The Extended Mallampati Score and a Diagnosis of Diabetes Mellitus Are Predictors of Difficult Laryngoscopy in the Morbidly Obese

George A. Mashour, MD, PhD*

Sachin Kheterpal, MD, MBA*

Vishnu Vanaharam, MD†

Amy Shanks, MS*

Luke Y.-J. Wang, MD*

Warren S. Sandberg, MD, PhD†

Kevin K. Tremper, MD, PhD*

BACKGROUND: The modified Mallampati (MMP) classification is a standard method of oropharyngeal evaluation for predicting difficult laryngoscopy. Previous studies have demonstrated that the predictive value of the MMP is improved when the patient's craniocervical junction is extended rather than neutral (Extended Mallampati Score, EMS). In the present study, we compared the predictive value of the MMP and EMS in the morbidly obese.

METHODS: We performed a prospective study of adult patients with a Body Mass Index (BMI) ≥40 over a 12-mo period comparing the MMP and EMS. The performance of the MMP, EMS, and other commonly used tests was compared for the ability to predict difficult laryngoscopy, defined as a Cormack-Lehane grade of 3 or 4. Positioning and direct laryngoscopic techniques were not standardized. The incidence of difficult laryngoscopy and difficult intubation was compared in patients with BMI ≥ or <40.

RESULTS: Three-hundred-forty-six patients with a BMI ≥40 were evaluated with both the MMP and EMS and received direct laryngoscopy. On average, craniocervical extension decreased the MMP class ($P < 0.0001$). Compared to the MMP, the EMS improved specificity and predictive value while maintaining sensitivity. Compared to the MMP and other tests, an EMS class of 3 or 4 and a diagnosis of diabetes mellitus were the only statistically significant predictors of difficult laryngoscopy in the morbidly obese. There was no difference in the incidence of difficult laryngoscopy or intubation in the morbidly obese compared to patients with a BMI <40.

CONCLUSIONS: The EMS was superior to the MMP in the prediction of difficult laryngoscopy in the morbidly obese population. A diagnosis of diabetes mellitus also warrants further investigation as a predictor of difficult laryngoscopy in this population. Finally, this study supports previous findings that morbid obesity is not itself a predictor of difficult laryngoscopy or intubation.

(Anesth Analg 2008;107:1919–23)

The modified Mallampati (MMP) examination is a standard method of evaluating the airway for potentially difficult laryngoscopy.[1–3] As originally described, the MMP examination is performed with the patient sitting upright, head neutral, tongue maximally protruded, and no phonation.[3] It has been demonstrated that the predictive value of the examination is dependent on the position of the cervical spine: Lewis et al. recommended that the MMP be performed with the patient sitting and with extension of the craniocervical junction.[4] Following these results, Mashour and Sandberg performed a paired-design cohort study in which 60 patients were evaluated with both the MMP examination and the MMP with extension (Extended Mallampati Score, or EMS).[5] In this study, the EMS was associated with lower classification scores, improved specificity and improved positive predictive value.[5]

Both forms of the Mallampati examination have been used in studies of the morbidly obese, a population in which risk of difficult laryngoscopy and intubation is still controversial.[6,7] In this study of the morbidly obese, we compared the MMP and EMS as predictors of difficult laryngoscopy, evaluated other predictors of difficult laryngoscopy, and compared the incidence of difficult laryngoscopy and intubation to patients who are not morbidly obese.

METHODS

All patients receiving anesthesia at our institution are evaluated by an anesthesia provider (attending

From the *Department of Anesthesiology, University of Michigan Medical School, Ann Arbor, Michigan; and †Department of Anesthesia and Critical Care, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts.

Accepted for publication June 13, 2008.

Supported by Institutional and Departmental Funds.

Address correspondence and reprint requests to George A. Mashour, MD, PhD, 1H247 UH/Box 0048, 1500 East Medical Center Dr., Ann Arbor, MI 48109-0048. Address e-mail to gmashour@umich.edu.

