Airway Assessment Before Intervention: What We Know and What We Do

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One of our colleagues failed to intubate the trachea of a patient whom he had easily intubated under direct laryngoscopy (DL) several weeks earlier for a craniotomy.[1] On this occasion, the patient's mouth opening was severely limited by contracture of the temporalis muscle after the previous temporal fossa craniotomy. The patient was confused and uncooperative, precluding a complete airway examination. This led to the failure to detect the limited mouth opening before the induction of general anesthesia. In other words, failure to assess the airway was the reason for the failed tracheal intubation. One year later, another colleague gave an anesthetic to the same patient and again, without consulting old anesthetic records or fully assessing the patient's airway before induction, he also encountered a failed tracheal intubation under general anesthesia. That was in the 1980s. We have learned a lot since then. Are we doing better today?

The American Society of Anesthesiologists closed claims project in the United States[2,3] and the fourth National Audit Project in the United Kingdom[4,5] have reported that difficulty with and failure to successfully manage the airway are associated with serious adverse respiratory events. The single most important factor likely to lead to an inability to intubate and oxygenate is the failure to predict difficulties before managing the airway.[6]

In the 1980s, Mallampati et al.,[7] Samsoon and Young,[8] Wilson et al.,[9] and other investigators[10] proposed several methods of assessing the airway in an effort to predict a difficult DL intubation, the most common method of tracheal intubation at the time. Despite some success and wide acceptance, all these methods have limitations. Because of the low incidence of a failed DL, we now know that almost all univariate predictors have low positive predictive value[11] and that the use of multivariate predictors appears to improve the positive predictive value of these airway assessment tools for DL.[12–14] A report from the Danish Anaesthesia Database,[15] which included 188,064 patients, showed that the diagnostic accuracy of the anesthesiologists' predictions of difficult DL intubation and difficult mask ventilation was poor. Of 3391 difficult intubations, 3154 (93%) were unanticipated. When difficult DL intubation was anticipated, only 25% (229 of 929) turned out to actually be difficult to intubate. One of the limitations of the study is that only 2 questions were asked in the preoperative airway assessment: (1) Is difficult DL intubation anticipated? and (2) Is difficult bag-mask-ventilation (BMV) anticipated? Unfortunately, no airway assessment tools were disclosed in the preinduction assessment. It is difficult to draw any conclusion regarding the value of preanesthesia airway assessment if many of the accepted airway evaluation tools for DL were not used.

Around the turn of the 21st century and with advances in technology, the focus of contemporary airway management practice has changed from tracheal intubation to the broader issue of oxygenation and ventilation.[16–18] This has involved emphasizing the utility of all of BMV, use of extraglottic devices (EGDs), tracheal intubation using DL and indirect laryngoscopes as well as other alternative techniques (visual and nonvisual), and the invasive surgical airway in managing the airway. Accordingly, in addition to assessing the predictors of a difficult DL, emphasis has been placed on expanding the preinduction airway examination to include evaluations of predictors of difficult BMV, difficult use of an EGD, difficult use of DL and indirect laryngoscopic intubation, and a difficult surgical airway.[18,19] It is encouraging to see that during the past decade, a considerable number of studies have emerged to investigate the predictors of difficult use of BMV, EGD, DL, and cricothyrotomy.[19] During the same period, a large number of rigid fiber-optic and videolaryngoscopic devices have been introduced into clinical practice. Despite their proven efficacy and increased use in patients with unanticipated and anticipated difficult DL intubations,[20] there has been little critical evaluation of the difficulties and challenges associated with using these devices, and little practical advice has been provided in the specifics of their utilization. Few investigations have reported factors associated with difficult use of these devices so far.[15,21–23] It is welcome news that, in this issue of the Journal, Nowakowski et al.[24] report findings regarding predictors of difficulty when using the Bonfils Rigid

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Fiberscope in a study involving 400 patients. Limited mouth opening, high body mass index, and high Cormack and Lehane grade are shown to be associated with longer intubation times with the Bonfils Rigid Fiberscope. Interestingly, these also are some of the predictors of difficult DL. It is encouraging to see that more investigators are beginning to show an interest in analyzing the specific strengths and weaknesses of devices that are promoted for airway management, and these findings will be reflected in a requirement for careful airway assessment. Clearly, it is not a simple task to assess the difficulties associated with using these newer devices while their designs are constantly changing with new modifications. In addition, an airway evaluation is not complete without an assessment of old anesthetic records and seeking any information present in databases. For the third anesthetic given to the patient presented earlier, a failed DL would have been anticipated had the anesthesia practitioner checked the patient's previous anesthetic records.

