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ORIGINAL ARTICLE

The influence of morbid obesity on difficult intubation and difficult mask ventilation

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Abstract

Purpose To determine the influence of morbid obesity on the incidence of difficult mask ventilation and difficult intubation.
Methods Over a 6-year period, all tracheal intubations in the operating room of a large tertiary teaching hospital were analyzed. A modified version of the intubation difficulty scale (mIDS) was used to define easy versus difficult intubation, where a score of two or greater was defined as difficult intubation. Difficult mask ventilation was defined as the use of one or more adjuncts to achieve successful mask ventilation.
Results Of 45,447 analyzed cases, 1893 (4.2%) were classified as difficult intubations. Morbidly obese patients were not more likely to have difficult intubation [Odds Ratio (OR) = 1.131, 95% confidence interval (CI): 0.958, 1.334, $p = 0.146$]. Factors that were associated with difficult intubation included patient age > 46 years, male sex, Mallampati 3–4, thyromental distance < 6 cm, and the presence of intact dentition. Of 37,016 cases in which mask ventilation was attempted, 1069 (2.9%) were difficult. Morbidly obese patients were more likely to have difficult mask ventilation (OR = 3.785, 95% CI: 3.188, 4.493, $p < 0.0001$). Other factors associated with difficult mask ventilation included patient age > 46 years, male sex, Mallampati 3–4, and a history of obstructive sleep apnea. Having intact dentition decreased the likelihood of difficult mask ventilation.
Conclusion Morbidly obese patients do not have a higher incidence of difficult intubation compared to non-morbidly obese patients. However, they have a significantly higher incidence of difficult mask ventilation. Other factors that are predictive of both difficult mask ventilation and difficult intubation include age > 46 years, male sex, and Mallampati 3–4.

Keywords Difficult intubation · Difficult mask ventilation · Morbid obesity · Difficult airway

Introduction

Airway management is an important aspect of the practice of anesthesiology. It has been shown that up to 30% of morbidity and mortality attributed to anesthesia is related to airway management, which makes it the most frequent cause of anesthetic complications [1]. Obesity has become a worldwide epidemic over the past decade. Within the obese population, the morbidly obese (body mass index [BMI] > 40 kg/m^2) segment is the fastest growing [2]. With the changing demographics of the population, it is increasingly important for the anesthesiologist to understand the role that obesity, particularly morbid obesity, plays in their practice.

Historically, obesity has been considered to be a risk factor for increased difficulty in airway management, but the outcomes of various studies are conflicting. Some authors concluded that obesity *is not* a risk factor for difficult intubation [3–6] whereas others found that obesity *is*

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an independent risk factor for intubation [7–10]. Moreover, these conflicting results are compounded by varying definitions of difficult intubation, resulting in a varied incidence of difficult intubation ranging from 5 to 15% [5, 7, 9]. The incidence of difficult mask ventilation also ranges widely, from 0.08 to 15% [11–16]. Many of these studies were underpowered due to small sample sizes, possibly preventing adequate discernment of the effect of obesity as a risk factor for difficult intubation. Only Kheterpal and Shiga's studies had more than 50,000 patients; the rest of the studies had sample sizes ranging from 100 to 10,000 [7, 16].

In this retrospective study, the primary aim was to determine to what degree morbid obesity affected the incidence of difficult intubation and difficult mask ventilation. Additionally, other demographic and anthropometric factors were assessed to evaluate their association with difficult intubation and mask ventilation. The primary outcome of this study was the incidence of difficult intubation and difficult mask ventilation in morbidly obese versus non-morbidly obese patients.