DOI: 10.1213/ane.0b013e31818a9946

anesthesiologist, fellow, nurse anesthetist, or anesthesiology resident) and data from this preoperative evaluation are entered into an anesthesia information management system (Centricity™ from General Electric Healthcare, Waukesha, WI). Preoperative airway evaluation includes the MMP, the EMS, cervical spine mobility, neck anatomy, jaw protrusion, thyromental distance, mouth opening, dentition, and the presence of a beard. The purpose of the study was to assess the value of these tests in the morbidly obese population, as defined by a Body Mass Index (BMI) ≥40. A full description of the preoperative airway assessment is shown in Appendix. In the present study we also sought a diagnosis of diabetes mellitus, as it is associated with morbid obesity, as well as difficult laryngoscopy.[8]

Anesthesia providers score adult patients using the standard MMP evaluation: sitting, head in neutral position, mouth open fully, tongue protruded maximally, no phonation and with the examiner eye-to-eye. The EMS was introduced at our institution in October 2006, and is performed with the patient sitting, craniocervical junction extended, mouth open fully, tongue protruded maximally, no phonation, and the examiner eye-to-eye. MMP and EMS classification are scored as follows:

Class 1: Entire uvula clearly visible
Class 2: Upper half of uvula visible
Class 3: Soft and hard palate clearly visible
Class 4: Only hard palate visible

The clinician performing the direct laryngoscopy (who may or may not have been the examiner) records Cormack-Lehane grades in the electronic chart as a description of laryngoscopic view. Laryngoscopic grading is as follows:

Grade 1: Full view of vocal cords
Grade 2a: Partial view of vocal cords
Grade 2b: View of arytenoid cartilage only
Grade 3: View of epiglottis only, no vocal cords
Grade 4: View of soft palate only, no epiglottis

The conduct of clinical care was not restricted by a study protocol and clinicians were free to choose the laryngoscopic position and intubating technique judged best to achieve optimal visualization in each particular patient. The decision to perform an awake fiberoptic intubation rather than direct laryngoscopy was also left to the clinician.

The study was approved by the IRB of the University of Michigan and informed consent was waived on the basis of minimal patient risk and no collection of protected health information. We prospectively studied adult patients receiving airway evaluation with both the MMP and the EMS documented electronically in the perioperative electronic database. Airway evaluation and management were performed by an anesthesia provider with at least 1 yr of airway experience (i.e., a second year anesthesia resident or above). The clinician evaluating the airway was often, but not exclusively, the same as that managing the airway. The clinicians were not aware that the EMS was introduced into the electronic record for the purpose of a study. All study data were collected from October 1, 2006 until September 30, 2007.

Statistical analyses were performed using SPSS version 15 (SPSS, Chicago, IL). Wilcoxon matched-pairs test for evaluation of ordinal data was used to compare the classification scores of the MMP and EMS. MMP or EMS classifications of 3 or 4 were considered predictive of difficult laryngoscopy based on the original studies of Mallampati et al.[2] as well as Samsoon and Young.[3] Thus, a "positive" examination is predictive of difficult laryngoscopy and a "negative" examination is predictive of easy laryngoscopy. Sensitivity, specificity, and predictive value were calculated and McNemar's statistic was used to analyze agreement between the predictions of the MMP or EMS and the outcome of laryngoscopy. Univariate predictors were analyzed using either χ^2 or Fisher's exact test. Statistical significance was defined as $P < 0.05$.

RESULTS

A total of 5173 patients were evaluated with both MMP and EMS before undergoing general anesthesia and direct laryngoscopy. Three-hundred-forty-six of these patients had a BMI ≥40 and were the focus of this study. Demographic characteristics of this morbidly obese study population (Table 1) included a mean BMI of 46 ± 6 and mean age of 50 ± 14. There was a larger percentage of females with a BMI ≥40 (67%), as has been found in other studies.[6] Seven patients with a BMI ≥40 were given an ASA 1 designation, despite meeting the criteria of morbid obesity. Of 45 patients with a BMI ≥40 and an ASA 4 designation, the majority (27 patients) were undergoing major cardiovascular surgery (e.g., coronary artery bypass, valve replacement, aortic aneurysm repair, etc.).

