ANESTHESIOLOGY

Frequency and Risk Factors for Difficult Intubation in Women Undergoing General Anesthesia for Cesarean Delivery: A Multicenter Retrospective Cohort Analysis

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EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- Previous estimates for the frequency of difficult and failed intubation in the obstetric population vary widely, ranging from 0.3 to 3.3% and from 0 to 0.4%, respectively
- These data are largely based on older studies and may be less relevant now, given the increasing use of regional anesthesia, as well as more advanced management of the airway, including video laryngoscopy

What This Article Tells Us That Is New

- In a cohort of more than 14,000 women receiving general anesthetics for cesarean delivery, the risk of difficult intubation was 1 in 49, and the risk of failed intubation was 1 in 808
- Risk factors for difficult intubation included increased body mass index, Mallampati score III or IV, small hyoid-to-mentum distance, limited jaw protrusion, limited mouth opening, and cervical spine limitations

ABSTRACT

Background: Estimates for the incidence of difficult intubation in the obstetric population vary widely, although previous studies reporting rates of difficult intubation in obstetrics are older and limited by smaller samples. The goals of this study were to provide a contemporary estimate of the frequency of difficult and failed intubation in women undergoing general anesthesia for cesarean delivery and to elucidate risk factors for difficult intubation in women undergoing general anesthesia for cesarean delivery.

Methods: This is a multicenter, retrospective cohort study utilizing the Multicenter Perioperative Outcomes Group database. The study population included women aged 15 to 44 yr undergoing general anesthesia for cesarean delivery between 2004 and 2019 at 1 of 45 medical centers. Coprimary outcomes included the frequencies of difficult and failed intubation. Difficult intubation was defined as Cormack–Lehane view of 3 or greater, three or more intubation attempts, rescue fiberoptic intubation, rescue supraglottic airway, or surgical airway. Failed intubation was defined as any attempt at intubation without successful endotracheal tube placement. The rates of difficult and failed intubation were assessed. Several patient demographic, anatomical, and obstetric factors were evaluated for potential associations with difficult intubation.

Results: This study identified 14,748 cases of cesarean delivery performed under general anesthesia. There were 295 cases of difficult intubation, with a frequency of 1:49 (95% CI, 1:55 to 1:44; n = 14,531). There were 18 cases of failed intubation, with a frequency of 1:808 (95% CI, 1:1,276 to 1:511; n = 14,537). Factors with the highest point estimates for the odds of difficult intubation included increased body mass index, Mallampati score III or IV, small hyoid-to-mentum distance, limited jaw protrusion, limited mouth opening, and cervical spine limitations.

Conclusions: In this large, multicenter, contemporary study of more than 14,000 general anesthetics for cesarean delivery, an overall risk of difficult intubation of 1:49 and a risk of failed intubation of 1:808 were observed. Most risk factors for difficult intubation were nonobstetric in nature. These data demonstrate that difficult intubation in obstetrics remains an ongoing concern.

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Estimates for the frequency of difficult and failed intubation in the obstetric population vary widely, ranging from 0.3 to 3.3% and from 0 to 0.4%, respectively. These frequencies are several times higher than those reported for the general surgical population.[1–13] However, the studies that have examined the rates of difficult and failed intubation in obstetrics are from countries other than the United States or in smaller centers. Furthermore, increased rates of neuraxial anesthesia use may have affected observed

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frequencies of difficult intubation in this population.[14] Video laryngoscope availability and use have also proliferated in recent years, which may have affected frequencies of difficult intubation.[15–17]

Given the potential maternal and neonatal morbidity and mortality associated with difficult or failed intubation, it is important to identify patients in whom intubation will be challenging to allow for preparations for difficult intubation to be made and, ideally, to encourage early neuraxial anesthesia in this patient group. Furthermore, studies have variably shown Mallampati score, obesity, age, and emergency surgery status to be potential risk factors for difficult intubation in obstetrics.[2,3,5,11,18,19] However, limitations in the literature regarding risk factors in obstetric patients include studies that are generally older, have limited power, include limited clinically granular data, or represent single-center studies.

This study aimed to provide an updated estimate of the frequency of difficult and failed intubation in women undergoing general anesthesia for cesarean delivery in the United States, leveraging the large number of cesarean delivery records contained in the Multicenter Perioperative Outcomes Group database. We also aimed to elucidate risk factors for difficult intubation to inform risk stratification based on factors that may be unique to women undergoing general anesthesia for cesarean delivery.

Materials and Methods

This is a multicenter, retrospective, observational cohort study utilizing the Multicenter Perioperative Outcomes Group database. The Multicenter Perioperative Outcomes Group is a consortium of institutions founded in 2008 with a shared data set to facilitate the investigation of perioperative outcomes. The comprehensive methodology of the Multicenter Perioperative Outcomes Group research database has been described in detail.[18,20] Each institution that is a part of the Multicenter Perioperative Outcomes Group uses an electronic health record to extract and export data into a shared database. Data and case validation are performed on the institutional level to ensure quality and consistency of data. The number of Multicenter Perioperative Outcomes Group institutions contributing obstetric cases per year is seen in appendix 2. Institutional review board approval has been obtained from each Multicenter Perioperative Outcomes Group center, and informed consent has been waived. The research protocol, including the data analysis and statistical plan, was written, filed, and approved by the Multicenter Perioperative Outcomes Group perioperative clinical research committee before accessing the data, although several elements of the plan were altered in response to peer review.

Our study population included all women aged 15 to 44 yr undergoing general anesthesia for cesarean delivery between February 6, 2004, and January 11, 2019, at 45 Multicenter Perioperative Outcomes Group sites. Applicable procedure codes and a previously described list of search terms for cesarean delivery[21] were used to define the study population.

