

# Incidence, Predictors, and Outcome of Difficult Mask Ventilation Combined with Difficult Laryngoscopy

## A Report from the Multicenter Perioperative Outcomes Group

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This article has been selected for the ANESTHESIOLOGY CME Program. Learning objectives and disclosure and ordering information can be found in the CME section at the front of this issue.

### ABSTRACT

**Background:** Research regarding difficult mask ventilation (DMV) combined with difficult laryngoscopy (DL) is extremely limited even though each technique serves as a rescue for one another.

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Received from the Department of Anesthesiology, University of Michigan Medical School, Ann Arbor, Michigan; Department of Anesthesiology and Perioperative Medicine, Oregon Health and Science University, Portland, Oregon; Department of Anesthesiology, University of Colorado, Aurora, Colorado; and Department of Anesthesiology, University of Tennessee Graduate School of Medicine, Knoxville, Tennessee. Submitted for publication March 1, 2013. Accepted for publication July 24, 2013. The project described was supported in part by the National Center for Research Resources, Grant UL1RR024986, which is now at the National Center for Advancing Translational Sciences, Grant 2UL1TR000433 (Bethesda, Maryland) and institutional funding. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Center for Advancing Translational Sciences. The authors declare no competing interests. A single-center subset of this data was presented at the Annual Meeting of the American Society of Anesthesiologists, Orlando, Florida, October 18, 2008, by Dr. Martin.

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### What We Already Know about This Topic

- Difficult mask ventilation and difficult laryngoscopy occur in 5 and 5.8% of general anesthesia population, respectively, and predictors of each situation are documented. Simultaneous occurrence of these situations is more critical, but a larger sample size is required to reveal the clinical features.

### What This Article Tells Us That Is New

- This study determined incidence of difficult mask ventilation combined with difficult laryngoscopy to be 0.4% of 176,679 adult cases and succeeded in identifying 12 independent predictors for the critical situation.

**Methods:** Four tertiary care centers participating in the Multicenter Perioperative Outcomes Group used a consistent structured patient history and airway examination and airway outcome definition. DMV was defined as grade 3 or 4 mask ventilation, and DL was defined as grade 3 or 4 laryngoscopic view or four or more intubation attempts. The primary outcome was DMV combined with DL. Patients with the primary outcome were compared to those without the primary outcome to identify predictors of DMV combined with DL using a non-parsimonious logistic regression. **Results:** Of 492,239 cases performed at four institutions among adult patients, 176,679 included a documented face mask ventilation and laryngoscopy attempt. Six hundred ninety-eight patients experienced the primary outcome, an overall incidence of 0.40%. One patient required an emergent cricothyrotomy, 177 were intubated using direct laryngoscopy, 284 using direct laryngoscopy with bougie introducer, 163 using videolaryngoscopy, and 73 using other techniques. Independent predictors of the primary outcome included age 46 yr or more, body mass index 30 or more, male sex, Mallampati III or IV, neck mass or radiation, limited thyromental distance, sleep apnea, presence of teeth,

beard, thick neck, limited cervical spine mobility, and limited jaw protrusion (c-statistic 0.84 [95% CI, 0.82–0.87]).

**Conclusion:** DMV combined with DL is an infrequent but not rare phenomenon. Most patients can be managed with the use of direct or videolaryngoscopy. An easy to use unweighted risk scale has robust discriminating capacity.

**E**ACH year, nearly 30 million procedures are performed in the United States with general anesthesia, regional anesthesia, deep sedation, or conscious sedation. Due to early data demonstrating the significant risk of depressed oxygenation or ventilation associated with sedation, The Joint Commission and Centers for Medicare and Medicaid Services now require preprocedural processes that evaluate the risk for cardiopulmonary compromise and the potential for a “difficult airway.”<sup>1</sup> In addition, the 2013 Practice Guidelines for Management of the Difficult Airway from the American Society of Anesthesiologists recommend an airway risk assessment before every anesthesia procedure.<sup>2</sup>

Unfortunately, the current airway risk assessment tools in widespread use are focused on one specific aspect of a difficult airway: difficult intubation. A patient-centered definition of the difficult airway would include difficulty in mask ventilation or laryngoscopy because each technique serves as a primary rescue technique for the other.<sup>2,3</sup> Recent data have demonstrated that the incidence and risk factors for difficult mask ventilation (DMV) are distinct from difficult laryngoscopy (DL) predictors.<sup>4–7</sup> A particularly dangerous clinical situation arises when a patient demonstrates DMV combined with difficult intubation, as opposed to either scenario in isolation. There are no published data focused on this combined outcome despite its clinical urgency and relevance.

By using a prospectively collected multicenter database of more than 1 million patients undergoing procedures requiring a structured airway assessment, we sought to identify the incidence, independent predictors, and outcomes of DMV combined with difficult intubation. These multicenter data will define a modern airway examination focused on a comprehensive, outcome-focused definition of the difficult airway as opposed to isolated DMV or difficult intubation. In addition, the techniques and tools used to manage the patients demonstrating a difficult airway across multiple centers and hundreds of providers will inform guidelines with real-world clinical practice and results.