EMS scores were significantly lower than MMP scores ($P < 0.0001$) (Table 2). Craniocervical extension decreased the MMP class in 41 patients, increased it in 4 patients, and left it unchanged in 301 patients. MMP was associated with a sensitivity of 41.2% and specificity of 76%, while the EMS was associated with an equivalent sensitivity of 41.2% and an improved specificity of 83% (Table 3). There were 23 cases in which the EMS prediction, but not the MMP prediction, agreed with the outcome of laryngoscopy as expressed by Cormack-Lehane grades (Table 4). There were no instances in which the MMP prediction agreed while the EMS did not. The improved agreement of prediction and confirmation associated with the EMS was statistically significant ($P < 0.0001$).

In addition to the EMS and MMP, other standard methods of airway evaluation and co-morbidities associated with morbid obesity were analyzed for prediction of difficult laryngoscopy. Of the risk factors

Table 1. Demographic Characteristics of Morbidly Obese Study Group

N	346
Age	50 ± 14
BMI	46 ± 6
Male	115
Female	231
ASA 1	7
ASA 2	123
ASA 3	171
ASA 4	45

BMI = body mass index.

Table 2. Comparison of Oropharyngeal Classifications Between Modified Mallampati (MMP) and Extended Mallampati Score (EMS) and corresponding Cormack-Lehane laryngoscopic views in the morbidly obese (Body Mass Index ≥40)

Class/Grade	MMP	EMS	Cormack-Lehane
1	92	105	219
2	168	178	110
3	83	61	17
4	3	2	0

The MMP and EMS scores are statistically different ($P < 0.0001$) according to Wilcoxon Signed Ranks test, with EMS classifications being lower.

Table 3. Comparison of Sensitivity, Specificity, and Predictive Value of the Modified Mallampati (MMP) and the Extended Mallampati Score (EMS) in Patients with Body Mass Index ≥40

	MMP (n = 346)	EMS (n = 346)
True positives	7	7
True negatives	250	273
False positives	79	56
False negatives	10	10
Sensitivity	41.2%	41.2%
Specificity	76%	83%
Positive predictive value	8.1%	11.1%
Negative predictive value	96.2%	96.5%

Table 4. Agreement Between Modified Mallampati (MMP), Extended Mallampati Score (EMS), and Cormack-Lehane Grade View

Agreement w/grade view	Patients w/BMI ≥40 (n = 346)
Both MMP and EMS agree	257
Both MMP and EMS disagree	66
EMS agrees, MMP disagrees	23
MMP agrees, EMS disagrees	0

Each airway prediction (Class 1 or 2 predicting "easy," and Class 3 or 4 predicting "hard") was compared to actual outcome (Grade 1 or 2 confirming "easy," and Grade 3 or 4 confirming "hard") for agreement.

The EMS prediction agreed 23 times in which MMP failed to agree. There were no instances, however, when the MMP agreed but the EMS failed to agree.

Differences are statistically significant, $P < 0.0001$ (McNemar's statistic).

listed (Table 5), only two had statistical significance, an EMS score of 3 or 4 ($P = 0.02$) and a diagnosis of diabetes mellitus ($P = 0.028$).

