea time (SAT) on difficult airway score (DASc) depicting inverse correlation between DASc and SAT

The mean SAT (256 ± 6 s) was found to significantly decrease (P < 0.001) with increasing DASc, whereas the recovery time (44 ± 5 s) and minimum SpO_2 (77 ± 7.7) had no association with DASc. The mean SAT (256 ± 6 s) was inversely related to DASc (P < 0.001) [Figure 1b].

Patient characteristics as per DASc category are depicted in Table 4. When we ran the logistic regression (with DASc ε6

Table 2: Patient characteristics

n=834	Mean±standard deviation
Age (years)	41±12
BMI (kg/m^2)	48±7.6
Waist circumference (cm)	138±15
NC (cm)	45±5.8
STOPBANG	5.3±1.6
Mean DASc	2.9±2.3
SAT (s)	256±66
Categorical variables	
Gender	%
Male/female	45/55
OSA	
Mild/moderate/severe	4.5/43.5/52
MPS	
I/II/III/IV	8.5/38/35/18.5
Others	*n*(%)
I/II/III	89.4/10.4/0.2

Values are reported as mean±SD for continuous variable and number of patients for categorical variables; DASc: challenging airway score; NC: neck circumference; MPS: Mallampati score; OSA: obstructive sleep apnea. OSA was graded as mild, moderate, and severe based on STOPBANG score.[7] Others: obvious determinants of airway difficulty including mandibular protrusion, beard and missing teeth, etc., "Others" was graded as I when none of these parameters is present, II when one, and III when two or more of these are present

Table 3: Predictors of difficult airway score by univariate analysis and ANCOVA

n=834	Individually considered *P*	All factors combined *P*
Preoperative factors		
Age	NS	NS
Gender M/F	NS	NS
BMI (kg/m^2)	<0.001	NS
Waist circumference (cm)	<0.001	NS
NC (cm)	<0.001	<0.001
MPS^	0.001	NS
STOPBANG	<0.001	NS
OSA^	0.001	NS
Others^	NS	NS

ANCOVA: analysis of covariance; BMI: body mass index. ^Categorical variables; NC: neck circumference; DASc: challenging airway score; OSA: obstructive sleep apnea; MPS: Mallampati score. P<0.05 is statistically significant; NS is not significant (P>0.05) as dependent) for all factors considered together, only BMI and NC were statistically significant. The independent effect of age, WC, STOPBANG, gender, others, OSA, and MPS was not statistically significant [Table 5]. BMI and NC were categorized into two categories each using the best cut-off obtained by ROC curve. The two identified predictors (BMI and NC) were high simultaneously in 33% of our cohort, and 22% of these patients had DASc ≥6 [Tables 5 and 6]. The absence of both had an 81% negative predictive value to include a difficult airway, while the presence of both the factors had a positive predictive value of 55%. This further has sensitivity of 66% and specificity of 73%.

Discussion

The focus of this study was to identify predictors of a difficult airway in the obese surgical population. The key feature of our findings is that BMI and NC were identified as factors that could predict the DASc in the obese. Although these parameters are closely related, they may exist independently in several patients. We used DASc <6 and ≥6 as the cut-off for defining a clinically significant difficult airway. In the reported cohort, the incidence of DASc ≥6 in obese patients was 14.4%.

This analysis further highlights SAT as the functional aspect of a difficult airway. Although all recommended measures were incorporated in the anesthesia plan to prolong SAT,[19-24] we found a statistically and clinically significant decrease in SAT, as DASc increased to more than 6 [Figure 1b]. Awareness of this association between SAT and DASc may be beneficial in planning intubation for some patients with definitive risk, such as the ones with gastroesophageal reflux or some in other emergency situations.

The close association of DASc and SAT further emphasizes that airway management in the obese is complex and planning must consider all risk factors including physiological challenges, in addition to considering the possibility of difficult MV or DI. Moreover, in view of low SAT and higher possibility of perioperative airway-related adverse events in obese patients, it is imperative that attention be paid to continuous oxygenation at all times.[20-26]

Further clinical implication of this analysis is that patients who have high BMI and high NC have greater possibility of DASc ≥6 and are likely to desaturate more and have lower SAT in case of a problematic airway. The values obtained from our study for SAT are considerably lower than values highlighted in some previous studies.[26-31] This could be attributed to variation in the methodology adopted for calculation. What needs to be further highlighted is that

Table 4: Patient characteristics for preoperative variables in the two DASc categories

	DASc <6; *n*=714 (85.6%)	DASc ≥6, *n*=120 (14.4%)
BMI (kg/m^2)	47.6±7.5	51±7.6
Age (years)	41±12	42±12
Waist circumference (cm)	137.5±15.8	141±14.8
NC (cm)	44.7±5.7	47.7±5.7
STOPBANG	5.2±1.5	5.7±1.5
SAT (s)	256±66	247±66
Recovery time (s)	44±5	44±6
Min SpO_2 (%)	76.9±7.6	77.2±7.7

Values are expressed as mean±standard deviation; DASc: difficult airway score; BMI: body mass index; NC: neck circumference; SAT: safe apnea time

Table 5: Adjusted OR of risk factors for difficult airway score category from multivariable logistic regression model