In hopes of minimizing the risk of complications, anesthesia organizations around the globe advocate for the identification of potential problems with oxygenation and ventilation before induction of general anesthesia, so that strategies and plans can be made beforehand.[4,5,19,25] Recognizing that there is no reliable way of predicting difficult airway management,[14,15] airway practitioners are being advised to identify and prepare alternative airway techniques such as an EGD and to call for assistance should oxygenation and ventilation become compromised. More importantly, if airway practitioners anticipate difficulties in using most of the airway techniques (e.g., BMV, EGD, and DL), it would be prudent to manage the airway awake with the patient breathing spontaneously. Furthermore, it is also important to discuss such an airway management plan before the induction of general anesthesia during the team briefing and the preinduction phase of the World Health Organization Surgical Safety Checklist.[26,27]

To understand the methods of preanesthetic airway assessment currently in use worldwide, we solicited preanesthetic airway assessment forms from colleagues in 10 countries. Several forms were electronic versions (mostly from North America) and the remainder was hard copies of standard preanesthetic assessment forms. Not surprisingly, the airway assessment section on these forms varied substantially, ranging from free text (descriptive) to a more detailed list of predictors of difficult DL, such as the Mallampati score, thyromental distance, jaw protrusion, mouth opening, and cervical spine movement. Interestingly, with the exception of the free text forms, all asked for a Mallampati score. Less frequently mentioned were the thyromental distance (60%), cervical spine movement (50%), dentition (50%), and mouth opening (40%). None of the forms listed other predictors of difficult DL, such as the sternomental distance, Wilson risk scores, neck circumference, or the upper lip bite test. Only one center asked for predicted difficulty in BMV and surgical airway (cricothyrotomy) and not one mentioned an assessment for predicted difficulty in using the EGD. Recognizing that some of the predictors of difficult DL are also predictors of difficulty in the use of other airway techniques such as BMV,[19,28] it appears that assessment for a difficult DL remains the main focus of airway assessment at most centers around the globe. More importantly, the broader approach in airway assessment, including forewarnings of difficulties with BMV, EGD use, videolaryngoscopy, and cricothyrotomy are largely ignored. It is disturbing to realize that, although we have made great strides in technology to improve airway management, efforts to assess risks, in this small sample, vary greatly. In addition, it is alarming to contemplate that little attention is being paid to assessing the overall difficulties that may arise in providing oxygenation and ventilation.

There appears to be a disconnect between what we know and what we actually do in clinical practice. What is the missing link? Perhaps human factors may be blamed for most of the discrepancies between recommendations and actual clinical practice.[29] In fourth National Audit Project,[4,5] human factors were considered to have contributed to almost all serious adverse outcomes. In that report, widespread deficiencies in judgment, communication, planning, equipment, and training were identified. How can these findings be applied to our clinical practice to improve outcomes? Perhaps we can borrow the approach from the Process Safety Management Guidelines and Compliance of the US Department of Labor.[30] Using this approach, "…the process design, process technology, process changes, operational and maintenance activities and procedures, non-routine activities and procedures, emergency preparedness plans and procedures, training programs, and other elements that affect the process are all considered in the evaluation…." This may be the right approach for us, but it would be costly and painful. Perhaps education through reading, seminars, workshops, and simulations would be a good start. Leadership from all organizations must embrace changes that would improve outcomes, implement programs with proven successes, engage collaborative efforts with other departments, and promote continuing medical education and simulation-based training addressing the issues around human factors, including planning and decision making.