## Materials and Methods

University of Michigan institutional review board approval (Ann Arbor, Michigan) was obtained for this observational study. The institutional review board of each contributing organization also approved aggregation of this limited dataset into the Multicenter Perioperative Outcomes Group–centralized data repository. Signed patient consent was waived because no patient care interventions were involved

in the conduct of the study, and all patient identifiers were destroyed after data collection was completed.

### Patient Population

All adult patients (aged  $\geq 18$  yr) undergoing surgery with general anesthesia at one of four tertiary care academic institutions (University of Michigan, University of Colorado, Oregon Health and Science University, and University of Tennessee) during a 6-yr period from 2006 to 2012 were included for patient analysis. All cases without an attempt at mask ventilation and laryngoscopy were excluded from the data collection and analysis. These included (1) rapid sequence inductions without mask ventilation, (2) planned awake fiberoptic intubation, (3) primary asleep fiberoptic intubation, (4) awake tracheostomy (5) primary use of a supraglottic airway (SGA), (6) preexisting endotracheal tube or invasive airway, and (7) cases performed without general anesthesia. Patients with multiple procedures during the study period had each procedure evaluated as a distinct data point.

### Data Collection

Data were acquired from the Multicenter Perioperative Outcomes Group database, a consortium of medical centers using observational data to assess and improve perioperative outcomes. The detailed methodology of the Multicenter Perioperative Outcomes Group group is discussed elsewhere but will be summarized briefly.<sup>8,9</sup> For each patient, a detailed anesthesia preoperative history and physical is documented by an anesthesia provider with the use of an electronic health record (EHR). This history and physical includes discrete data elements regarding patient anthropomorphic details, airway physical examination information, and other general patient clinical information (table 1). For each data element, a user may easily select from predefined pick lists for each item, or may choose to enter free-text information if they feel that the pick-list options do not accurately describe the clinical situation. A detailed airway physical examination with discrete data for cervical spine mobility, dentition, neck anatomy, thyromental distance, jaw protrusion, mouth opening, and Mallampati oropharyngeal classification (as modified by Samssoon and Young<sup>10</sup>) is incorporated into the anesthesia history and physical. Thyromental distance is subjectively assessed to be normal or less than three fingerbreadths. Jaw protrusion is assessed as normal, limited, or severely limited based on the ability to protrude the mandibular incisors or gums to extend past, meet, or recede behind the maxillary incisors or gums. Mouth opening is assessed as normal or subjectively limited to less than 3 cm. Neck circumference is assessed as subjectively thick or obese and is not measured. A history of sleep apnea was defined to include patients with confirmed sleep apnea by polysomnogram or treatment with bilevel positive airway pressure or continuous positive airway pressure. A sensitivity analysis definition including patients at high suspicion of sleep apnea due to daytime somnolence and observed apneic episodes was also tested.

**Table 1.** Univariate Patient Comparison for the Entire Study Population

	DMV Combined with DL No (N = 175,981)	DMV Combined with DL Yes (N = 698)	P Value	Odds Ratio (95% CI)	Percent Complete Date (%)†
Age ≥46	118,227 (67%)	596 (85%)	<0.001	2.9 (2.3–3.5)	100
Body mass index (kg/m <sup>2</sup> ) ≥30	49,130 (35%)	373 (69%)	<0.001	4.0 (3.3–4.8)	82
Male sex	82,700 (47%)	534 (77%)	<0.001	3.7 (3.1–4.4)	100
Limited thyromental distance	10,407 (6.8%)	101 (17%)	<0.001	2.8 (2.2–3.4)	94
Mallampati III or IV	26,529 (17%)	308 (49%)	<0.001	4.7 (4.0–5.5)	93
Presence of beard	14,751 (13%)	146 (30%)	<0.001	3.0 (2.5–3.6)	80
Sleep apnea	25,393 (17%)	268 (45%)	<0.001	4.0 (3.4–4.7)	90
Presence of teeth	127,682 (83%)	545 (91%)	<0.001	2.0 (1.5–2.6)	96
Limited or severely limited jaw protrusion	10,811 (8.3%)	98 (18%)	<0.001	2.5 (2.0–3.1)	88
Thick neck	22,128 (13%)	265 (38%)	<0.001	4.7 (4.0–5.5)	100
Neck mass or radiation	1,542 (1.0%)	18 (3.0%)	<0.001	3.1 (1.9–4.9)	96
Limited mouth opening	5,349 (3.5%)	49 (8.1%)	<0.001	2.4 (1.8–3.3)	96
Snoring	54,725 (31%)	367 (53%)	<0.001	2.5 (2.1–2.9)	100
Center 1*	48%	46%	0.131	0.9 (0.8–1.0)	100
Center 2*	20%	14%	<0.001	0.6 (0.5–0.8)	100
Center 3*	15%	24%	<0.001	1.9 (1.6–2.2)	100
Center 4*	17%	16%	0.686	1.0 (0.8–1.2)	100

\* To ensure the blinding of specific center and outcomes, absolute sample sizes for each centers are not included. The percent data reflect the distribution of patients by center (*i.e.*, center 2 represented 20% of the patients without the primary outcome). † Percent data complete is based on the derivation data for centers 1, 2, and 3. Center 4 did not include beard and jaw protrusion as a standard airway examination element.

DL = difficult laryngoscopy; DMV = difficult mask ventilation.