Outcomes

Coprimary outcomes included the frequencies of difficult and failed intubation in obstetrics. Potential difficult intubation cases were identified in an automated fashion *via* electronic search of the database for any of the following: observed or labeled difficult tracheal intubation, direct or video laryngoscopy Cormack–Lehane view of 3 or higher, three or more intubation attempts, fiberoptic intubation, laryngeal mask airway placement, surgical airway, documentation of neuromuscular blockade administration without concurrent documentation of endotracheal tube placement, or any documented attempt at direct or video laryngoscopy without concurrent documentation of endotracheal tube placement. This initial definition of difficult intubation used to perform the electronic search of the database for difficult intubations was intentionally expansive to allow for maximal sensitivity of results. All cases electronically identified as potentially difficult were reviewed by two independent investigators (S.C.R. and R.H. or M.S.), who manually classified cases as difficult or failed. All discrepancies between reviewers were resolved by discussion among coauthors (S.C.R., R.H., M.S., and T.T.K.). In the final manual review of cases, difficult intubation was identified using previously defined designations: difficult laryngoscopy (defined as direct or video laryngoscopy Cormack–Lehane view of 3 or greater), three or more intubation attempts, flexible scope intubation after failed laryngoscopy, rescue supraglottic airway, or surgical airway. Failed intubation was a subset of difficult intubation and was defined as any attempt at intubation without successful endotracheal tube placement, including mask ventilation or supraglottic airway placement, after an attempt at intubation was made.[16,22,23] We calculated frequencies of difficult and failed intubation and

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associated 95% CI values for women undergoing general anesthesia for cesarean delivery.

Risk Factors

We assessed the following potential risk factors for difficult intubation in women undergoing general anesthesia for cesarean delivery based on biologic plausibility and risk factors previously studied in the literature[2,5,11,18,19,24]: age (35 to 39 yr or more than 40 yr *vs.* less than 35 yr), body mass index (25 to 39.9 kg/m^2 or more than 40 kg/m^2 *vs.* less than 25 kg/m^2), race/ethnicity (Asian or Pacific Islander, Black, Hispanic, or other/unknown *vs.* White), American Society of Anesthesiologists (Schaumburg, Illinois) Physical Status (III or IV *vs.* I or II), year of delivery 2004 to 2011, Mallampati score (III or IV *vs.* I or II), small hyoid-to-mentum distance (less than three fingerbreadths), subjectively limited jaw protrusion, limited mouth opening (less than 3 cm), altered neck anatomy, cervical spine limitations, labor to cesarean status, induction of labor, presence of preterm delivery, presence of multiple gestation, and presence of preeclampsia or eclampsia.

Statistical Analysis

All cases of general anesthesia for cesarean delivery were pooled across 45 institutions to estimate the incidence of difficult intubation, both overall and stratified by individual patient characteristics and number of risk factors, as well as the incidence of failed intubation. The incidences are presented as point estimates with 95% Wilson score CI. The interrater reliabilities between pairs of investigators for manually classifying cases as difficult and failed intubations were quantified as interrater reliability (κ) statistics with 95% CI.

A set of multilevel logistic regression models was used to estimate the association of 16 potential risk factors, both unadjusted and adjusted for other potential risk factors, with the odds of difficult intubation. The correlation between surgeries at the same hospital was accounted for by including a random intercept for hospital identification in each model. Cases with unknown hospital identification (n = 114) were excluded from risk factor analyses. The data set consisted of variables collected for clinical, not research, purposes at 45 hospital sites with varied local documentation practices, electronic health records, and data submission processes during a 15-yr period, so the vast majority (81%) of potential risk factors had missing data. Potential risk factors with less than 40% missing data were deemed appropriate for analysis using multiple imputation and inclusion in the risk factor–adjusted model; these variables had more observed than missing data, allowing for a meaningful comparison between the distributions of the observed and imputed data in the assessment of imputation model fit. In contrast, potential risk factors with 40% or more missing data were determined to be suboptimal candidates for multiple imputation analysis and were only assessed using complete case analysis. Specifically, potential risk factors with 40% or more missing data were each assessed in individual models for their site-adjusted association with the odds of difficult intubation using complete case analysis and not assessed in combination with other potential risk factors. Potential risk factors with less than 40% missing data were each assessed in both individual models for their site-adjusted association with the odds of difficult intubation, as well as in a combined model for their site and other potential risk factor–adjusted association with the odds of difficult intubation using multiple imputation analysis. Specifically, the fully conditional specification approach[25] was used to create 65 imputed data sets based on observed potential risk factors (those with less than 40% missing data) and difficult intubation values. A total of 65 imputations were performed because 63% of deliveries had at least one missing value for the variables included in the imputation model, and it has been recommended that the number of imputations should be at least as large as the number of observations with incomplete data.[26] Imputation model fit was assessed by comparing the distributions of observed *versus* imputed values in each of the first five imputed data sets for each imputed variable. The odds ratios and corresponding standard errors were estimated using multilevel logistic regression for each of the 65 imputed data sets. Point estimates and standard errors were then combined using Rubin's rules[27] to produce pooled odds ratios with corresponding 95% CI values. As a descriptive analysis, the risk of difficult intubation was calculated as stratified by the number of potential risk factors with site-adjusted odds ratios for difficult intubation of 1.5 or higher.

Logistic regression was used to model the association between delivery date and the odds of difficult intubation utilizing a restricted cubic spline with four knots to allow for a nonlinear relationship between the exposure and log odds of the outcome.[28] The logistic regression model was used to estimate the odds ratio for difficult intubation for January 11, 2019 (representing the last day of data), *versus* July 25, 2011 (halfway between the start and end of data), with corresponding 95% CI values.

All statistical hypothesis tests were two-sided. Statistical analyses were performed with SAS software version 9.4 (SAS Institute, USA) and the rms package implemented in R software version 3.6.1 (R Foundation for Statistical Computing, Austria).