In summary, the case we presented earlier[1] and other outcome studies[2–5] serve to remind us that preanesthetic assessment of the airway is essential to avoid catastrophe. Unfortunately, during the past 30 years, although tremendous advances in airway management devices have taken place, failure to identify difficulties before airway intervention continues with disturbing frequency. Recommendations have been made, and yet our practice does not appear to reflect these needed changes. In the Danish Anaesthesia Database study,[15] the investigators concluded that "…prediction of difficulties remains a challenging task. There may be ample room for improvement, based on a rigorous, evidence based and systematic approach…" This is a call to action. We must find solutions to improve and correct problems related to incomplete airway assessment so that appropriate airway management strategies can be planned before induction of anesthesia. We must do it ourselves and do it now. ■

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Predictors of Difficult Intubation with the Bonfils Rigid Fiberscope

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BACKGROUND: Endotracheal intubation is commonly performed via direct laryngoscopy (DL). However, in certain patients, DL may be difficult or impossible. The Bonfils Rigid Fiberscope® (BRF) is an alternative intubation device, the design of which raises the question of whether factors that predict difficult DL also predict difficult BRF. We undertook this study to determine which demographic, morphologic, and morphometric factors predict difficult intubation with the BRF.

METHODS: Four hundred adult patients scheduled for elective surgery were recruited. Patients were excluded if awake intubation, rapid sequence induction, or induction without neuromuscular blocking agents was planned. Data were recorded, including age, sex, weight, height, American Society of Anesthesiologist classification, history of snoring and sleep apnea, Mallampati class, upper lip bite test score, interincisor, thyromental and sternothyroid distances, manubriomental distances in flexion and extension, neck circumference, maximal neck flexion and extension, neck skinfold thickness at the cricoid cartilage, and Cormack and Lehane grade obtained via DL after paralysis was confirmed. Quality of glottic visualization (good or poor), as well as the number of intubation attempts and time to successful intubation with the BRF, was noted. Univariate analyses were performed to evaluate the association between patient characteristics and time required for intubation. Variables that exhibited a significant correlation were included in a multivariate analysis using a standard least squares model. A $P < 0.05$ was considered significant.

RESULTS: Glottic visualization with the BRF was good in 396 of 400 (99%) cases. On the first attempt, 390 patients were successfully intubated with the BRF; 6 patients required >1 attempt; 4 patients could not be intubated by using the BRF alone. These 4 patients were intubated by using a combination of DL and BRF (2 patients), DL and a Frova bougie (1 patient), and DL and an endotracheal tube shaped with a semirigid stylet (1 patient). Mean time for successful intubation was 26 ± 13 seconds. Multivariate analysis showed that decreased mouth opening ($P = 0.008$), increased body mass index ($P = 0.011$), and higher Cormack and Lehane grade ($P = 0.038$) predicted longer intubation times, whereas shorter thyromental distance predicted slightly shorter intubation times ($P < 0.0001$).

CONCLUSIONS: Mouth opening, body mass index, and high Cormack and Lehane grade predict longer intubation times, as with DL. Decreasing thyromental distance predicts slightly shorter intubation times with the BRF, possibly because of a design initially optimized for a pediatric population with receding chins. These findings, along with the high success rate of BRF in this study, and the possibility of further increasing success rates by combining BRF with DL, help define the role of BRF intubation in contemporary airway management. (Anesth Analg 2016;122:1901–6)

General anesthesia often requires endotracheal intubation, most commonly performed via direct laryngoscopy (DL). In some patients, however, DL can be difficult or even impossible,[1–4] potentially leading to significant morbidity. When difficulty with DL is anticipated or encountered after induction of anesthesia, the anesthesiologist must choose among several alternative methods for securing the airway.[5] One successful alternative intubation device is the Bonfils Rigid Fiberscope® (BRF),[6,7] a rigid fiberscope with a 40° curved tip and a 110° angle of view through a proximal eyepiece or camera/monitor system. Intubation with the BRF is described in patients with normal airways, patients with obstructing airway tumors, and patients with anticipated and nonanticipated difficult airways, including patients with failed intubation attempts with DL.[8–11] The very different design and high success rate of the BRF in intubation situations where DL is difficult raise the question of whether demographic, morphologic, or morphometric predictors of difficult DL also predict difficult BRF. A prospective study was therefore designed to determine which patient characteristics, if any, predict difficult BRF intubation in an elective surgical population.