Each intraoperative record is documented using the perioperative clinical information system as well. At the four participating institutions, clinicians describe the ease or difficulty of mask ventilation in the intraoperative record using a previously described four-point scale.<sup>11,12</sup> Grade 3 is defined as mask ventilation that is inadequate to maintain oxygenation, unstable mask ventilation, or mask ventilation requiring two providers. Grade 4 mask ventilation is defined as impossible mask ventilation noted by absence of end-tidal carbon dioxide measurement and lack of perceptible chest wall movement during positive-pressure ventilation attempts despite airway adjuncts and additional personnel. In this grading scale, the use of neuromuscular blockade (NMB) or the type of blockade (depolarizing or nondepolarizing) does not affect the designation of mask ventilation grade. The use of NMB during induction of anesthesia (depolarizing or nondepolarizing) was recorded. Due to limitations of EHR data at the minute-by-minute density, it is not possible to reliably ascertain whether NMB was administered concurrent with, during, or after observation of DMV. Laryngoscopy view is documented using a structured pick list of the Cormack-Lehane scale.<sup>13</sup> In addition, all other intraoperative clinical documentation regarding primary intubation laryngoscopy device, use of videolaryngoscopy, airway adjuncts, number

of intubation attempts, and alternative or advanced airway management techniques is entered into the intraoperative record of the perioperative clinical information system.

### Outcomes

The primary outcome was DMV combined with DL. DMV is defined as grade 3 or 4 mask ventilation. DL was defined as a grade 3 or 4 Cormack-Lehane laryngoscopy view,<sup>13</sup> or four or more intubation attempts recorded. Laryngoscopy view was inclusive of direct or videolaryngoscopy. Patients experiencing DMV without DL or DL without DMV did not meet the primary outcome definition. Prospectively defined secondary outcomes included (1) the initial airway rescue technique: intubation with continued difficult face mask ventilation, ventilation using an SGA, patient awakening, or emergent surgical airway and (2) the ultimate airway management technique: direct laryngoscopy, rigid videolaryngoscopy, optical stylet, flexible fiberoptic intubation, case performed using alternate anesthesia technique, patient awakened and case cancelled, or emergency surgical airway. For each case meeting search criteria of DMV combined with DL, the entire intraoperative record was individually reviewed by two study investigators (selected

from Drs. Healy, Aziz, Fiona Linton, Freundlich, Fernandez-Bustamante, Epps, and Jonathan Linton) to independently confirm the primary airway rescue technique, ultimate airway management technique, and any documentation of improvement or worsening of mask ventilation with the use of NMB. In case of disagreement, a third study investigator (Dr. Kheterpal) reviewed the anesthesia record and served as arbiter of the final categorization.

### Care Process

Anesthesia services are provided by anesthesiology-attending staff working independently or with assistance from certified registered nurse anesthetists, anesthesia residents, and fellows-in-training. In general, both mask ventilation and intubation were attempted initially by the anesthesiology resident or certified registered nurse anesthetist if one is involved in the case. All clinical decisions regarding airway management are made by the attending staff. The attending staff may have chosen to perform an awake fiberoptic intubation, rapid sequence induction, or videolaryngoscopy at his or her discretion, thereby eliminating an attempt at mask ventilation or direct laryngoscopy. Mask ventilation was generally performed without a harness using a clear disposable mask. Direct laryngoscopy was performed using a direct laryngoscopy handle and blade. The blade was typically a metal, reusable blade, but in a very small minority of cases, plastic disposable blades were used. These data are not collected in the EHR and not available for analysis. Videolaryngoscopy was performed using Glidescope® (Verathon, Bothell, WA) or C-MAC® (Karl Storz, Tuttlingen, Germany) devices.

### Statistical Analysis

Statistical analysis was performed using SPSS® Version 20 (IBM Corporation, Yonkers, NY). Patients with and without the primary outcome of DMV combined with DL were compared. Age and body mass index were dichotomized to identify the specific value which maximized the sum of sensitivity and specificity for the primary outcome. First, descriptive analyses were performed on all covariate (table 1) variables and the outcome. Categorical data were assessed using the Pearson chi-square test.

To determine independent predictors of DMV combined with DL, a binary logistic regression model was used. Because center 4 did not collect data on jaw protrusion, one of the studied covariates, the logistic regression model was performed using data from centers 1, 2, and 3 only. Center effect was incorporated using a dummy variable for each center. The dataset was randomly split into a derivation (67%) and validation (33%) cohort for the development of the prediction score. Before building the derivation model, collinearity diagnostics were run to determine whether any two covariates are highly correlated with one another. All remaining variables were entered into a nonparsimonious binary logistic regression with the occurrence of the primary outcome, DMV combined with difficult intubation,

as the dependent dichotomous outcome. The model fit was assessed using the Omnibus Test for Model Coefficients and the Hosmer and Lemeshow Test. All variables considered to be significant ( $P < 0.05$ ) in the model were established as independent predictors. Effect size was reported with adjusted odds ratios and 95% CIs for all independent predictors. The discriminating capacity of the resulting model was evaluated using the *c*-statistic.