Before analysis, we expected to identify approximately 13,000 patients receiving general anesthesia for cesarean delivery in the Multicenter Perioperative Outcomes Group database. The incidence of difficult intubation for patients receiving general anesthesia for cesarean delivery has been reported as 0.2 to 3.0%.[1–5] Assuming a 1.0% incidence of difficult tracheal intubation, we determined that analysis of 13,000 patients would allow for a 99% probability of

obtaining a 95% Wilson CI half-width for the incidence of ±0.2%.

Results

We identified 14,537 cases of cesarean delivery performed under general anesthesia in the Multicenter Perioperative Outcomes Group database in which difficult and/or failed intubation status was reported. Of these, 1,236 cases were identified as potentially difficult (fig. 1). Upon manual review, there were 295 cases of difficult intubation; the frequency of difficult intubation was 2.03% (95% CI, 1.81 to 2.27). There were 18 cases of failed intubation; the frequency of failed intubation was 0.12% (95% CI, 0.08 to 0.20). There were 45 unique institutions in which cesarean deliveries were identified: 31 academic, medical school–affiliated hospitals and 14 community hospitals. The interrater reliability (κ) between independent reviewers for the outcome of difficult intubation was 0.88 (95% CI, 0.85 to 0.90); κ for the outcome of failed intubation was 0.82 (95% CI, 0.78 to 0.86).

Methods for managing difficult and failed intubations are seen in table 1. Of difficult intubations, 87.8% involved difficult laryngoscopy, defined as a direct or video laryngoscopy Cormack–Lehane grade 3 or 4 view (68.5% of cases were classified as difficult intubations solely due to difficult laryngoscopy); 16.3% required three or more attempts at intubation; 11.5% of cases required a supraglottic airway and were followed by a successful intubation; and 2.4% of cases required flexible scope intubation and were followed by a successful intubation. Of the 18 failed intubations, all were rescued by supraglottic airway placement. One case additionally had a failed flexible scope intubation attempt and a subsequent successful rescue surgical airway. There was one maternal cardiac arrest in the difficult intubation cohort, with ensuing cardiopulmonary resuscitation and eventual return of spontaneous circulation; the etiology of arrest was unknown, but hysterectomy was required for ongoing bleeding. There were no maternal deaths in either the difficult or failed intubation cohorts. Of the difficult intubation cases, there was one noted aspiration event, one noted instance of dental injury, and four instances of pharyngeal injury; however, these outcomes were not routinely commented upon in each case and were only noted if specifically found to be mentioned in the intraoperative anesthetic record.

We evaluated 16 different patient characteristics for a potential association with difficult intubation (tables 2 and 3). Potential risk factors with 40% or more missing data were assessed using complete case analysis, whereas factors with less than 40% missing data were assessed using multiple imputation analysis. Appendix 3 shows similar distributions of observed *versus* imputed values in each of the first five imputed data sets for each imputed variable, suggesting acceptable imputation model fit. Elevated body mass index was strongly associated with increased odds of difficult intubation. Compared to women with a body mass index less than 25 kg/m^2, women with a body mass index of 25 to 39.9 kg/m^2 had an odds ratio of 1.55 for difficult intubation (95% CI, 0.88 to 2.73), and women with a body mass index 40 kg/m^2 or higher had an odds ratio of 2.71 (95% CI, 1.53 to 4.8). Of 28 women with a body mass index of 40 kg/m^2 or more, 1 experienced a difficult intubation. Several airway factors were also strongly associated with the

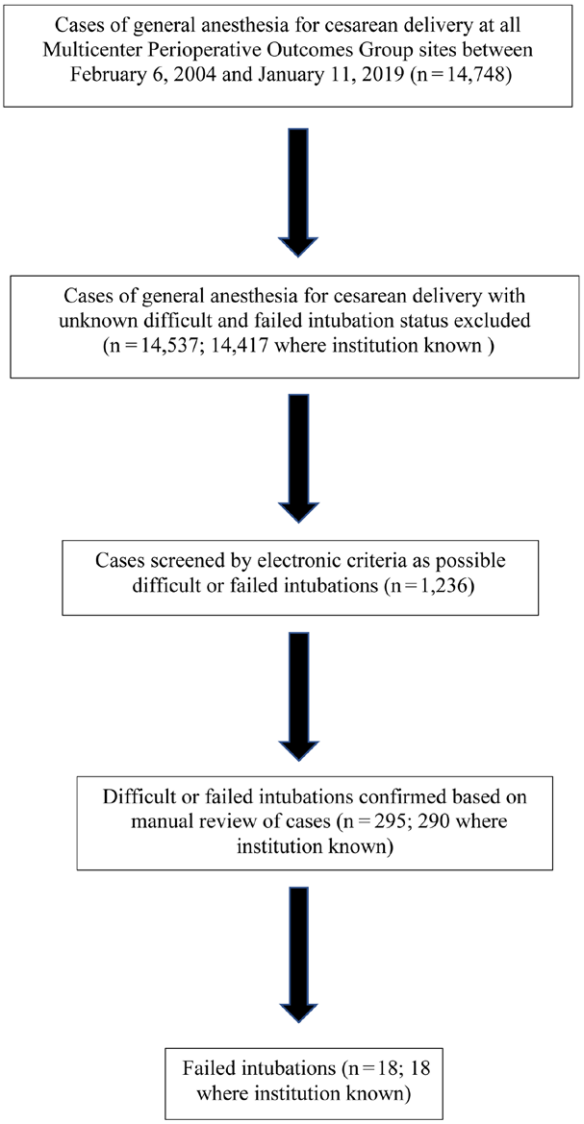

Fig. 1. Cohort selection of obstetric patients. Automated electronic screening criteria were documentation of any of the following: observed or labeled difficult tracheal intubation, direct or video laryngoscopy Cormack–Lehane view of 3 or higher, three or more intubation attempts, fiberoptic intubation, laryngeal mask airway placement, surgical airway, documentation of neuromuscular blockade administration without concurrent documentation of endotracheal tube placement, or any documented attempt at direct or video laryngoscopy without concurrent documentation of endotracheal tube placement.