Methods

The study was approved by the local institutional review board. This was a retrospective study of all patients who underwent tracheal intubation for elective surgery at a large, tertiary, academic teaching hospital from 2011 to 2017. Approximately half the intubations were performed by anesthesiology resident trainees, whereas the other half were performed by certified registered nurse anesthetists. The information extracted from the electronic medical record included demographic information such as age, sex, height, weight, body mass index (BMI), and American Society of Anesthesiologists (ASA) class. Additionally, airway details such as Mallampati score, thyromental distance, mouth opening, and dentition were also obtained. All aspects of airway management were extracted, including ease of mask ventilation, method of laryngoscopy, number of attempts, and adjunct device usage for both mask ventilation and tracheal intubation. A data extraction specialist gathered, de-identified, and exported the information to a spreadsheet. Of the 79,015 anesthesia records queried, 18,168 records were excluded for using methods other than direct laryngoscopy, 6,802 records were excluded for missing BMI, 3,587 records were excluded for incomplete intubation details, 646 records were excluded for age < 18, and 4,365 records were excluded for missing ASA class or Mallampati score to yield 45,447 total records for intubation data (Fig. 1). Of these 45,447 records, an additional 7,431 records were excluded for rapid sequence intubation, and 1,000 records were excluded for missing mask ventilation information to yield 37,016 total records for mask ventilation data (Fig. 1). Any entry with incomplete data was excluded. All patients who underwent general anesthesia for a Cesarean section were eliminated as this study was not intended to evaluate airway management in pregnant women. Patients were categorized according to their BMI; morbidly obese was defined as BMI ≥ 40 kg/m^2 and all other patients were defined as non-morbidly obese.

It is standard practice at our institution to place all morbidly obese patients in a 'ramped' position, such that a horizontal line drawn from the patient's sternum lines up with the external auditory meatus, which has been shown to increase arterial oxygen saturation during pre-oxygenation [17, 18].

Intubation grading scale

For tracheal intubation, the type of laryngoscope blade and the Cormack–Lehane grade seen during laryngoscopy were recorded. Patients whose tracheas had already been intubated, had a tracheal stoma, or did not undergo direct laryngoscopy were excluded. The intubation difficulty scale (IDS) is a previously validated index and can be useful for determining the best preoperative measurements of predicting intubation difficulty [19]. A modified version of the IDS was used to score the intubation [20]. Since the last three questions of the IDS relating to increased lifting force, vocal cord abduction vs. adduction, and use of external laryngeal pressure were not routinely documented, these questions were eliminated from the original calculation, leaving the first 4 components for the modified IDS (mIDS) score. The first four questions were used exactly as they were originally described (Table 1) [20]. A mIDS score of 2 or greater was considered a difficult intubation.

Mask Ventilation Grading Scale

All details pertaining to mask ventilation were recorded. Any use of adjunct equipment such as an oral airway or nasopharyngeal airway was documented. If two-handed ventilation was used, it was noted. To assess the difficulty of mask ventilation, a grading scale from 0 to 4 was used (Table 2) [21, 22]. A score of 2 or greater was considered difficult mask ventilation.

Data classification

Mallampati 1 and 2 were grouped together as "low," and 3 and 4 were grouped together as "high." Thyromental distance was treated as a binary value, with the cutoff being ≥ 6 centimeters or < 6 centimeters. Neck range of motion was also treated as a binary value of either full range of motion or limited range of motion. Dental health was noted in the medical records and categorized into two groups—edentulous or intact.

