CAN DIFFICULT INTUBATION BE EASILY AND RAPIDLY PREDICTED?

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Aim. Failed endotracheal intubation and inadequate ventilation with subsequent insufficient oxygenation can result in serious complications potentially leading to permanent health damage. Difficult intubation may occur not only in patients with apparent pathologies in the orofacial region but also, unexpectedly, in those without abnormalities. This study aimed at finding anthropometric parameters that are easy to examine and that would aid in predicting difficult intubation.

Method. A case-control study was undertaken. Based on defined criteria, 15 parameters were examined in patients with unanticipated difficult intubation. The parameters included a previous history of difficult intubation, pathologies associated with difficult intubation, clinical symptoms of airway pathology, the Mallampati score, upper lip bite test, receding mandible, and cervical spine and temporomandibular joint movement. Thyromental, hyomental and sternomental distances and inter-incisor gap were measured. The methods were precisely defined and the measurements were carried out by a trained anesthesiologist. Statistical analysis was performed on data from 74 patients with difficult intubation and 74 control patients with easy intubation.

Results. Significant predictors of difficult intubation were inter-incisor gap (IIG), thyromental distance (TMD) and class 3 limited movement of the temporomandibular joint. The IIG and TMD cut-offs were set at 42 mm and 93 mm, respectively.

Conclusion. The results will be used to confirm these predictors in an anesthesiology clinic along with the aid of the laryngoscopic findings to improve the prediction of unanticipated difficult intubation.

INTRODUCTION

Failed tracheal intubation with subsequent inability to maintain an open airway and adequate oxygenation is not a common complication but it is the most frequent cause of brain damage or death during anesthesia. The incidence of all types of difficulties related to intubation or secured airway is estimated to range from 1% to 3%. Failed intubation accounts for 0.05-0.35% (ref.¹). Safe airway management is crucial in anesthesiology and resuscitation. It is an integral part of the anesthesia that is administered in all types of operations. Airway management, adequate ventilation and oxygenation are among the basic therapeutic procedures in resuscitation. Tracheal intubation is routinely performed by anesthesiologists.

The inability to control the airway and ventilate the patient effectively may result in serious complications, having immediate impact on the quality of life and potentially leading to the patient's death. The main problem is hypoxia resulting in damage to the CNS at various levels. The risk of injury to the airway is also not negligible.

Ultimately, these complications may influence both the professional career and private life of the anesthesiologist. Mistakes in the algorithm for unanticipated difficult intubation are mainly due to unpreparedness. These considerations formed the basis of this study aimed at finding parameters that are easy to examine and that could better predict difficult intubations.

MATERIALS AND METHODS

The goal was to define parameters that are easy to measure in anesthesiology clinic and that would help predict unanticipated difficult intubation.

A case-control study was selected as the most appropriate. At the outset, criteria for difficult intubation were precisely defined to create a patient group. The criteria for difficult intubation with the optimal position of the head (the so-called sniffing position), applying external pressure to the cricoid cartilage (Sellick's maneuver) and after calling in an experienced anesthesiologist are as follows:

- the patient cannot be intubated despite more than three attempts at direct laryngoscopy or more than three attempts at tracheal tube insertion
- tracheal intubation attempts lasting more than ten minutes
- with direct laryngoscopy, only the epiglottis or root of the tongue is seen (Cook's modification² of Cormack-Lehane's classification³, grades 3A, 3B, 4 – see Table 1)

Table 1. Laryngoscopic view – Cook's modification² of Cormack-Lehane's classification³.

Grade	Laryngoscopic view
1	With direct laryngoscopy, the glottic opening is clearly visualized. The posterior commissure and the entire length of both vocal cords can be seen.
2A	With direct laryngoscopy, the glottic opening is partly visualized. The posterior commissure and parts of both vocal cords can be seen.
2B	With direct laryngoscopy, the posterior commissure is visualized. The vocal cords cannot be seen.
3A	With direct laryngoscopy, only the epiglottis is visualized. Epiglottis can be lifted using an introducer or bougie.
3B	With direct laryngoscopy, only the epiglottis is visualized. Epiglottis cannot be lifted using an introducer or bougie.
4	With direct laryngoscopy, only the root of the tongue is visualized.