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METHODS

After approval by the IRB, 400 adult patients, based on BRF and patient availability, were recruited at the Centre

Hospitalier de l'Université de Montréal from January to July 2014, after having signed a written informed consent. The estimated sample size for linear regression assuming small effect size of 0.05, 90% power, and 1% significance level was estimated to be 420 patients.[12–14] Using this number, as well as a previously published study by the same group of investigators[15] as a guide, the Institutional Scientific Review Board agreed that a 400-patient sample was considered satisfactory. All were scheduled to undergo elective neurosurgical, otorhinolaryngologic, neurologic, thoracic, gynecologic, orthopedic, plastic, or general surgery under general anesthesia. Patients were excluded if they could not provide informed consent or if awake intubation, a rapid sequence induction, or an induction without neuromuscular blocking agents was planned. Demographic and morphometric data were recorded before induction of anesthesia, including age, sex, weight, height, American Society of Anesthesiologist classification, history of snoring and sleep apnea, Mallampati class, and upper lip bite test score. Interincisor, thyromental, and sternothyroid distances; manubriomental distances in flexion and extension; neck circumference; and neck skinfold thickness at the cricoid cartilage were noted in centimeters and were analyzed as continuous data. Finally, maximal neck flexion and extension were measured in degrees.

The induction technique and agents were chosen by the attending anesthesiologist but had to include a neuromuscular blocking agent. Two senior anesthesiology residents, who had intubated >40 patients each[6,16] with the BRF before the study began, performed all the intubations. Paralysis was confirmed by the absence of motor response to train-of-four stimulation at the ulnar nerve. With the patient in the sniffing position,[17] DL was performed with a Macintosh 3 or 4 blade, using backward upward rightward pressure[18] on the larynx as necessary when the vocal cords were not initially visualized; the best resulting glottic visualization Cormack and Lehane grade was noted. The patient's head was thereafter placed in a neutral position, and oral aspiration of secretions was performed. The BRF, previously treated with Fred™ 2 (Covidien, Mansfield, MA) antifogging agent and mounted with a size 7.0 (female patients) or 8.0 (male patients) endotracheal tube, was inserted into the mouth, and intubation was performed via a midline or retromolar approach, facilitated by the use of a jaw lift. A laryngoscope was not used to assist BRF.[7] Correct placement of the tube was confirmed by capnography.

Several measures were collected to grade ease of intubation with the BRF. Glottic visualization with the BRF was graded as good or poor when the glottis was visualized or not. The number of attempts required was recorded (an attempt began with insertion of the BRF into the mouth and ended with BRF withdrawal). The time from insertion of the BRF into the mouth to capnographic confirmation of endotracheal intubation was used as the primary outcome. After 120 seconds of intubation attempts, the BRF technique was considered a failure, and the attending anesthesiologist at his discretion decided whether to continue BRF intubation with or without a laryngoscope or intubate the patient using another device.

After consultation with the statistical service of the Centre de recherche du Centre hospitalier de l'Université de Montréal, a logarithmic transformation of the dependent variable was completed. Univariate analyses were performed to evaluate the association between patient characteristics and time required for intubation. Pearson and Spearman coefficients were calculated (GraphPad Prism® version 6.00 for Windows, GraphPad Software, La Jolla, CA) and were used, respectively, for continuous and ordinal data. Variables that exhibited a significant correlation with time required for intubation in the univariate analysis were included in a subsequent multivariate analysis using a standard least squares model (JMP® version 11, SAS Institute Inc., Cary, NC) to identify those that remained significantly and independently correlated with time to intubate. Five values were missing for final analysis; 4 upper lip bite test scores because of lack of patient comprehension of the task and 1 neck circumference because the value was not noted during data collection. To minimize the number of excluded variables, the multivariate analysis was recomputed while replacing the missing values by the extremes of their ranges. Because no difference in the analysis results was established with this test, the median values in each category were used as replacements for the missing ones. A linear regression of the variables having exhibited a positive correlation in the multivariate analysis was completed to better describe their effects on the dependent variable. To better describe the relationship between variables, 2 × 2 interactions were completed. Unless otherwise stated, data are presented as percentages or means ± 1 SD. A P value of <0.05 was considered significant.