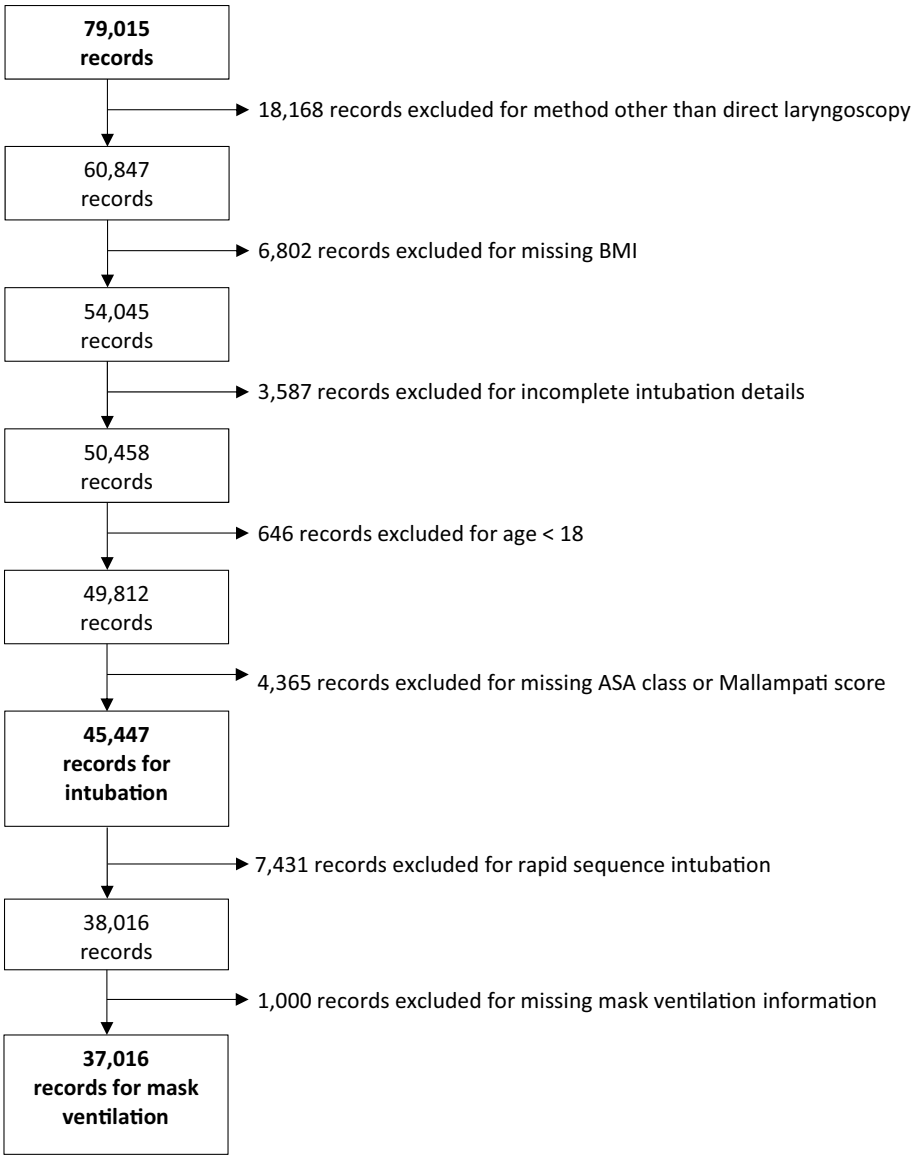

Fig. 1 Enrollment flowchart

Table 1 Intubation Grading Scale

Score	Modified Intubation Difficulty Scale
0	Number of additional intubation attempts
1	Number of additional operators
2	Number of alternative intubation techniques used (add 1 for each adjunct)
3	Laryngoscopic view minus 1 Cormack–Lehane grades [21] Grade 1—Vocal cords completely visible Grade 2—Arytenoids visible but cords not completely visible Grade 3—Only epiglottis visible Grade 4—Epiglottis not visible
Sum	Total mIDS score

A mIDS score ≥ 2 is defined as difficult intubation

Statistical analysis

A post-hoc power analysis showed that the study has 79% and 83% power to detect a 1% difference in the incidence of difficult intubation and difficult mask ventilation, respectively, between the two groups (morbidly obese vs. non-morbidly obese). Data were summarized as mean ± standard deviation (SD) or median and interquartile range (IQR) for continuous variables. Categorical variables were summarized as frequency and percentages. Univariate logistic regression analyses were used to assess the association of outcomes with demographic and clinical characteristics. Variables with a statistically significant association in the univariate analyses were then combined in a multivariable logistics regression analysis. Since BMI categories were highly associated with ASA status, we excluded ASA status

Table 2 Mask Ventilation Grading Scale

Score	Mask ventilation difficulty
0	Rapid sequence intubation (excluded from mask ventilation data analysis)
1	Easy ventilation with no adjuncts utilized
2	Moderately difficult ventilation with one adjunct utilized
3	Significantly difficult ventilation with two or more adjuncts utilized
4	Impossible mask ventilation

A score ≥ 2 is defined as difficult mask ventilation

in the multivariable analyses to reduce multicollinearity. Results were presented as odds ratios (OR) and 95% confidence intervals for ORs as well as *p* values for each model. $P < 0.05$ was considered statistically significant. All analyses were done using SAS 9.3 (SAS Inc, Cary, NC).

Results

Incidences of difficult intubation, difficult mask ventilation, and concurrent difficult intubation and difficult mask ventilation

The incidence of difficult intubation among the morbidly obese patients was 180 out of 4219 morbidly obese patients (4.3%) compared to 1713 out of 41,228 (4.2%) non-morbidly obese patients who were intubated. The incidence of difficult mask ventilation in these two groups were 215 out of 3078 morbidly obese patients (7.0%) compared to 854 out of 33,938 (2.5%) non-morbidly obese patients who was mask ventilated.

Factors associated with difficult intubation

Factors associated with a greater likelihood of difficult intubation are shown in Table 3. These factors include patient age > 46 years, male sex, high Mallampati score (3–4), a thyromental distance < 6 cm, and the presence of intact dentition.