Based on the literature, the following 15 factors were selected for study in patients who are difficult to intubate: a previous history of difficult intubation (DI) (ref.⁴), pathologies associated with difficult intubation⁴, clinical symptoms of airway pathology⁴, the Mallampati score^{3,5}, upper lip bite test (ULBT) (ref.^{6,7}), receding mandible⁸, hyomental distance (HMD) (ref.⁸), temporomandibular joint movement⁸, anterior or posterior flexion of the cervical spine⁸, horizontal length of the mandible (HLM) (ref.⁹), neck circumference, thyromental distance (TMD) (ref.^{3,10,11}), sternomental distance (SMD) (ref.^{3,9,12}), inter-incisor gap (IIG) (ref.^{3,4,8,12}) – distance between the incisors with mouth fully open. Methods for measuring the individual parameters were precisely defined (see Table 2).

The study was approved by the University Hospital Olomouc ethics committee and carried out by the Department of Anesthesiology, Resuscitation and Intensive Medicine. Included were patients over 18 years of age undergoing surgery under general anesthesia with their airway secured by tracheal intubation in whom intubation was difficult, in accordance with the above criteria. Patients in whom difficult intubation could be anticipated were excluded from the study. The reasons for difficult

intubation was varied. Congenital causes include cleft lip and/or palate, micrognathia, malposition or size of anterior teeth, congenital deformities of the facial skeleton as a part of congenital syndromes, and short thick neck. Inflammatory processes were para- and retropharyngeal abscesses, acute epiglottitis, temporomandibular joint inflammation, ankylosing spondylitis, ankylosis of the atlanto-occipital joint, or trismus, making direct laryngoscopy difficult. Difficult tracheal intubation may also result from trauma, such as facial bone fracture, soft tissue damage and hematoma. The most frequent endocrine causes are acromegaly or a goiter. Other causes include oral and neck cancer, previous radiotherapy of these regions, edema of the laryngeal soft tissues in an allergic reaction/anaphylactic shock. Patients with clear pathologies in the orofacial region were not included.

On the following day, all the parameters were recorded by an anesthesiologist trained in methods for measuring parameters of difficult intubation. After giving informed consent, patients in whom unanticipated difficult intubation occurred were asked about previous difficult intubation and potentially associated conditions. The anesthesiologist paid attention to clinical symptoms of airway pathology and the potential presence of a receding mandible. He assessed the Mallampati score, upper lip bite test, temporomandibular joint movement and cervical spine movement. With a ruler, he measured IIG, HMD, TMD and SMD. A measuring tape was used to measure neck circumference and HLM.

In the next phase of the study, each patient with difficult intubation was matched to a control, i.e. a patient with easy intubation and comparable gender, age, height and weight. The tolerance ranges were 10 years of age, 10 cm in height and 10 kg in weight. A total of 74 case-control pairs were created and compared.

The data were statistically analyzed using the SPSS 15.0 software (SPSS Inc., Chicago, USA). The categorical parameters were compared with Fisher's exact test. The quantitative data were analyzed using the Mann-Whitney U test and Student's t-test. Normality was assessed with the Shapiro-Wilk test. The cut-off values for non-metric parameters were determined by the ROC analysis. To define significant factors for predicting difficult intubation, logistic regression analysis was used. The tests were performed at a significance level of 0.05.

RESULTS

Over a period of three years (2007–2010), a total of 98 patients were examined, in whom the above criteria for unanticipated difficult intubation were met as attempts were made to secure their airways with an endotracheal tube. Subsequently, patients with difficult intubation were matched with patients who also underwent surgery under general anesthesia with orotracheal intubation without difficulties. Twenty-four patients with difficult intubation were excluded since corresponding controls could not be found for them. Thus, a total of 74 pairs were created

Table 2. Parameters for prediction of difficult intubation.