RESULTS

Patient characteristics, including the Cormack and Lehane grade with DL, are included in Table 1. The first attempt with the BRF was successful in 390 patients, 6 patients required >1 attempt to achieve successful tracheal intubation with the BRF, and 4 patients could not be intubated with the BRF alone because of the inability to visualize the glottis. Of those 4 patients, 2 were intubated using DL simultaneously with BRF. In the other 2 patients, BRF with DL was not attempted; 1 was intubated using DL and a malleable stylet to shape the endotracheal tube and the other with DL and a tracheal introducer. The mean intubation time for all successful intubations was 26 ± 13 seconds. Glottic visualization with the BRF was good in 396 of 400 (99%) of cases. In the 6 patients with a grade III Cormack and Lehane grade on DL, BRF was successful on the first attempt in 4, on the second attempt in 1, and was not successful in 1 patient. Fogging of the lens hampered intubation in 11 cases (3%). Secretions also complicated visualization in 16 cases (4%).

Multiple patient characteristics were correlated with time required for intubation using univariate analysis (Table 2). These included patient weight, body mass index (BMI), high Cormack and Lehane grade, upper lip bite test, sternothyroid distance, thyromental distance (TMD), mouth opening, neck circumference and skinfold thickness, history of snoring, and female sex. After multivariate analysis, only 4 variables remained correlated with intubation times. Decreasing TMD appeared to be correlated with shorter intubation times, whereas decreasing mouth opening, increasing BMI, and higher Cormack and Lehane grade predicted longer intubation times (Table 2, Fig. 1). There was no evidence that interaction could be present from

Table 1. Patient Characteristics

Patient characteristic	Number of Bonfils Rigid Fiberscope® attempts: 1 attempt (n = 390)	2+ attempts (n = 6)	Failure (n = 4)	Range
Age (y)	52 ± 15	58 ± 15	41 ± 15	18–90
Male/female	138 (35)/252 (65)	4 (67)/2 (33)	0/4 (100)	
Weight (kg)	75 ± 17	75 ± 17	101 ± 17	41–143
Height (cm)	166 ± 9	164 ± 8	171 ± 6	140–197
Body mass index (kg/m^2)	27 ± 6	28 ± 4	35 ± 7	15–55
ASA classification[a]	2	1.5	2	1–4
History of snoring (yes/no)	188 (48)/202 (52)	3 (50)/3 (50)	2 (50)/2 (50)	
Sleep apnea				
Suspected	25 (6)	0	0	
Diagnosed	6 (2)	0	0	
CPAP treated	16 (4)	0	0	
Mallampati class				
1	117 (30)	0	0 (0)	
2	193 (50)	0	2 (50)	
3	75 (19)	5 (83)	2 (50)	
4	5 (1)	1 (17)	0	
Mouth opening (mm)	43 ± 6	40 ± 6	41 ± 9	20–60
Thyromental distance (mm)	67 ± 15	67 ± 22	65 ± 12	30–115
Sternothyroid distance (mm)	82 ± 20	78 ± 21	75 ± 37	40–175
M-M distance in extension (mm)	170 ± 25	161 ± 12	163 ± 30	75–230
M-M distance in flexion (mm)	21 ± 11	23 ± 11	25 ± 20	5–80
Neck circumference (mm)[b]	370 ± 44	385 ± 74	385 ± 5	290–550
Neck skinfold thickness (mm)	4 ± 3	5 ± 3	7 ± 1	1–15
Upper lip bite test				
1	214 (55)[c]	3 (50)[c]	1 (25)	
2	158 (41)	2 (33)	3 (75)	
3	15 (4)	0	0	
Total range of neck motion (°) (angle)	97 ± 18	96 ± 13	89 ± 9	39–159
Cormack and Lehane grade[d]				
1	291 (75)	3 (50)	1 (25)	
2	95 (24)	2 (33)	2 (25)	
3	4 (1)	1 (17)	1 (75)	
4	0 (0)	0 (0)	0 (0)	

Mean ± 1 SD or n (%).

ASA = American Society of Anesthesiologists; CPAP = continuous positive airway pressure; M-M = manubriomental.

[a]ASA classification noted as median.

[b]Neck circumference was not recorded in 1 patient during data collection.

[c]Upper lip bite test could not be performed in 3 patients in the 1 attempt group and in 1 patient in the 2 or more attempts group because of lack of comprehension of the task.

[d]Backward upward rightward pressure was systematically performed if the vocal cords were not visualized with direct laryngoscopy. The best available Cormack and Lehane grades were noted.