To improve clinical usability, an unweighted risk scale assigning one point to each independent risk factor was created. In addition, a weighted prediction score based on the  $\beta$  coefficient of the independent predictors was derived from the logistic regression model. The weighted points were calculated by taking the specific  $\beta$  coefficient for each independent predictor divided by the lowest  $\beta$  coefficient of all the independent predictors, multiplied by two, and rounded to the nearest integer. Each patient received a weighted risk score based on the sum of the points for each predictor they possessed. The unweighted and weighted risk scales and the 95% CIs were compared using the *c*-statistic. Unweighted and weighted risk scores were applied to the derivation and validation datasets. Center effect was not incorporated into these risk scales because it is not a clinical element usable for airway management at a given center.

A *post hoc* analysis regarding use of NMB was performed to offer insight into the association between DMV and NMB. First, the incidence of primary outcome, DMV combined with DL, was compared between patients receiving NMB and those who did not using chi-square analysis. Next, the incidence of DMV (with or without DL) was compared among patients receiving NMB and those that did not.

### Power Analysis

Previous preliminary data demonstrated a DMV combined with DL incidence of 0.37%.<sup>4</sup> Assuming that approximately 150,000 patients would meet study inclusion criteria, approximately 550 cases demonstrating the primary outcome were expected. After addressing cases with missing data, assumed to be 20% due to variation in documentation practices across included sites, a population of 440 events would allow use of a derivation and validation cohort and inclusion of approximately 20 covariates in a multivariate analysis while minimizing the impact of model overfitting.<sup>4,14</sup>

### Results

Of the 492,239 anesthesia cases in adult patients performed at the four Multicenter Perioperative Outcomes Group institutions during the study period, 176,679 included a documented attempt at face mask ventilation and laryngoscopy and met the inclusion criteria for this study. Six hundred ninety-eight patients experienced DMV combined with DL, for an overall incidence of 0.40%, or approximately 1 of every 250 patients. Table 1 indicates the univariate associations between primary outcome and the studied covariates. Figure 1 demonstrates

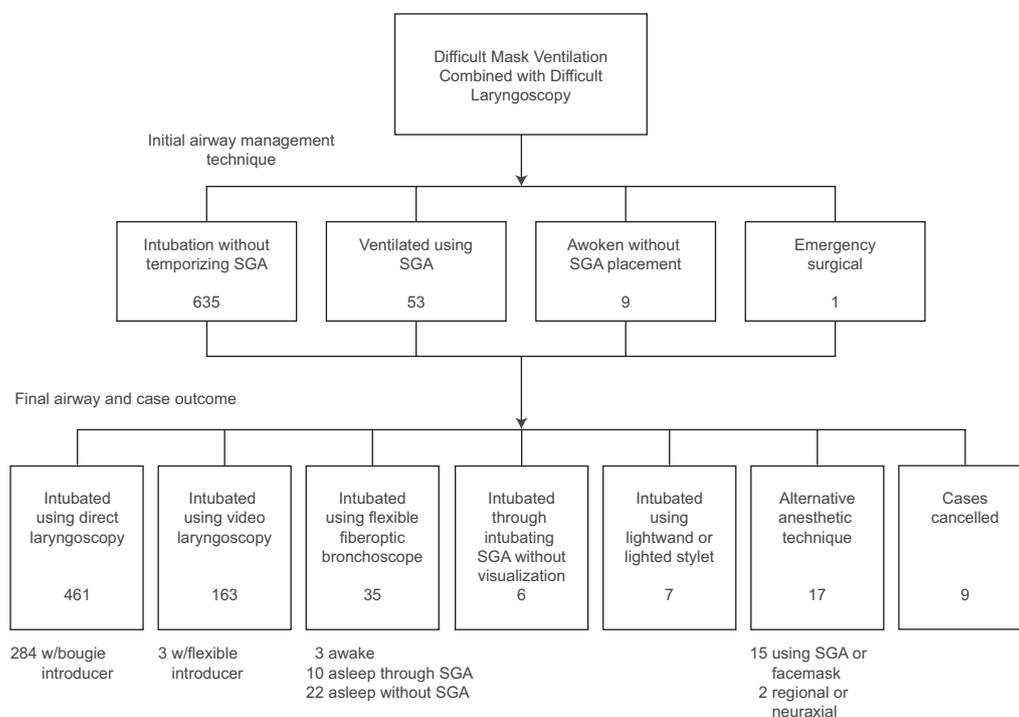
the incidence of the secondary outcomes initial airway rescue technique and final airway and case outcome. In brief, 177 patients were intubated using direct laryngoscopy without bougie introducer, 284 using direct laryngoscopy with bougie introducer, 163 using video or indirect laryngoscopy, 35 using a flexible fiberoptic bronchoscope, and 6 using an intubating SGA without visualization. Of the 35 patients intubated using a flexible fiberoptic bronchoscope, six patients were intubated through an SGA using an Aintree® intubation catheter (Cook Medical, Bloomington, IN) over a pediatric bronchoscope. Seventeen patients had the surgical procedure performed using an alternative anesthesia plan, eight procedures were cancelled, and one patient required an emergent cricothyrotomy. There were no intraoperative patient deaths related to airway management. Of the 698 cases, 19 included a specific comment indicating an improvement of mask ventilation after NMB administration. There were no cases documenting worsening of mask ventilation. There were no cases documenting improvement or worsening of DL, presumably due to the fact that DL was performed after administration of NMB in all cases where NMB was used. Of the seven patients demonstrating grade 4 mask ventilation and a grade 4 laryngoscopic view, four patients were intubated using direct laryngoscopy with bougie, two patients were intubated using videolaryngoscopy, and one patient had the case performed with an SGA. Two patients required temporizing ventilation using an SGA.