Table 1. Characteristics of Difficult and Failed Intubations in Obstetric Patients Undergoing General Anesthesia for Cesarean Delivery, 2004 to 2019

Characteristics	Difficult Intubations, No. (%)	Failed Intubations, No. (%)
Total	295 (2.0)	18 (0.1)
Criteria for difficult intubation		
Cormack–Lehane view grade III or IV*	259 (87.8)	8 (44.4)
Requiring three or more attempts at intubation†	48 (16.3)	3 (16.7)
Flexible bronchoscopy attempted after previous failed laryngoscopy	7 (2.4)	1 (5.6)
Supraglottic airway attempted	34 (11.5)	18 (100)
Surgical airway attempted	1 (0.3)	1 (5.6)
Approach to management		
Failed direct laryngoscopy (if attempted)‡	49 (19.2)	14 (100)
Failed video laryngoscopy (if attempted)§	26 (32.1)	10 (100)
Facemask ventilation Han scale 3 or 4	7 (2.4)	2 (11.1)
Complications		
Aspiration noted	1 (0.3)	1 (5.6)
Dental injury noted	1 (0.3)	0
Pharyngeal injury noted	4 (1.4)	0
Cardiac arrest	1 (0.3)	0
Intraoperative death	0	0

*Cormack–Lehane View recorded in 68.3% of patients undergoing general anesthesia for cesarean delivery. †Number of intubation attempts recorded in 63.5% of patients undergoing general anesthesia for cesarean delivery. ‡Direct laryngoscopy attempted in 255 difficult intubations and 14 failed intubations. §Video laryngoscopy attempted in 81 difficult intubations and 10 failed intubations.

risk of difficult intubation. Compared to a Mallampati score of I or II, a Mallampati score of III had an odds ratio of 2.37 (95% CI, 1.72 to, 3.27) for difficult intubation, and a Mallampati score of IV had an odds ratio of 4.6 (95% CI, 2.61 to 8.2) for difficult intubation, such that 1 in 28 women with a Mallampati score of III and 1 in 12 women with a Mallampati score of IV experienced a difficult intubation. Small hyoid-to-mentum distance, limited jaw protrusion, limited mouth opening, and cervical spine limitations were all associated with an increased risk of difficult intubation. Notably, one in nine women with a limited mouth opening experienced a difficult intubation. Of obstetric factors, 1 in 33 women with preeclampsia or eclampsia experienced a difficult intubation.

Factors that retained the strongest associations with the risk of difficult intubation with odds ratios for difficult intubation greater than 1.5 after adjustment for all other potential risk factors (with the exception of small hyoid-to-mentum distance, limited jaw protrusion, limited mouth opening, altered neck anatomy, and cervical spine limitations due to large amounts of missing data) included age 35 yr or more (odds ratio, 1.65; 95% CI, 1.23 to 2.21), age 40 yr or more (odds ratio, 2.17; 95% CI, 1.34 to 3.51); body mass index 40 kg/m^2 or higher (odds ratio, 2.02; 95% CI, 1.12 to 3.63), American Society of Anesthesiologists Physical Status IV (odds ratio, 1.65; 95% CI, 0.93 to 2.92), Mallampati score of III (odds ratio, 2.05; 95% CI, 1.46 to 2.86), and Mallampati score of IV (odds ratio, 3.79; 95% CI, 2.10 to 6.9; table 3).

Figure 2 shows the frequency of difficult intubation stratified by the number of risk factors present, with 1,066 patients having complete documentation of all the factors associated with difficult intubation. Factors included in this analysis were those with odds ratios for difficult intubation of 1.5 or higher without adjustment for other potential risk factors. With increasing numbers of risk factors present, an increasing frequency of difficult intubation was observed. With one risk factor for difficult intubation, the frequency of difficult intubation was 0.8% (95% CI, 0.3 to 2.2); with two risk factors, the frequency was 1.0% (95% CI, 0.3 to 2.8); with three risk factors, the frequency was 3.7% (95% CI, 1.8 to 7.4); with four risk factors, the frequency was 3.8% (95% CI, 1.3 to 10.6); and with five or more risk factors, the frequency was 8.8% (95% CI, 3.0 to 23.0). Figure 3 shows the frequency of difficult intubation over time from 2004 to 2019 as modeled with a restricted cubic spline with four knots. The estimated odds ratio and 95% CI for difficult intubation on January 11, 2019 (representing the last day of data), *versus* July 25, 2011 (halfway between the start and end of data), were 0.41 (95% CI, 0.254 to 0.66).

Discussion

In this large, multicenter study, we examined the frequency of difficult intubation in more than 14,000 general anesthetics for cesarean delivery; we observed a risk of difficult intubation of 1:49 and a risk of failed intubation of 1:808. Most cases of difficult intubation were classified as such due to difficult laryngoscopy, as defined by a grade III or IV Cormack–Lehane view. A total of 18% of difficult intubation cases required three or more attempts at laryngoscopy, and 12% of cases were rescued by a supraglottic airway. We identified several risk factors for difficult intubation in obstetrics, and for some patient characteristics,