Parameter	Methods	Ranges and units
Previous history of DI	Does the patient have a history of difficult intubation?	yes – no
Pathologies associated with DI	Does the patient have a condition commonly associated with difficult intubation?	specify (ankylosing spondylitis, acromegaly, etc.)
Clinical symptoms	hard to define – a feeling of a potential problem	yes – no
Mallampati score	full mouth opening protrusion of the tongue	1 = the soft palate, uvula, pharynx, tonsils 2 = the soft palate, uvula 3 = the soft palate, base of the uvula 4 = the soft palate only
Upper lip bite test	biting the upper lip with the lower incisors	1 = the incisors in front of the lip 2 = the lip partly visible 3 = the lip visible
Receding mandible	a line drawn from the upper eye lid to the maxilla	yes – the chin behind the line no – the chin in front of the line
Hyomental distance (HMD)	the body of the hyoid bone – the mentum	mm
TM joint movement	mouth opening + slux*	1 = IIG > 50 mm + slux > 0 2 = IIG < 50 mm + slux > 0 3 = IIG < 50 mm + slux < 0
Anterior flexion of the C-spine	the goniometer head to the ear canal	anterior flexion in degrees
Posterior flexion of the C-spine	1st arm in the long axis of the neck above the ear 2nd arm to the nasal wing	posterior flexion in degrees
Mandibular length	outer angle – the middle of the chin (follow the shape of the mandible)	cm
Neck circumference	measured at the level of the cricoid, perpendicular to the long axis of the neck	cm
Thyromental distance (TMD)	the superior thyroid notch – the lower edge of the middle of the chin	cm
Sternomental distance (SMD)	jugulum – the lower edge of the middle of the chin	cm
Inter-incisor gap (IIG)	between the incisors (gums)	cm

*slux- subluxation (maximal forward protrusion of the lower incisors beyond the upper incisors)

and statistically compared. (Table 3) shows no statistically significant difference between the two groups ($p > 0.05$).

The categorical data are shown in (Table 4). There were significant differences in pathologies associated with difficult intubation, clinical symptoms of airway pathology, proportion of patients with class 3 or 4 Mallampati

score, class 3 ULBT, the presence of a receding mandible and limited temporomandibular joint movement ($p < 0.0001$) between the case and control groups. The only statistically insignificant parameter was a previous history of difficult intubation.

Table 3. Demographics of patients with difficult and easy intubation.

	Difficult (N=74)	Easy (N=74)	<i>P</i>
Gender M/F	35 (47.3%)/39 (52.7%)	35 (47.3%)/39 (52.7%)	1.000 ^a
Age (yr)	59.2 ± 11.6 ²	59.9 ± 10.6 ²	0.702 ^b
Weight (kg)	82.9 ± 16.6 ²	82.5 ± 16.8 ²	0.908 ^b
Height (cm)	169.3 ± 9.1 ²	171.3 ± 8.8 ²	0.170 ^b
BMI (kg.m ⁻²)	27.7 (26.0–31.4) ¹	27.4 (24.2–30.4) ¹	0.255 ^c
Obesity	27 (36.5%)	23 (31.1%)	0.602 ^a

^a Fisher's exact test, ^b Student's t-test, ^c Mann-Whitney test¹ median (25th–75th percentile)² mean ± SDobesity = BMI > 30 kg.m⁻²**Table 4.** Categorical data (frequencies).