Table 2. Significant Correlations Between Time to Intubate and Patient Characteristics

Patient characteristic	Correlation coefficient (95% CI)	Univariate P[a]	Multivariate P[b]
Thyromental distance	0.22 (0.13 to 0.31)	<0.0001	<0.0001
Mouth opening	−0.13 (−0.22 to −0.028)	0.0122	0.0080
Body mass index	0.21 (0.12 to 0.31)	<0.0001	0.0114
Cormack and Lehane	0.24 (0.14 to 0.33)	<0.0001	0.0377
Weight	0.23 (0.13 to 0.32)	<0.0001	NS
Upper lip bite test[c]	0.20 (0.10 to 0.29)	<0.0001	NS
Neck skinfold thickness	0.19 (0.09 to 0.28)	0.0001	NS
Sternothyroid distance	0.12 (0.023 to 0.22)	0.0154	NS
Neck circumference[d]	0.12 (0.02 to 0.21)	0.0196	NS
Sex (female)	−0.11 (−0.21 to −0.01)	0.0342	NS
History of snoring	0.10 (0.002 to 0.20)	0.0406	NS

CI = confidence interval.

[a]P values after univariate correlation analysis.

[b]P values after multiple regression using standard least squares model.

[c]Upper lip bite test was performed in 4 patients because of lack of comprehension of the task.

[d]Neck circumference was not recorded in 1 patient during data collection.

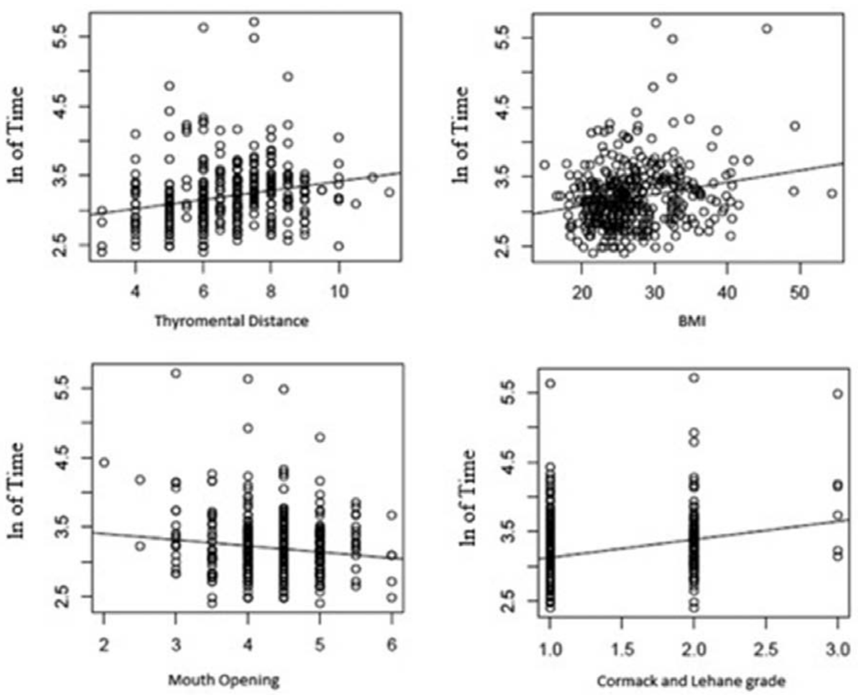

Figure 1. Linear regression of variables having exhibited a significant correlation with time required for intubation in the multivariate analysis. Linear regressions were investigated for linearity and residuals checked for normality. Analysis for quadratic term on body mass index (BMI) and mouth opening was performed. It was not significant for BMI. Although the results were significant for mouth opening, the correlation was in the same direction as the linear regression and did not seem to provide a better visual fit. The linear regression was considered satisfactory, as the goal was to detect linear associations and not to perform mathematical modeling.

the univariate and multivariate results; 2 × 2 interactions were verified, and none was significant. Interaction with Cormack and Lehane grade could not be tested because there was insufficient power to detect such an association.

In 12 patients, a size 6.5 or 9.0 endotracheal tube was substituted for the standard size in the study, at the request of the surgeon or the attending anesthesiologist, without impact on the intubation technique. Data collection was incomplete in 5 patients: 4 patients were unable to reliably execute the upper lip bite test and, in 1 patient, the measurement of neck circumference was accidentally omitted. No patients and no data were excluded from the analysis. No adverse events or complications associated with an increase in the use of the BRF were noted during this study.