Table 2. Obstetric Patient Characteristics

Characteristics	Total, No.	Difficult Intubation, No.	Frequency of Difficult Intubations per 1,000 (95% CI)	Data Complete, %
Age				100
Less than 35 yr	11,526	209	18.1 (15.9–20.7)	
35–39 yr	2,368	66	27.9 (22.0–35.3)	
40 yr or older	637	20	31.4 (20.4–48.0)	
Body mass index				69.6
Less than 25 kg/m^2	1,252	8	6.4 (3.2–12.6)	
25–39.9 kg/m^2	7,089	124	17.5 (14.7–20.8)	
40 kg/m^2 or higher	1,768	63	35.6 (28.0–45.3)	
Race/ethnicity				100
Asian or Pacific Islander	522	6	11.5 (5.3–24.8)	
Black	2,921	72	24.6 (19.6–30.9)	
Hispanic	383	12	31.3 (18.0–54.0)	
White	7,160	126	17.6 (14.8–20.9)	
Other/unknown	3,545	79	22.3 (17.9–27.7)	
ASA Physical Status				96.9
I	519	16	30.8 (19.1–49.5)	
II	8,289	138	16.6 (14.1–19.6)	
III	4,703	119	25.3 (21.2–30.2)	
IV	536	15	28.0 (17.0–45.7)	
V	35	0	0 (0–98.9)	
VI	1	0	0 (0–793.5)	
Year of delivery				100
2004 to 2005	125	2	16.0 (4.4–56.5)	
2006 to 2007	253	1	4.0 (0.7–22.0)	
2008 to 2009	579	15	25.9 (15.8–42.3)	
2010 to 2011	1,346	38	28.2 (20.6–38.5)	
2012 to 2013	2,249	59	26.2 (20.4–33.7)	
2014 to 2015	3,141	70	22.3 (17.7–28.1)	
2016 to 2017	4,722	89	18.8 (15.3–23.1)	
2018 to 2019	2,116	21	9.9 (6.5–15.1)	
Mallampati score				63.9
I or II	7,450	118	15.8 (13.2–18.9)	
III	1,673	59	35.3 (27.4–45.2)	
IV	163	14	85.9 (51.9–139.0)	
Small hyoid-to-mentum distance, n				26.0
No	3,683	78	21.2 (17.0–26.4)	
Yes	88	6	68.2 (31.6–140.9)	
Limited jaw protrusion, n				29.8
No	4,227	74	17.5 (14.0–21.9)	
Yes	107	5	46.7 (20.1–104.8)	
Limited mouth opening, n				29.3
No	4,183	67	16.0 (12.6–20.3)	
Yes	71	8	112.7 (58.2–206.9)	
Altered neck anatomy, n				33.9
No	4,555	68	14.9 (11.8–18.9)	
Yes	376	9	23.9 (12.6–44.9)	
Cervical spine limitations, n				26.3
No	3,771	77	20.4 (16.4–25.4)	
Yes	54	4	74.1 (29.2–175.5)	
Labor to cesarean status, n				72.1
No	8,482	180	21.2 (18.4–24.5)	
Yes	1,990	49	24.6 (18.7–32.4)	
Induction of labor, n				83.9
No	11,701	241	20.6 (18.2–23.3)	
Yes	492	15	30.5 (18.6–49.7)	
Presence of preterm delivery, n				72.4
No	9,098	195	21.4 (18.7–24.6)	
Yes	1,423	27	19.0 (13.1–27.5)	
Presence of multiple gestation, n				72.4
No	9,986	211	21.1 (18.5–24.1)	
Yes	535	11	20.6 (11.5–36.4)	
Presence of preeclampsia or eclampsia, n				72.4
No	9,320	186	20.0 (17.3–23.0)	
Yes	1,201	36	30.0 (21.7–41.2)	

ASA, American Society of Anesthesiologists.

Table 3. Associations between Obstetric Patient Characteristics and Odds of Difficult Intubation

Characteristics	Site-adjusted Odds Ratio (95% CI)	Site- and Factor-adjusted Odds Ratio (95% CI)	Risk of Difficult Intubation
Overall			1:49
Age			
Less than 35 yr	Reference	Reference	1:55
35–39 yr	1.66 (1.24–2.21)	1.65 (1.23–2.21)	1:36
40 yr or more	2.14 (1.33–3.44)	2.17 (1.34–3.51)	1:32
Body mass index			
Less than 25 kg/m^2	Reference	Reference	1:156
25–39.9 kg/m^2	1.55 (0.88–2.73)	1.48 (0.84–2.60)	1:57
40 kg/m^2 or higher	2.71 (1.53–4.8)	2.02 (1.12–3.63)	1:28
Race/ethnicity			
Asian or Pacific Islander	0.89 (0.388–2.06)	0.89 (0.383–2.07)	1:87
Black	1.46 (1.06–2.02)	1.34 (0.96–1.87)	1:41
Hispanic	2.06 (1.07–4.0)	1.91 (0.98–3.75)	1:32
White	Reference	Reference	1:57
Other/unknown	1.17 (0.86–1.59)	1.10 (0.80–1.52)	1:45
ASA status			
I or II	Reference	Reference	1:57
III	1.61 (1.25–2.07)	1.23 (0.93–1.63)	1:40
IV–VI	2.01 (1.17–3.48)	1.65 (0.93–2.92)	1:38
Year of delivery, 2004–2011*	1.21 (0.88–1.67)	1.37 (0.98–1.92)	1:41
Mallampati score			
I or II	Reference	Reference	1:63
III	2.37 (1.72–3.27)	2.05 (1.46–2.86)	1:28
IV	4.6 (2.61–8.2)	3.79 (2.10–6.85)	1:12
Small hyoid-to-mentum distance†	3.03 (1.27–7.3)		1:15
Limited jaw protrusion†	2.67 (1.04–6.9)		1:21
Limited mouth opening†	8.2 (3.72–17.9)		1:9
Altered neck anatomy†	1.85 (0.89–3.86)		1:42
Cervical spine limitation†	4.5 (1.54–13.0)		1:14
Labor to cesarean status	1.11 (0.78–1.59)	1.20 (0.82–1.75)	1:41
Induction of labor	1.13 (0.62–2.06)	1.03 (0.54–1.94)	1:33
Presence of preterm delivery	1.02 (0.67–1.55)	0.98 (0.63–1.51)	1:53
Presence of multiple gestation	1.09 (0.58–2.05)	1.09 (0.57–2.09)	1:49
Presence of preeclampsia or eclampsia	1.67 (1.16–2.40)	1.28 (0.87–1.89)	1:33

All odds ratio and CI values were obtained *via* combination of point estimates and standard errors from 65 imputed data sets using Rubin's rules, except where otherwise specified.