Of 346 patients with a BMI ≥40, 105 (30%) had a diagnosis of diabetes. Of the population with morbid obesity and diabetes, 21 patients were identified as having type 1 or insulin-dependent diabetes, while 84 had diet- or oral hypoglycemic-controlled diabetes. In order to explore the relationship between abnormalities of glycemic control and difficult laryngoscopy, we reviewed cases in which hemoglobin (Hgb) A1c was available. Of the total population in this study (n = 5173), 256 patients had Hgb A1c values available at the time of their procedure. In this subpopulation, patients with easy laryngoscopy (grade 1 or 2 view) had a mean Hgb A1c of 6.2 ± 1.3, while those with difficult laryngoscopy (grade 3 or 4 view) had a mean Hgb A1c of 8.7 ± 1.9. This difference was statistically significant ($P < 0.001$). Due to limited numbers of patients with available Hgb A1c values, we were not able to analyze specifically the morbidly obese population.

There were no statistically significant differences in grade view in the morbidly obese compared to patients with a BMI <40 evaluated during the same time period (Table 6). There were also no statistically significant differences in the number of difficult intubations (3 or more attempts) in the morbidly obese (0 events, 346 patients) compared to BMI <40 (21 events, n = 4827 patients).

DISCUSSION

Here we report that the EMS and a diagnosis of diabetes mellitus are predictors of difficult laryngoscopy in patients with a BMI ≥40. Given the increased consumption of oxygen and decreased functional residual capacity in the morbidly obese population, accurate prediction of difficult laryngoscopy is especially important. The MMP examination has become a standard method of oropharyngeal evaluation, although as a single test it is thought to be of limited diagnostic value.[9] Indeed, there has been wide variation in the reported sensitivity and specificity of the MMP, as well as low positive predictive value. There are statistical reasons for such values. As Yentis has noted, positive predictive values will always be low when the outcome of interest (such as difficult laryngoscopy or tracheal intubation) is relatively uncommon.[10] Other reasons for poor predictive value include an intrinsic lack of value to the test or poor execution of the test.

It has been established that the positive predictive value of the MMP is dependent on the position of the patient. Lewis et al. studied 24 different sets of conditions in 213 patients, combining various body, head, and tongue positions.[4] They demonstrated that the position associated with the best positive predictive value of the MMP was the patient sitting, head extended, and tongue maximally protruded. This very well designed study was not clinically realistic, however, as there were only two examiners for the patients and laryngoscopic positioning and technique were standardized. Mashour and Sandberg tested the EMS on the basis of these results, allowing multiple examiners and nonstandardized laryngoscopy.[5] In a study

Table 5. Univariate Risk Factors for Difficult Laryngoscopy in Patients with Body Mass Index ≥40

Risk factor	Confirmed easy (Grade 1 or 2)	Confirmed difficult (Grade 3 or 4)	*P*
EMS score 3 or 4	17%	41%	$P = 0.02$
MMP score 3 or 4	24%	41%	NS
Diabetes mellitus	24%	47%	$P = 0.028$
OSA	30%	41%	NS
Snoring	49%	47%	NS
Thick neck	62%	69%	NS
Limited C-spine mobility	10%	12%	NS
Limited jaw protrusion	12%	18%	NS
Limited mouth opening	3%	12%	NS
Thyromental distance <6 cm	4%	12%	NS

C-spine = cervical spine; EMS = extended Mallampati score; MMP = modified Mallampati examination; OSA = obstructive sleep apnea; NS = not significant.

Table 6. Distribution of Cormack-Lehane Grade View in the Morbidly Obese Receiving Direct Laryngoscopy Compared to Lower Body Mass Index (BMI)

Grade view	BMI ≥40	BMI <40
	($n = 346$)	($n = 4827$)
1	63%	69%
2	32%	28%
3	5%	3%
4	0%	0%

There are no statistically significant differences.

There were also no statistically significant differences in the number of difficult intubations (three or more attempts) in the morbidly obese (0, $n = 346$) compared to BMI <40 (21, $n = 4827$).

of 60 patients, they found that performing the MMP with the patient sitting and in craniocervical extension improved the positive predictive value. This study was limited due to the relatively small number of patients and the detailed instructions given to the examiners. Furthermore, since the examiners knew the hypothesis being tested and were the ones performing laryngoscopy, there was the potential for a Hawthorne effect. Having already established the validity of improved MMP prediction with craniocervical extension, we believe it is important to test its generalizability to other patient populations in routine clinical practice.