DISCUSSION

In this study, successful tracheal intubation with the BRF occurred in 396 (99%) cases. In all 4 cases where intubation with the BRF alone was not successful, failure to visualize the glottis appeared to be the result of difficulty in mobilizing the epiglottis to create an opening between it and the posterior pharyngeal wall without the BRF passing directly into the esophagus. DL performed simultaneously with BRF is a technique that has been described before[10] and that allows the anesthesiologist to lift the epiglottis off the posterior pharynx. When attempted in 2 of the cases of failed BRF in this study, this technique proved successful. In the other 2 failures with BRF alone, the anesthesia team chose to intubate using DL and another intubation aide; DL + BRF was not attempted (but may also have been a successful alternative). The success rate for BRF intubation in this study is similar to the 98.3% success rate previously reported in a case series of 60 patients[6] and somewhat better than the 91.7% success rate with the BRF reported by Wahlen and Gercek[19] (12 patients) or the 86.1% reported by Wong[20] (36 patients). The success rate for BRF in this study is comparable with the 99.75% success obtained in a similar study by this group using the GlideScope videolaryngoscope[15] and with the 99.7% success rate reported for DL.[21]

When the study was designed, analysis of the correlation between number of intubation attempts and patient characteristics was planned.[15] However, the low number of patients with >1 intubation attempt (10/400) in this study precluded this type of analysis.

In this study, decreased mouth opening, increased BMI, and higher Cormack and Lehane grade were independently associated with time to intubation with the BRF. All these 3 factors are also associated with difficult DL. However, decreasing TMD appears to be correlated with slightly shorter (Fig. 1) intubation times with the BRF, in contrast to the findings of studies evaluating DL or videolaryngoscopy.[1,15] This could be attributable to key differences between DL and BRF: with DL, a longer TMD allows proper alignment of the oral, pharyngeal, and laryngeal planes as the operator displaces the anterior pharyngeal structures with the laryngoscope to visualize the glottis[22]; with the BRF, however, the anterior pharyngeal wall is not displaced by the BRF itself, the jaw being instead lifted by the operator to create an opening beneath the epiglottis to allow passage of the scope and glottic visualization. Although it is not possible to definitely explain from our results why decreased TMD predicted slightly shorter intubation times, it is interesting to note that the BRF was designed for pediatric patients with a receding chin,[7] and it is therefore possible that the fixed angle and length of the distal portion of the scope may make it particularly suitable for intubation of patients with short TMDs.

Mouth opening was inversely correlated with time required for intubation with the BRF. A mouth opening of