Collinearity diagnostics did not demonstrate a condition index over 30, so all covariates were entered into the nonparsimonious logistic regression model (table 1). The derivation

cohort consisted of 98,607 cases of which 60,454 (61%) were included in the logistic regression model. The Omnibus test of Model Coefficients demonstrated a chi-square of 469.141, 16 degrees of freedom and a *P* value less than 0.001. The Hosmer and Lemeshow Test demonstrated a chi-square of 6.568, 8 degrees of freedom and a *P* value of 0.584. Age 46 or greater, male sex, body mass index 30 kg/m<sup>2</sup> or greater, limited thyromental distance, Mallampati oropharyngeal class III or IV, presence of beard, sleep apnea, presence of teeth, limited neck extension, limited jaw protrusion, thick neck, and neck radiation changes or neck mass all demonstrated statistical significance (*P* < 0.05) and clinical significance (adjusted odds ratio >1.5; table 2). The c-statistic of this nonparsimonious model was 0.84 (95% CI, 0.82–0.87), demonstrating good discriminating capacity.

Application of the unweighted and weighted risk scales in the derivation cohort demonstrated a c-statistic of 0.81 (95% CI, 0.78–0.83) for both scales. Application of the risk scales in the validation cohort demonstrated a c-statistic of 0.81 (95% CI, 0.78–0.84) for both the unweighted and weighted risk scales (table 3). The unweighted risk scale was transformed into a risk classification system based on grouping of patients with similar incidence of the primary outcome and ensuring that contiguous risk classes had a statistically significant difference in incidence (table 4).

Of the 176,679 cases included in the analysis, 170,365 (96.4%) included NMB administration during induction of anesthesia, whereas 6,314 (3.6%) did not. Among the patients who did receive NMB, 661 (0.39%) demonstrated the primary outcome, whereas 37 (0.59%) patients without NMB



**Fig. 1.** Initial airway management technique and final airway outcome for 698 patients demonstrating difficult mask ventilation combined with difficult laryngoscopy. SGA = supraglottic airway.

**Table 2.** Derivation Cohort Nonparsimonious Multivariate Logistic Regression Results

Predictor	$\beta$ Coefficient	Standard Error	P Value	Adjusted Odds Ratio (95% CI)
Age $\geq$ 46	0.658	0.182	<0.001	1.93 (1.35–2.76)
Body mass index $\geq$ 30 kg/m <sup>2</sup>	0.770	0.158	<0.001	2.16 (1.58–2.94)
Male sex	0.902	0.159	<0.001	2.46 (1.80–3.36)
Limited thyromental distance	0.877	0.183	<0.001	2.40 (1.68–3.44)
Mallampati III or IV	1.166	0.139	<0.001	3.21 (2.45–4.22)
Presence of beard	0.497	0.157	0.002	1.64 (1.21–2.24)
Sleep apnea	0.466	0.180	0.010	1.59 (1.12–2.27)
Presence of teeth	0.868	0.237	<0.001	2.38 (1.50–3.79)
Unstable cervical spine or limited neck extension	0.384	0.170	0.024	1.47 (1.05–2.05)
Limited or severely limited jaw protrusion	0.382	0.174	0.028	1.47 (1.05–2.05)
Thick neck	0.424	0.154	0.006	1.53 (1.13–2.07)
Neck radiation changes or neck mass	0.945	0.397	0.017	2.57 (1.18–5.60)
Limited mouth opening	0.409	0.249	0.100	1.51 (0.93–2.45)
Snoring	0.269	0.188	0.151	1.31 (0.91–1.89)
Center 1	-0.855	0.180	<0.001	0.43 (0.30–0.61)
Center 2	-1.687	0.394	<0.001	0.19 (0.09–0.40)

demonstrated the primary outcome ( $P = 0.02$ ). Among the patients who did receive NMB, 4,444 (2.6%) experienced DMV (with or without DL), whereas 228 (3.6%) patients without NMB demonstrated the primary outcome ( $P < 0.01$ ).

**Discussion**

These comprehensive multicenter data encompassing nearly 500,000 adult operating room anesthetics across four centers

**Table 3.** Difficult Mask Ventilation Combined with Difficult Laryngoscopy Prediction Score

Predictor	Weighted Points	Unweighted Points
Mallampati III or IV	6	1
Neck radiation changes or neck mass	5	1
Male sex	5	1
Limited thyromental distance	5	1
Presence of teeth	5	1
Body mass index $\geq$ 30 (kg/m <sup>2</sup> )	4	1
Age $\geq$ 46	3	1
Presence of beard	3	1
Thick neck	2	1
Sleep apnea	2	1
Unstable cervical spine or limited neck extension	2	1
Limited or severely limited jaw protrusion	2	1
Total possible	44	12
Validation cohort c-statistic	0.81 (0.78–0.84)	0.81 (0.78–0.84)

demonstrate that the clinically challenging scenario of DMV combined with DL occurs in approximately 1 of every 250 cases. We have identified several important airway physical examination and patient history features that increase the risk of DMV combined with DL. Finally, we have demonstrated the safety of current operating room practices by noting that only one patient required an emergent surgical airway and there were no intraoperative patient deaths related to airway management.