*Reference 2012 to 2019. †Due to missingness of 40% or more, site-adjusted odds ratios and CI values for factors obtained using complete case analysis and factors not included in site- and factor-adjusted model were estimated using multiple imputation.

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the risk of difficult intubation was substantial. One in 28 women with a body mass index 40 kg/m^2 or more, 1 in 12 women with a Mallampati score of IV, and 1 in 9 women with a limited mouth opening experienced a difficult intubation. Most factors strongly associated with difficult intubation were nonobstetric in nature and were related to patient or airway characteristics. When examining the rates of difficult intubation over time, we found a decrease in the frequency of difficult intubation in the second half of the study period. The proliferation of video laryngoscopy during the time period may be associated with this observation,[15–17] although additional studies are needed to confirm this finding.

The frequencies of difficult and failed intubation that we observed in our study are in line with those seen in the published literature.[1–13] However, these frequencies are difficult to compare directly among studies, as there is no standard definition for such outcomes, and the patient populations and time frames in which the studies were conducted vary widely. For example, definitions for failed intubation vary from unsuccessful intubations after a single dose of succinylcholine to inability to intubate during general anesthesia, with the latter being closer to the relatively more stringent definition for failed intubation we have adopted.[3,8,9] Nonetheless, our rate of difficult intubation, 1:49, is consistent with results in the published literature, which range widely from 1:30 to 1:400; our rate of failed intubation, 1:808, is also within the range of the published literature, from no cases of failed intubation in one community-based case series to 1:200.[1–5] We also found that all 18 cases of failed intubation were rescued with a supraglottic airway device, which is also consistent with a trend in the literature toward increasing supraglottic airway use in cases of failed intubation.[5,29] However, our large, multicenter,

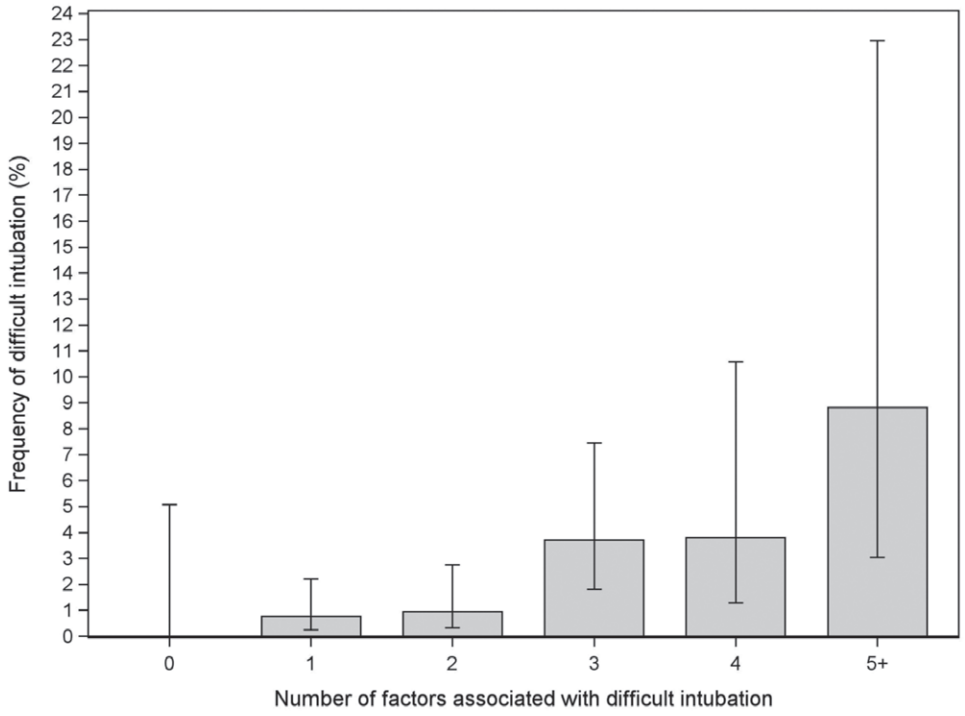

Fig. 2. Frequency of difficult intubation stratified by number of risk factors present. The *x axis* shows the number of factors associated with difficult intubation. The factors included in the analyses are those with univariate odds ratio for difficult intubation greater than 1.50: age 35 yr or more, body mass index of 25 or higher, American Society of Anesthesiologists Physical Status III or IV, Mallampati score III or IV, small hyoid-to-mentum distance, limited jaw protrusion, limited mouth opening, altered neck anatomy, cervical spine limitations, and presence of preeclampsia or eclampsia (race excluded given widely varying estimates). The *y axis* shows the frequency of difficult intubation, with *error bars* representing 95% CI.

United States–based study encompassed multiple hospital types and a variety of patient populations. Further, in contrast to many previous studies in this area, we were also able to examine risk factors for difficult intubation.

Our findings suggest that difficult intubation in women undergoing general anesthesia for cesarean delivery remains a significant concern, particularly among a subset of patients that we have identified with substantial risk factors for difficult intubation, such as elevated body mass index and abnormal airway anatomy. These patients are the ones in whom early anesthetic planning may be preferable to reduce the likelihood that their airway will need to be instrumented. Despite the proliferation of video laryngoscopy and the shift toward neuraxial anesthesia, airway concerns in women undergoing general anesthesia for cesarean delivery remain, and providers should be cognizant of the possibility of difficult intubation, as well as the increased risk of difficult intubation with an increasing number of risk factors.