	OR	95% CI for OR		*P*
		Lower	Upper	
BMI (kg/m^2)*	1.044	1.008	1.081	0.015
Age (years)	1.005	0.988	1.023	NS
Waist circumference (cm)	0.992	0.975	1.009	NS
NC (cm)*	1.077	1.029	1.127	0.001
STOPBANG	1.006	0.743	1.363	NS
Gender	1.025	0.654	1.604	NS
Others I: reference				NS
Others II	1.412	0.161	12.368	NS
Others III	1.638	0.173	15.483	NS
OSA (mild) reference				NS
OSA (moderate)	2.028	0.366	11.228	NS
OSA (severe)	0.942	0.423	2.094	NS
MPS I: reference				NS
MPS II	0.684	0.260	1.802	NS
MPS III	0.909	0.532	1.553	NS
MPS IV	0.643	0.374	1.106	NS

*OR: odds ratio; CI: confidence interval; BMI: body mass index; NC: neck circumference; OSA: obstructive sleep apnea; MPS: Malampatti score; NS: not significant (P>0.05). *P<0.05 is statistically significant. OSA was graded as mild, moderate, and severe based on STOPBANG score[7]*

SAT for the obese in our cohort is much lower than SAT for lean patients. This further emphasizes that additional measures must be taken in routine airway management of the obese to prevent critical hypoxemia and to ensure continued oxygenation, more so in settings outside the operation theater.[31-33]

Although previous investigators have identified age and gender as risk factors for a difficult airway, in our study we did not find age to be affecting the DASc. This could be because we consolidated multiple aspects of a difficult airway into one parameter.

The prevalence of undiagnosed OSA in the surgical population is high and has been suggested as an important factor in

Table 6: Diagnostic value of the cut-off for the risk factors in predicting a difficult airway score category

		DASc <6	DASc ≥6
		556	277
BMI (kg/m^2) *P*<0.001	<45; negative predictive value=82%	259 (31%)	56 (7%)
	≥45; positive predictive value=43%	297 (36%)	221 (26%)
BMI sensitivity=79.8%; specificity=46.6%			
NC (cm); *P*<0.001	<44.5; negative predictive value=84%	332 (40%)	63 (7%)
	≥44.5; positive predictive value=49%	224 (27%)	214 (26%)
NC has a sensitivity=77%; specificity=60%			
Considering multiple factors simultaneously			
		DASc <6	DASc ≥6
Both BMI and NC are less	Negative predictive value=81%	403 (48%)	153 (19)
Both BMI and NC are high	Positive predictive value=55%	95 (11%)	183 (22%)
Sensitivity=66% and specificity=73%			

DASc: difficult airway score; BMI: body mass index; NC: neck circumference; BMI and NC categorized into two using the best cut-off obtained by ROC; Values have been rounded off to first decimal place

contributing to perioperative adverse events. Given the high prevalence of OSA in our patients, all patients are screened using STOPBANG score, which is a clinical scoring system with high correlation with polysomnography. Moreover, OSA has emerged as one of the most significant preoperative parameters that might challenge airway-related adverse events.[6] Airway-related adverse events are higher in obese patients, more so in those with OSA. We aimed at identifying parameters that could be red flagged preoperatively, to allow suitable measures to be incorporated, to lessen possible perioperative hypoxemia and other airway-related adverse events. Since BMI and NC are important components of STOPBANG score, the latter can be used as a guide to plan airway strategies.[30-36] More studies will be required to corroborate the association between STOPBANG score and DASc.

Although MPS showed association with DASc from grades I to IV, it did not contribute to DASc ≥6, and when considered together with all other factors, it lost its significance.

Although BMI has remained debatable for its predictive value in difficult airway, it cannot be ruled out as a predictor of a difficult airway. Contrary to other studies, this analysis had BMI 45 kg/m^2 as cut-off; we found that a BMI <45 kg/m^2 had an 82% and NC <44.5 cm had 84% negative predictive value. As per this analysis, BMI can be emphasized as a relevant parameter to be noted while planning airway management.[35-39] Presence of both these predictors simultaneously in the same clinical setting has a greater predictive value (55%).

While comparing the results of this study to others, it should be borne in mind that every possible measure was taken to standardize the airway management and to prolong SAT as per current recommendations. Positioning on a ramp has a major role in enhancing laryngoscopy, facilitating MV and intubation, and prolonging SAT.[19-24] Some of the previous reports on airway management in the obese have not clearly specified the position used, hence their results may not be comparable to our results. Previously published literature does not include the limited oxygen reserves while categorizing a difficult MV or a DI. Limited SAT is the physiological aspect of a difficult airway and can be possibly used to redefine a difficult airway.

This study demonstrates that BMI and NC have a strong association with DASc in obese patients. Each of these parameters (i.e., BMI ≥ 45kg/m^2, NC ≥ 44.5cm) has the potential to predict a difficult airway in the obese, but the presence of both these in the same patient (positive predictive value of 55%) will increase the specificity (73%) of the predictive model. NC remains the single most important predictor.

In view of short SAT in the obese, particular attention must be paid to improve and maintain oxygenation at all times. These predictive parameters should be included in routine screening during preoperative and preprocedural assessment to better predict and plan the management of airway in the obese.

Compliance with ethical standards

This study was conducted in compliance with Good Clinical Practice (GCP) and in accordance with the ethical principles that have their origin in the Declaration of Helsinki.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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