The 2013 Practice Guidelines for Management of the Difficult Airway from the American Society of Anesthesiologists defines a difficult airway as difficulty with facemask ventilation or tracheal intubation, or both.<sup>2</sup> Although the study of difficult tracheal intubation is mature, the focused study of DMV began more recently in 2000 by Langeron *et al.*<sup>15</sup> The focused study of patients with DMV combined with difficult intubation remains nonexistent and is challenging for several reasons. First, the definition of “difficult” for each intervention is unclear and typically inconsistent across providers and centers.<sup>11</sup> Second, the frequency of DMV combined with difficult intubation is presumably low based on previous literature focused on one of the outcomes.<sup>4–6</sup> Our methodology addressed both of these issues.

Data regarding patients demonstrating combined DMV and difficult intubation are essential to guide clinical practice and future guideline development. The 698 cases of DMV combined with DL reported in this article represent the largest analytical dataset of the combined “difficult airway.” First, they inform us that although this phenomenon is infrequent, it is far from rare, occurring once in every 250 general anesthetics requiring mask ventilation and endotracheal intubation. This likely underestimates the true incidence

**Table 4.** Risk Index Classification System—Validation Cohort

Preoperative Risk Class	Total Patients, n	Patients with DMV combined with DL % (n)	Odds Ratio (95% CI)
Class I (0–3 risk factors)	57,439	0.18 (107)	Reference
Class II (4 risk factors)	10,534	0.47 (50)	2.56 (1.83–3.58)
Class III (5 risk factors)	5,815	0.77 (45)	4.18 (2.95–5.93)
Class IV (6 risk factors)	2,775	1.69 (47)	9.23 (6.54–13.04)
Class V (7–11 risk factors)*	1,509	3.31 (50)	18.4 (13.1–25.8)

\* Although 12 risk factors were identified, no patient in the dataset possessed all 12 risk factors. As a result, Class V is comprised of patients with 7–11 risk factors.

DL = difficult laryngoscopy; DMV = difficult mask ventilation.

because many patients with difficult airways may have been directed to awake intubation strategies or techniques that do not involve mask ventilation and laryngoscopy.

Our secondary outcomes describe the initial airway rescue technique and ultimate airway outcome in DMV combined with DL scenarios (fig. 1). Across four centers and hundreds of providers, these data reveal what techniques are used by practicing clinicians. The initial airway management technique analysis demonstrates that although mask ventilation was difficult, only 53 of 698 patients required placement of an SGA. Nine patients were awoken without SGA placement, indicating that facemask ventilation and return of spontaneous ventilation allowed this option. One patient required an emergent surgical airway despite attempts at videolaryngoscopy and SGA placement due to hypoxia and bradycardia. For the remaining 635 patients, intubation with intermittent difficult facemask ventilation was performed.

The ultimate airway and case outcome demonstrates a diverse set of practice patterns in use across these four centers. Although the various practice guidelines offer guidance on the pathway to management of DMV combined with DL, these data reveal the realities of contemporary clinical practice. First, many patients (177) were intubated using direct laryngoscopy alone although many more patients required the aid of a bougie introducer (284). The use of direct and videolaryngoscopy allowed successful airway management of the overwhelming proportion of this population demonstrating difficult airways. This observation is consistent with the results of a prospective evaluation of a novel airway management algorithm at a single medical center.<sup>3</sup> In the current analysis, 41 patients required use of a flexible fiberoptic bronchoscope or intubating SGA. Of note, in 17 cases, the providers chose to simply continue the procedure without endotracheal intubation. In aggregate, these data suggest that the use of videolaryngoscopy as a rescue technique in the most challenging of airway situations plays a significant role, consistent with existing literature.<sup>2,3,16–19</sup>

Our data also offer the first empiric guidance on the value of the airway examination and patient history in predicting DMV combined with DL. We evaluated aspects of the patient history and physical examination (table 1) that have