In a realistic clinical setting, we demonstrate that the EMS is superior to the MMP in the prediction of difficult laryngoscopy in the morbidly obese population. The EMS predictions demonstrate better agreement with Cormack-Lehane grades compared to the MMP ($P < 0.0001$) in 23 morbidly obese patients, representing 6.6% of the study population with a more accurate examination (Table 4). Given the widespread and standard use of the Mallampati examination, as well as the increasing number of morbidly obese patients, even small improvements conferred by the EMS could have a clinically significant effect. Since performing the Mallampati examination with craniocervical extension is usually low risk, time efficient, and inexpensive, it is worthwhile considering this position for routine use.

Our data show that EMS class 3 or 4 in the morbidly obese, compared to MMP and other standard methods of airway evaluation is a better predictor of difficult laryngoscopy (Table 5). Other commonly used bedside tests, such as thyromental distance and mandibular protrusion were not effective in predicting difficult laryngoscopy in this study. Given the low sensitivity and predictive values of both Mallampati examinations within the morbidly obese population, further tests need to be developed. Our study suggests the diagnosis and evaluation of diabetes mellitus as one possibility.

We demonstrate that a diagnosis of diabetes mellitus is a predictor of difficult laryngoscopy in the morbidly obese, independently of BMI. While type II diabetics are reported to have an increased incidence of difficult laryngoscopy,[8] this seems to be the first study identifying diabetes as a risk factor for difficult laryngoscopy in the morbidly obese. Furthermore, our data demonstrating higher Hgb A1c values in patients with difficult laryngoscopy suggest the possibility that severity of diabetes may play a role in airway management. The possibility of a biochemical predictor of difficult laryngoscopy is provocative. Glycosylation of joints due to chronic hyperglycemia can result in limited mobility, which may also affect the cervical and laryngeal areas.[11] These observations warrant further prospective study.

Our data agree with those of Brodsky et al.,[6] in that morbid obesity is not an independent predictor of difficult direct laryngoscopy *per se* (Table 6). We cannot exclude, however, the potential presence of a "channeling bias," whereby those predicted to have difficult intubation received fiberoptic rather than direct laryngoscopy. The implication of this bias is that patients with potentially worse airways would be unaccounted for in our analysis. The same could be true, however, for individuals in the control population with a BMI <40.

There are several limitations to our study. There was a heterogeneity of examiners and laryngoscopists, which creates the potential for inter-rater variability in the evaluation of both oropharyngeal classifications and laryngoscopic grade views. This reflects, however, the heterogeneity of routine clinical practice which, as discussed above, may be considered an advantage of the study. Furthermore, because in some

instances the clinician evaluating the Mallampati class was also the person performing laryngoscopy, there is the potential for biased data. Clinicians were not informed, however, that a study was being conducted comparing the two oropharyngeal examinations. Finally, other airway examinations were not prospectively controlled for or quantified. For example, "thick neck" was a qualitative judgment by the examiner, whereas neck circumference has been quantified in other studies of airway evaluation in the obese or morbidly obese.[6,12]

In conclusion, we find that the EMS is a better predictor of difficult laryngoscopy than MMP in the morbidly obese population. As found in our smaller, better controlled study, the EMS is associated with lower oropharyngeal scores, improved specificity, and improved predictive value. This study, therefore, represents a validation of the EMS in the morbidly obese population in a routine perioperative setting. In agreement with Brodsky et al.[6] we did not find a higher incidence of difficult laryngoscopy associated with morbid obesity. Finally, a diagnosis of diabetes mellitus and degree of glycemic control should be explored further as predictors of difficult laryngoscopy in the morbidly obese.