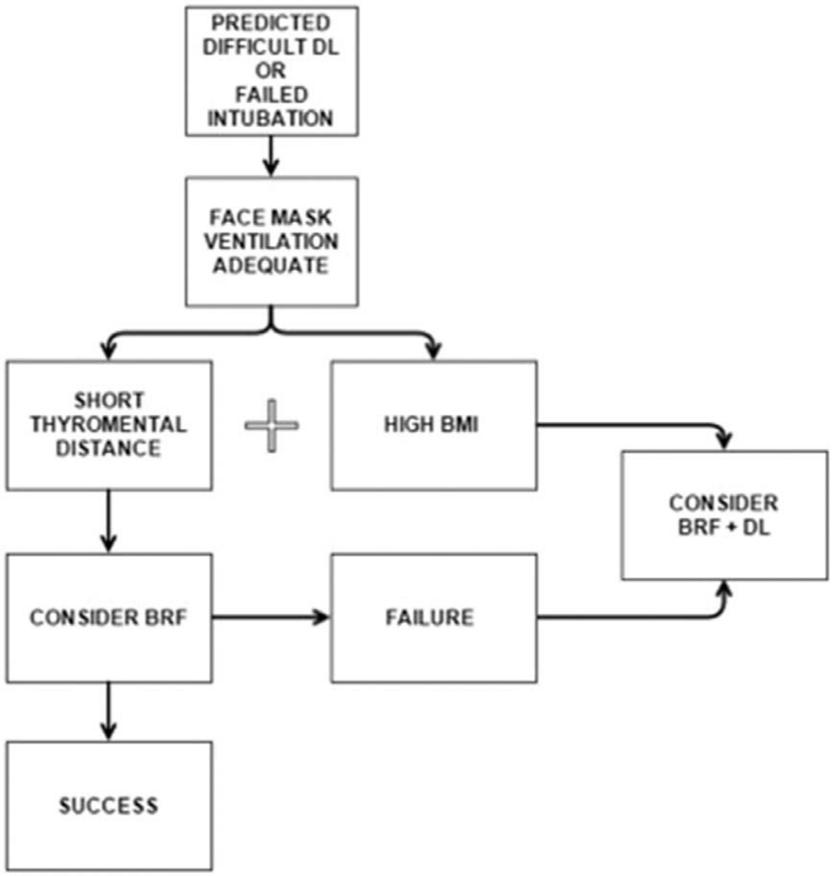

Figure 2. Proposed use of Bonfils Rigid Fiberscope (BRF) in difficult intubation. BMI = body mass index; DL = direct laryngoscopy.

<35 mm has also been predictive of difficult DL in previous studies,[23,24] although results of a meta-analysis were less clear.[25] One previous study[26] compared DL with the BRF in 76 patients with simulated difficult airways (using a rigid cervical collar to restrict cervical movement and mouth opening). In this study, successful tracheal intubation occurred in 82% of the BRF group versus only 40% in the DL group. It may be that, although a small mouth opening does prolong intubation times with the BRF, the BRF's small size could still make it less susceptible to outright failure than DL.

Increasing BMI also predicted the time required for intubation, as is the case in studies exploring the relationship between BMI and failed tracheal intubation using DL.[2,27] Redundant mucosal tissues hampering glottic visualization may explain this finding in both techniques.

Finally, Cormack and Lehane grade III at DL also correlated with longer intubation times at BRF. A Cormack and Lehane grade of III or IV is a well-established criterion for difficult DL.[21] The BRF has previously been studied versus flexible fiberoptic bronchoscopy in unanticipated difficult airways, as defined by failed intubation at DL or Cormack and Lehane grade III or IV at DL. Rudolph et al.[11] had a 100% success rate with BRF in the unanticipated difficult airway ($n = 116$), including success with BRF after 2 failed attempts at fiberoptic bronchoscopy intubation. Kim et al.[10] had a 90% (18/20) success rate with BRF. In this study, Cormack and Lehane grade III at DL was observed in 6 (1.5%) patients, an incidence similar to previous studies that noted only the best glottic view obtained with or without backward upward rightward pressure[28]; BRF intubation without assistance with a laryngoscope was successful in 5 of these 6 patients (83%).

Figure 2 presents an algorithmic interpretation of the findings of this study. In addition to having a high success rate as a primary intubation tool, the BRF is an attractive alternative to DL in patients with short TMDs, with or without reduced mouth opening. Conversely, patients with a high BMI, or in which BRF alone fails, may benefit from a combined BRF and DL technique. Other maneuvers such as head tilt or neck extension may also be useful in modifying the spatial relationship between the epiglottis and the anterior pharyngeal wall. Further studies could evaluate the clinical utility of the addition of DL to BRF, as well as other possible maneuvers.

Our study has several limitations. The use of end-tidal CO_2 as a confirmation for successful intubation led to slightly longer intubation times when the capnograph sampling line was longer (when the head of the patient was far from the anesthesia machine). Another limitation is that the Cormack and Lehane grade at DL was determined by the same person who subsequently performed BRF, which could potentially have influenced the performance of the second technique. Furthermore, because only patients receiving neuromuscular blockade were studied, patients with nonreassuring airways in whom awake intubation or intubation without paralysis was selected were not included. Anticipated difficult airways using DL may therefore be underrepresented in our patient group.

In conclusion, mouth opening, BMI, and high Cormack and Lehane grade predict a longer time to successful intubation, as has already been noted with other intubation techniques, such as DL and videolarygoscopy. Decreasing TMD predicts slightly shorter intubation times with BRF, a relation that may reflect the original patient population for which BRF was designed. The high success rate of BRF in this study, the unique relationship between TMD and intubation times, and the possibility of further increasing BRF success rates by combining it with DL help define the role of BRF in the management of difficult intubation.

DISCLOSURES

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Attestation: Michal Nowakowski attests to the integrity of the original data and the analysis reported in this manuscript and approves the final manuscript.
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