Factors associated with difficult mask ventilation

Factors associated with a greater likelihood of difficult mask ventilation are shown in Table 4. These factors include patient age > 46 years, male sex, BMI ≥ 40 kg/m^2, high Mallampati score (3–4), and a history of obstructive sleep apnea. The presence of intact dentition was associated with a decreased likelihood of difficult mask ventilation.

Discussion

We found that the overall incidence of difficult intubation was similar in morbidly obese patients (4.3%) compared with non-morbidly obese patients (4.2%). However, the incidence of difficult mask ventilation was 7.0% in morbidly obese patients compared with 2.5% of non-morbidly obese patients. These findings are in line with those from previous studies [7, 16, 23]. Although morbid obesity influenced difficult mask ventilation, it did not have an influence on difficult intubation.

The incidence of difficult intubation can vary widely depending on the definition and study population. Previous studies have chosen to define difficult intubation based on a variety of criteria such as number of attempts multiplied by Cormack–Lehane grade, Cormack–Lehane grade alone, number of total attempts, time to successful intubation, or other unvalidated scales [5, 23–25]. In particular, the Cormack–Lehane grade only represents one aspect of the

Table 3 Factors associated with difficult intubation

	Easy intubation, $n = 43{,}554$	Difficult intubation, $n = 1893$	*p* value	Odds ratio (95% confidence interval)
Age > 46 years	19,871 (45.6)	1148 (60.6)	< 0.0001	1.909 (1.730, 2.107)
Male gender	17,530 (40.2)	1082 (57.2)	< 0.0001	1.866 (1.695, 2.054)
BMI ≥ 40 kg/m^2	4039 (9.3)	180 (9.5)	0.146	1.131 (0.958, 1.334)
High Mallampati (3–4)	5645 (13.0)	405 (21.4)	< 0.0001	1.649 (1.467, 1.854)
TMD < 6 cm	1405 (3.2)	84 (4.4)	0.011	1.348 (1.072, 1.694)
Intact dentition	37,919 (87.1)	1720 (90.9)	< 0.0001	1.916 (1.626, 2.257)
History of OSA	2364 (5.4)	152 (8.0)	0.067	1.181 (0.988, 1.412)
Limited neck ROM	871 (1.9)	53 (2.8)	0.631	1.073 (0.806, 1.428)

BMI body mass index, *TMD* thyromental distance, *OSA* obstructive sleep apnea, *ROM* range of motion

Table 4 Factors associated with difficult mask ventilation

	Easy MV, $n = 35{,}947$	Difficult MV, $n = 1069$	p value	Odds ratio (95% confidence interval)
Age > 46 years	16,923 (47.1)	688 (64.4)	< 0.0001	1.717 (1.498, 1.969)
Male gender	14,410 (40.1)	736 (68.8)	< 0.0001	3.825 (3.329, 4.395)
BMI ≥ 40 kg/m^2	2863 (8.0)	215 (20.1)	< 0.0001	3.785 (3.188, 4.493)
High Mallampati (3–4)	4553 (12.7)	255 (23.9)	< 0.0001	1.684 (1.448, 1.958)
TMD < 6 cm	1,187 (3.3)	50 (4.7)	0.0714	1.319 (0.976, 1.782)
Intact dentition	31,239 (86.9)	859 (80.4)	0.0002	0.727 (0.616, 0.858)
History of OSA	1856 (5.2)	173 (16.2)	< 0.0001	2.158 (1.802, 2.585)
Limited neck ROM	738 (2.1)	41 (3.8)	0.1248	1.297 (0.930, 1.809)

BMI body mass index, *TMD* thyromental distance, *OSA* obstructive sleep apnea, *ROM* range of motion

process of intubation and was not originally intended to be used as an indicator of intubation difficulty [26]. Moreover, the Cormack–Lehane classification suffers from poor reliability, despite its widespread use [27].