APPENDIX: Elements of Preoperative Airway Assessment, Formatted in a Perioperative Electronic Information System as Structured "Pick-Lists"

- Cervical spine (limited extension, limited flexion, known unstable, possible unstable)
- Neck anatomy (limited laryngeal mobility, mass, radiation changes, thick/obese, thyroid cartilage not visible, tracheal deviation)
- Thyroid cartilage to mentum distance (<6 cm, >6 cm)
- Mouth opening interincisor or intergingival distance (<3 cm, >3 cm)
- Mandibular protrusion test (normal: lower incisors can be protruded anterior to upper incisors, limited: lower incisors can be advanced to only meet upper incisors, severely limited: lower incisors cannot be advanced to meet upper incisors)
- Mallampati classification (I, II, III, or IV) as modified by Samsoon and Young. Performed with patient sitting with head in neutral or extended position, mouth maximally open, tongue maximally protruded, without phonation
- Full beard (yes, no, moustache, or goatee)
- Dentition (normal, dentures upper partial, dentures upper complete, dentures lower partial, dentures lower complete, edentulous, teeth missing/loose/broken)
- History of cough (chronic, recent, productive, nonproductive)
- History of rhinorrhea
- History of chronic obstructive pulmonary disease (chronic bronchitis or emphysema requiring treatment with inhaled or systemic steroids or bronchodilators)
- History of asthma (requiring treatment with inhaled or systemic steroids or bronchodilators)
- History of snoring occurring nightly
- History of obstructive sleep apnea (requiring continuous positive airway pressure, bilevel positive airway pressure, or surgery)

Airway evaluations are nonquantitative and based on physical examination, unless otherwise noted.

REFERENCES

1. Mallampati SR. Clinical sign to predict difficult tracheal intubation (hypothesis). Can Anaesth Soc J 1983;30(3 Pt 1):316–7
2. Mallampati SR, Gatt SP, Gugino LD, Desai SP, Waraksa B, Friberger D, Liu PL. A clinical sign to predict difficult tracheal intubation: a prospective study. Can Anaesth Soc J 1985;32:429–34
3. Samsoon GL, Young JR. Difficult tracheal intubation: a retrospective study Anaesthesia 1987;42:487–90
4. Lewis M, Keramati S, Benumof JL, Berry CC. What is the best way to determine oropharyngeal classification and mandibular space length to predict difficult laryngoscopy? Anesthesiology 1994;81:69–74
5. Mashour GA, Sandberg WS. Craniocervical extension improves the specificity and predictive value of the Mallampati airway evaluation. Anesth Analg 2006;103:1256–9
6. Brodsky J, Lemmens, HJM, Brock-Utne JG, Vierra M, Saidman LJ. Morbid obesity and tracheal intubation. Anesth Analg 2002;94:732–6
7. Juvin P, Lavaut E, Dupont H, Lefevre P, Demetriou M, Dumoulin JL, Desmonts JM. Difficult tracheal intubation is more common in obese than in lean patients. Anesth Analg 2003;97:595–600
8. Erden V, Basaranoglu G, Helatioglu H, Hamzalogue NS. Relationship of difficult laryngoscopy to long-term non-insulin-dependent diabetes and hand abnormality detected using the 'prayer sign'. Br J Anaesth 2003;91:159–60
9. Shiga T, Wajima Z, Inoue T, Sakamoto A. Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance. Anesthesiology 2005;103:429–37
10. Yentis SM. Predicting difficult intubation—worthwhile exercise or pointless ritual? Anaesthesia 2002;57:105–9
11. Riessell E, Orko R, Maunuksela EL, Lindgren L. Predictability of difficult laryngoscopy in patients with long-term diabetes mellitus. Anaesthesia 1990;45:1024–7
12. Gonzalez H, Minvile V, Delanoue K, Mazerolles M, Concina D, Fourcade O. The importance of increased neck circumference to intubation difficulties in obese patients. Anesth Analg 2008;106:1132–6