Strengths of this study include the expansion of our current understanding of difficult intubation in women undergoing general anesthesia for cesarean delivery, based on the largest multicenter sample evaluated to date. Our large sample size provides us with adequate power to more precisely estimate the risk of difficult intubation associated with a variety of patient characteristics and to examine obstetrical risk factors for difficult intubation. Limitations of this study include those inherent to an observational study based on electronic health record data. Risk factors for difficult tracheal intubation may be incompletely identified if documentation is not comprehensive for each case. In particular, many airway factors of interest (small hyoid-to-mentum distance, limited jaw protrusion, limited mouth opening, altered neck anatomy, and cervical spine limitations) had more than 65% missing data, precluding multiple imputation analysis and estimation of their association with difficult intubation while adjusting for other potential risk factors. We attempted to account for missing data in potential risk factors without significant missingness (*i.e.*, less than 40%) using multiple imputation analysis and appeared to obtain a well-fit imputation model. However, all estimates and CI values from both complete case and multiple imputation analyses must be interpreted in the context of this missingness. In addition, there were multiple cases that were labeled as difficult intubations by the provider in the anesthetic record but either did not have a documented reason for this designation or did not meet our criteria for

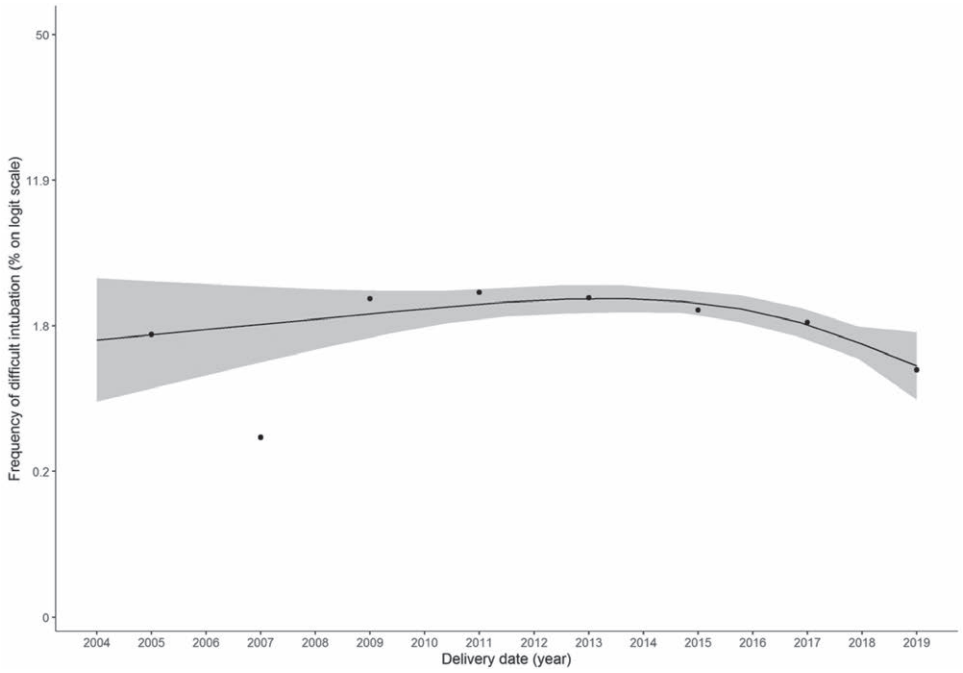

Fig. 3. Frequency of difficult intubation over time. The *x axis* shows the delivery date (yr). On the *y axis*, the *lines* and *band* represent the predicted frequency and 95% CI, respectively, for difficult intubation over time as estimated using a logistic regression model with restricted cubic spline. The axis is on the logit scale to correspond to the logistic regression model. *Scatterplot dots* are shown representing observed percentages of difficult intubations for every 2-yr period.

difficult intubation. Therefore, these cases were not counted as difficult intubations in our final manual review, and this discrepancy could potentially mean that our calculated frequency of difficult intubation is lower than the actual frequency of difficult intubation. Further, although worsening of Mallampati scores throughout labor is a known phenomenon,[30] the Multicenter Perioperative Outcomes Group database contained only one airway examination per patient. It is also not possible to determine provider experience level with each given device or attempt; some attempts at intubation may be performed by relatively inexperienced providers at teaching hospitals. Institutional factors may also differ in determining whether direct *versus* video laryngoscopy is attempted initially, potentially altering the ability to compare rescue device success rates. We were also not able to determine whether cesarean delivery cases were performed on an emergent basis, which might have an impact on a provider's ability to secure an airway. While the Multicenter Perioperative Outcomes Group database consists of a large database of multiple institutions, academic institutions are overrepresented. As a result, the patient population may skew toward a higher acuity and may not be representative of community practices. Furthermore, our results may not be generalizable to all obstetric patients as a whole, given that women with a known or suspected difficult airway may be more likely to have had a planned regional anesthetic.

These data from a large, multicenter sample from the United States demonstrate that we need to continue to be vigilant for the possibility of difficult intubation in women undergoing general anesthesia for cesarean delivery. A thorough evaluation and early epidural analgesia for patients in whom it is appropriate may help minimize the need for intubation in the highest-risk patients.

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Competing Interests

The authors declare no competing interests.