A more comprehensive measure of difficult intubation is the intubation difficulty scale (IDS). The IDS is a previously validated scale that takes into account multiple factors that may lead to a difficult intubation [20]. As this study was retrospective, information for the last 3 questions of the IDS was not available, and thus a modified intubation difficulty scale was used. The overall incidence of difficult intubation, defined as a mIDS of ≥ 2, was 4.2%, which is in line with previous studies [23, 24]. Of the factors associated with difficult intubation, male sex, age over 46, intact dentition, and high Mallampati score were found to have the highest odds ratios. These findings have been correlated with difficult intubation in previous studies [5, 7, 10]. In this study, morbid obesity was not predictive of difficult intubation. One explanation for this may be that the distribution of adiposity rather than the amount of adipose alone plays a greater role in determining the difficulty of intubation. Many morbidly obese women carry their excess weight in their hips and buttocks (the classic 'pear' shape) whereas morbidly obese men carry more excess weight in their trunk and abdomen [28]. Anatomical changes that occur in the upper neck and airway including increased neck circumference, more pretracheal fat mass, and larger dorsal fat pad are found more prominently in morbidly obese men compared to morbidly obese women [10, 29, 30]. Thus, two patients with the same BMI of 45 kg/m^2 may have very different anatomical features, which may or may not predispose them to a difficult intubation. Therefore, BMI, by itself, is a poor predictor of difficult intubation.

Mask ventilation and tracheal intubation are intimately connected. Mask ventilation plays an important role in preparation for tracheal intubation and can serve as a rescue technique when difficult intubation is encountered. Acknowledging its importance, it has been argued that mask ventilation is understudied compared to other techniques of airway management [22]. This study found that the overall incidence of difficult mask ventilation was 2.9%, which is in line with several other studies that have reported an incidence ranging from 1.4 to 5% [14, 16]. The lack of standard criteria to define difficult mask ventilation likely contributes to the variable rates from different studies. Additionally, since multiple demographic and anthropometric variables can affect mask ventilation, the difference in populations studied will affect the incidence of difficult mask ventilation as well. This study found that the three factors most predictive of difficult mask ventilation are male sex, BMI ≥ 40 kg/m^2, and a history of obstructive sleep apnea. Morbid obesity was found to be predictive of difficult mask ventilation but not difficult intubation. Additionally, factors associated with difficult mask ventilation were found to have higher odds ratios, suggesting that a preoperative risk assessment may be more strongly predictive for difficult mask ventilation than for difficult intubation.

Interestingly, the presence of intact dentition was found to have opposing influences on intubation and mask ventilation. This study found that the presence of intact dentition was associated with an increased likelihood of difficult intubation but was associated with a decreased likelihood of difficult mask ventilation. During mask ventilation, the presence of teeth provides more structure to facial soft tissue and thus permits greater air space in the oropharynx as compared to the edentulous patient [31]. In contrast, the presence of teeth provides a physical obstruction during intubation, which causes a relative decrease in the ability to maneuver the laryngoscope and endotracheal tube during intubation as compared to the edentulous patient.

This study has several limitations. As a retrospective study, the analysis of potential factors associated with difficult intubation and difficult mask ventilation was limited to information readily available in the electronic medical record. For this reason, the answers to the last three questions of the original IDS were unavailable, and thus we used a modified version of the scoring system (mIDS). Recent literature has demonstrated that anthropometric

measurements (e.g., neck circumference, neck circumference to thyromental distance ratio, upper lip bite test) may further increase the predictive potential for difficult intubation [10, 30, 32]. However, such measurements are not routinely documented in the medical record and fell beyond the scope of this study. The results of this study may not be extrapolated to all patient populations, given the exclusion of pediatric patients, obstetric patients, and patients who did not undergo direct laryngoscopy as the first intubation technique (e.g., fiberoptic intubation for a known or suspected difficult airway). Thus, these findings are best compared to a general, elective, non-obstetric adult surgical population. Additionally, as this study was carried out in a teaching hospital and half the intubations were performed by resident trainees, the results cannot be extrapolated to hospitals where tracheal intubations are performed by more experienced personnel.

In summary, morbid obesity is not a predictor for difficult intubation but is a predictor of difficult mask ventilation. As the incidence of morbid obesity continues to rise, anesthesiologists must be familiar with the pathophysiology of morbid obesity as they will undoubtedly be caring for these patients in the operating room. When difficulty with airway management is encountered, the ramifications have the potential to be severe if the situation is not well managed. Fortunately, a number of factors can be used to anticipate when difficulty is more likely to occur. By identifying these factors, difficult situations can be anticipated and mitigated through an appropriate allocation of resources and personnel. Lastly, the morbidly obese will prove an important constituent of the surgical population in the years to come. Knowledge of their specific needs, particularly as it relates to increased difficulty with mask ventilation, will remain invaluable.

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