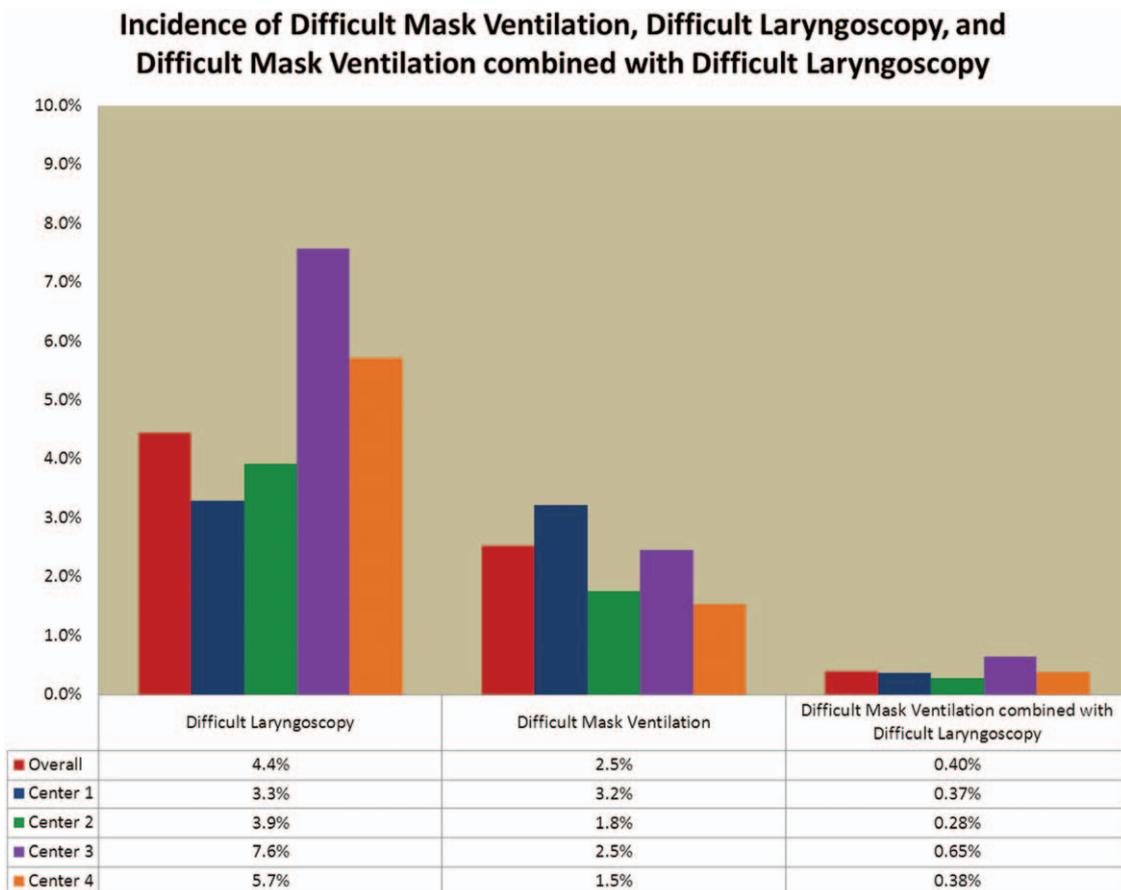
previously been demonstrated to be associated with either DMV or DL. Twelve of the clinical predictors did demonstrate statistically and clinically significant predictive capabilities, as measured by the *P* value and adjusted odds ratio. A comprehensive airway assessment attempting to predict DMV combined with DL should include all of the elements listed in table 3 because they did demonstrate statistically and clinically predictive value. Table 4 allows the practitioner to risk stratify a patient quickly and demonstrates that Class IV and V patients represent a high-risk group warranting advanced airway management preparedness.

Many of the elements we have identified have previously been reported as independent predictors of DMV or difficulty laryngoscopy alone. However, these data are the first to focus on the prediction of the combined outcome of grave clinical concern to the practicing anesthesiologist. The use of data across four different medical centers with divergent care patterns increases the likelihood that these data represent real-world clinical phenomena as opposed to idiosyncratic patient populations or care patterns at a single center. Single-center data have previously demonstrated the role of advanced age, male sex, obesity, limited thyromental distance, Mallampati oropharyngeal proportion, presence of beard, sleep apnea, presence of teeth, limited neck extension, limited jaw protrusion, thick neck, and neck radiation changes or neck mass in the prediction of isolated DMV or DL.<sup>2,4–6,11,15,20–24</sup> A detailed discussion of each risk factor and its pathophysiologic relationship to DMV combined with DL is beyond the scope of this article. However, it should be noted that although some features are presumably related primarily to one component of the outcome, such as presence of beard and DMV, many features represent a shared pathology across DMV and DL and videolaryngoscopy. For example, limited jaw protrusion has been posited as an important element of the airway examination given that both mask ventilation, *via* the jaw thrust, and laryngoscopy, *via* displacement of the tongue into the submental space and movement of the mandible to expand the submental space, depend upon adequate mandibular excursion.<sup>23</sup> A large tongue with associated oropharyngeal disproportion has been postulated as a common abnormality across DMV, DL, and sleep apnea.<sup>25</sup>

A historical controversy regarding the use and impact of NMB on DMV has implications on the interpretation of our data.<sup>7,26,27</sup> An increasing body of well-conducted prospective trials indicates that administration of NMB may actually improve face mask ventilation.<sup>28–30</sup> We believe that these trials and future-controlled experimental models are the definitive data regarding the impact of NMB on DMV, not our dataset or analysis. However, we did note that 19 of 698 cases included documentation of improved face mask ventilation after onset of NMB. In addition, the incidence of DMV or DMV combined with DL was increased in patients who did not receive NMB. These data must be interpreted with great caution and defer to prospective trials conducted by Goodwin *et al.*,<sup>28</sup> Warters *et al.*,<sup>30</sup> and Ikeda *et al.*<sup>29</sup>