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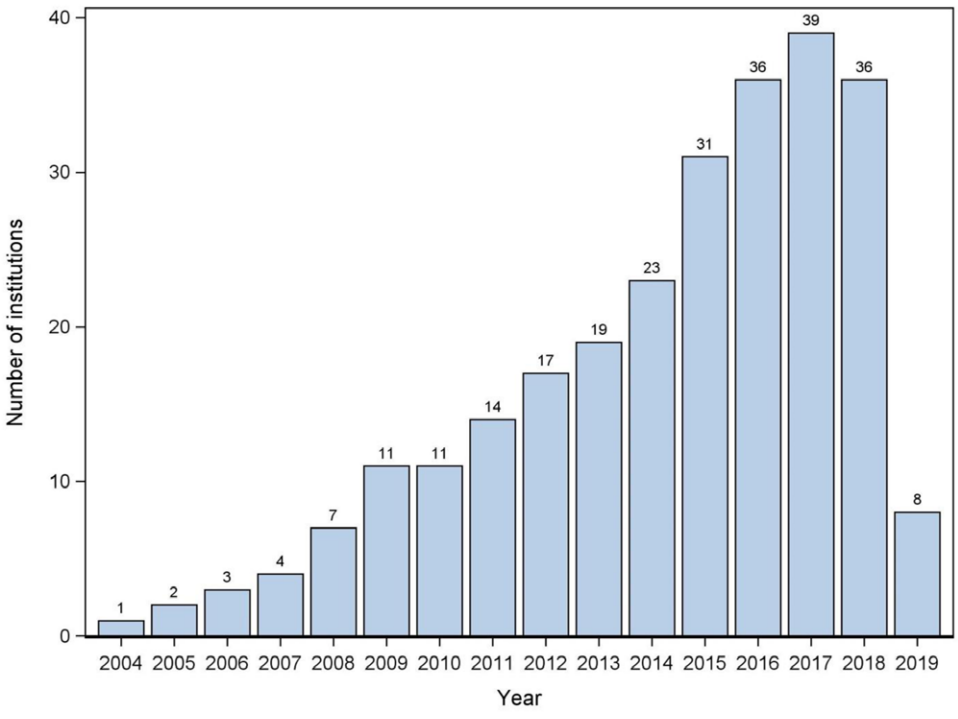
Appendix 1. Multicenter Perioperative Outcomes Group Collaborators

The following Multicenter Perioperative Outcomes Group study group members are collaborators: J. David Clark, M.D., Ph.D., Karen B. Domino, M.D., M.P.H., Robert E. Freundlich, M.D., M.S., M.S.C.I., F.A.S.A., Roya Saffary, M.D., Robert B. Schonberger, M.D., M.H.S., Alvin F. Stewart, M.D., Brad M. Taicher, D.O., M.B.A., Sarah Tingle, M.D., Brandon Michael Togioka, M.D., Richard Urman, M.D., M.B.A., Shital Vachhani, M.D.

Appendix 2. Number of Multicenter Perioperative Outcomes Group Institutions Contributing Obstetric Cases per Year



Appendix 3. Distribution of Observed *versus* Imputed Values for Five Imputed Data Sets

Characteristics	Observed Values	Imputed Values 1	Imputed Values 2	Imputed Values 3	Imputed Values 4	Imputed Values 5
Body mass index, No. (%)						
Less than 25 kg/m^2	1,246 (12.5)	550 (12.5)	575 (13.0)	556 (12.6)	553 (12.5)	554 (12.6)
25–39.9 kg/m^2	7,015 (70.1)	3,110 (70.5)	3,078 (69.8)	3,029 (68.7)	3,116 (70.7)	3,004 (68.1)
40 kg/m^2 or more	1,746 (17.5)	750 (17.0)	757 (17.2)	825 (18.7)	741 (16.8)	852 (19.3)
ASA Physical Status						
I or II	8,740 (62.6)	311 (69.9)	298 (67.0)	293 (65.8)	298 (67.0)	311 (69.9)
III	4,664 (33.4)	118 (26.5)	133 (29.9)	141 (31.7)	138 (31.0)	123 (27.6)
IV–VI	568 (4.1)	16 (3.6)	14 (3.2)	11 (2.5)	9 (2.0)	11 (2.5)
Mallampati score, No. (%)						
I or II	7,369 (80.2)	4,263 (81.5)	4,226 (80.8)	4,278 (81.8)	4,213 (80.5)	4,257 (81.4)
III	1,655 (18.0)	884 (16.9)	929 (17.8)	861 (16.5)	915 (17.5)	886 (16.9)
IV	162 (1.8)	84 (1.6)	76 (1.5)	92 (1.8)	103 (2.0)	88 (1.7)
Labor to cesarean status, No. (%)						
No	8,432 (81.3)	3,309 (81.9)	3,291 (81.4)	3,312 (81.9)	3,288 (81.3)	3,321 (82.1)
Yes	1,942 (18.7)	734 (18.2)	752 (18.6)	731 (18.1)	755 (18.7)	722 (17.9)
Induction of labor, No. (%)						
No	11,608 (96.0)	2,224 (95.8)	2,203 (94.9)	2,213 (95.4)	2,203 (94.9)	2,217 (95.5)
Yes	488 (4.0)	97 (4.2)	118 (5.1)	108 (4.7)	118 (5.1)	104 (4.5)
Presence of preterm delivery, No. (%)						
No	9,008 (86.4)	3,415 (85.5)	3,446 (86.3)	3,411 (85.4)	3,374 (84.5)	3,450 (86.4)
Yes	1,414 (13.6)	580 (14.5)	549 (13.7)	584 (14.6)	621 (15.5)	545 (13.6)
Presence of multiple gestations, No. (%)						
No	9,895 (94.9)	3,799 (95.1)	3,793 (94.9)	3,799 (95.1)	3,769 (94.3)	3,797 (95.0)
Yes	527 (5.1)	196 (4.9)	202 (5.1)	196 (4.9)	226 (5.7)	198 (5.0)
Presence of preeclampsia or eclampsia, No. (%)						
No	9,230 (88.6)	3,537 (88.5)	3,548 (88.8)	3,589 (89.8)	3,524 (88.2)	3,557 (89.0)
Yes	1,192 (11.4)	458 (11.5)	447 (11.2)	406 (10.2)	471 (11.8)	438 (11.0)

ASA, American Society of Anesthesiologists.