Despite the value of these data, there are many limitations. First, as an observational dataset based on the EHR, the data have limitation in the quality and structure of the record even though the EHR was designed to enable data extraction for reporting and research. As a result, data elements that may be of scientific value, but are not clinically usable across hundreds of thousands of patients, such as actual measured thyromental distance or neck circumference, were not available in the dataset. Because the EHR only records pulse oximetry data every 60 s, we choose to exclude this important metric

from the outcome definition. There are also documentation inconsistencies and inaccuracies inherent in the EHR. Next, the study of DMV combined with DL is challenged by patient selection: it is unethical to direct a patient with a known difficult airway toward techniques that do not maintain spontaneous ventilation. As a result, both prospective interventional trials and observational analyses exclude patients with a high suspicion of a difficult airway that are diverted to awake intubation techniques. Some may consider that the current dataset is focused on the “unanticipated difficult airway.” However, clinical practice variation results in many patients with difficult airway features undergoing a standard induction and being included in a dataset such as ours. More than 5.5% of patients had six or more risk factors for DMV combined with DL, demonstrating that these data apply to many of the patients encountered in daily practice (table 4). The four participating institutions are all academic medical centers with their unique patient populations, care processes, and documentation patterns. The varying rates of the primary outcome across the four centers may be due to several forms of variation: underlying patient population, provider skill, advanced airway device availability, practice patterns, or data artifact (fig. 2). Finally, a particular challenging airway scenario occurs in the “cannot intubate—cannot



**Fig. 2.** Incidence of difficult laryngoscopy, difficult mask ventilation, and difficult mask ventilation combined with difficult laryngoscopy across four contributing centers.

ventilate” patient. The data extracted for this analysis were not designed to address this unique and rare patient population. Further studies are necessary.

In conclusion, this is the first large multicenter study evaluating the incidence, predictors, and outcome of DL combined with DMV, an infrequent but not rare event. Rescue is most often achieved with direct and videolaryngoscopy. The real-world data regarding techniques used for rescue may help inform guidelines for airway management.

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## Appendix

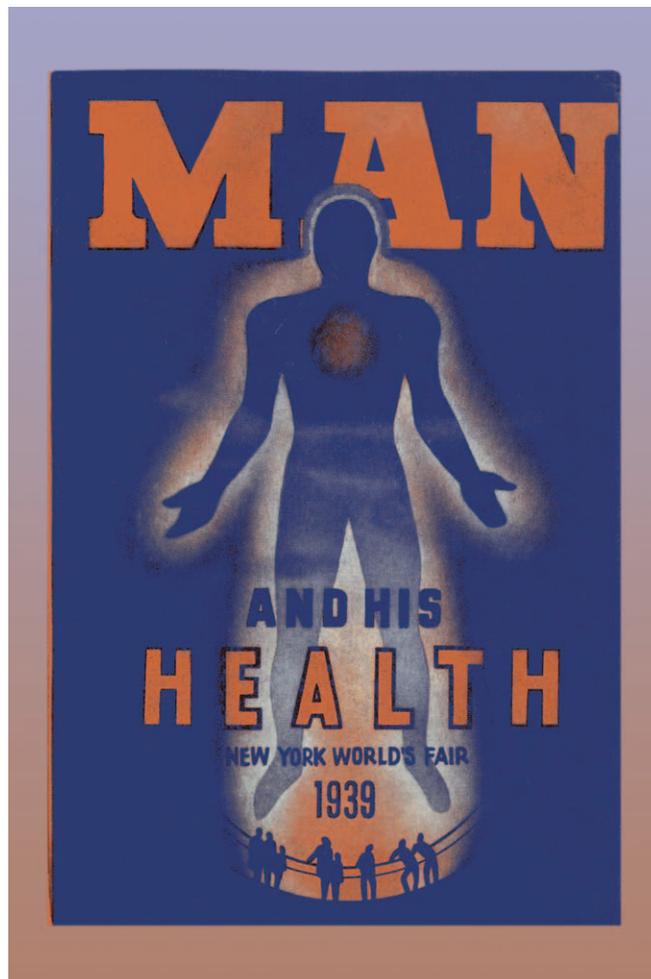
The authors thank the active members of the Multicenter Perioperative Outcomes Group (MPOG) Perioperative Clinical Research Committee: Ana Fernandez-Bustamante, M.D., Ph.D., Assistant Professor, Department of Anesthesiology, University of Colorado, Aurora, Colorado; Leslie C. Jameson, M.D., Associate Professor and Vice Chair, Department of Anesthesiology, University of Colorado, Aurora, Colorado; Daniel A. Biggs, M.D., Assistant Professor, Department of Anesthesiology, University of Oklahoma Health Sciences Center, Oklahoma City, Oklahoma; Jesse Ehrenfeld, M.D., M.P.H., Associate Professor, Department of Anesthesiology, Vanderbilt University Medical Center, Nashville, Tennessee; Jerry L. Epps, M.D., Associate Professor and Chair, Department of Anesthesiology, University of Tennessee Graduate School of Medicine, Knoxville, Tennessee; Robert M. Craft,

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### Man and His Health



Running from 1939–1940, the New York World's Fair included a Medicine and Public Health Building, which was highlighted in a 95-page volume bound with an orange spine titled *Man and His Health ... New York World's Fair 1939*. The book's cover (*above*) is dominated by the blue image of the building's mammoth exhibit, "Pulsation of Life"—a 22-foot-tall human model with a pulsating heart. (The guidebook's color scheme of blue and orange reflects colors traditionally associated with the State of New York.) Near the "Pulsation of Life," the Winthrop Chemical Company sponsored the "Anesthesia" Exhibit, which was designed by a committee chaired by Paul Meyer Wood, M.D. The success of this exhibit helped inspire Dr. Wood to continue collecting books and apparatus for his namesake library-museum, which he helped relocate from multiple New York sites to Park Ridge, Illinois. (Copyright © the American Society of Anesthesiologists, Inc.)

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