	Difficult (N=74)	Easy (N=74)	<i>P</i>
Previous history of difficult intubation	6 (8.6%)	1 (1.4%)	0.116 ^a
Pathologies associated with difficult intubation	20 (27.0%)	1 (1.4%)	< 0.0001^a
Clinical symptoms	28 (37.8%)	1 (1.4%)	< 0.0001^a
Mallampati score class 3 or 4	67 (90.5%)	28 (37.8%)	< 0.0001^a
ULBT class 3	25 (33.8%)	5 (6.8%)	0.0001^a
Receding mandible	29 (39.2%)	8 (10.8%)	0.0001^a
TM joint movement class 3	35 (47.3%)	3 (4.1%)	< 0.0001^a

^a Fisher's exact test, ULBT = upper lip bite test, TM = temporomandibular

(Table 5) shows the descriptive characteristics of the quantitative parameters. Statistically significant differences were found for HMD ($p < 0.0001$), TMD ($p < 0.0001$) and IIG ($p < 0.0001$). Additionally, patients with difficult intubation were significantly different in anterior

and posterior flexion of the cervical spine ($p 0.016$ and $p = 0.0002$, respectively), HLM ($p = 0.005$) and SMD ($p = 0.005$). No statistically significant difference was found for neck circumference.

Table 5. Quantitative parameters.

	Difficult (N=74)	Easy (N=74)	<i>P</i>
HMD (mm)	55.0 (50.0–65.0) ¹	60.0 (60.0–70.0) ¹	< 0.0001^a
Anterior flexion of the C-spine (°)	40.0 (30.0–51.3) ¹	45.0 (38.8–51.3) ¹	0.016^a
Posterior flexion of the C-spine (°)	30.0 (25.0–40.0) ¹	40.0 (35.0–50.0) ¹	0.0002^a
HLM (cm)	11.0 (10.0–11.6) ¹	11.5 (10.5–12.5) ¹	0.005^a
Neck circumference (cm)	40.6 ± 4.9 ²	40.0 ± 4.4 ²	0.372 ^b
TMD (mm)	85.0 (70.0–96.3) ¹	105.0 (95.0–115.0) ¹	< 0.0001^a
SMD (mm)	155.0 (130.0–166.3) ¹	165.0 (145.0–175.0) ¹	0.005^a
IIG (mm)	40.0 (35.0–40.5) ¹	45.0 (40.0–52.0) ¹	< 0.0001^a

^a Mann-Whitney test, ^b Student's t-test¹ median (25th–75th percentile)² mean ± SD

HMD = hyomental distance, HLM = horizontal length of the mandible, TMD = thyromental distance, SMD = sternomental distance, IIG = inter-incisor gap

For TMD and IIG, the ROC analysis was used to define cut-off values for predicting difficult intubation. For IIG, the optimal cut-off value was 42 mm, sensitivity 79.7%, specificity 71.6%, positive predictive value 73.8%

and negative predictive value 77.9%. For TMD, the optimal cut-off value was 93 mm, sensitivity 67.6%, specificity 78.4%, positive predictive value 75.8% and negative predictive value 70.7% (see Table 6).

Table 6. ROC analysis.

	IIG cut-off=42	TMD cut-off=93
AUC (95%CI)	0.824 (0.759–0.889)	0.789 (0.718–0.860)
Sensitivity	0.797 (0.688–0.882)	0.676 (0.557–0.780)
Specificity	0.716 (0.599–0.815)	0.784 (0.673–0.871)
Accuracy	0.757 (0.680–0.824)	0.730 (0.651–0.799)
PPV	0.738 (0.627–0.830)	0.758 (0.636–0.855)
NPV	0.779 (0.662–0.871)	0.707 (0.597–0.803)

AUC = Area under the curve

PPV = Positive predictive value

NPV = Negative predictive value

IIG = Difficult intubation if IIG ≤ 42

TMD = Difficult intubation if TMD ≤ 93

To select significant predictors for difficult intubation, logistic regression was used (see Table 7). Significant factors for predicting difficult intubation were clinical symptoms of airway pathology, with an odds ratio (OR) of 39.8, class 3 limited movement of the temporomandibular joint (OR 10.2), neck circumference (OR 1.27), TMD (OR 0.894) and IIG (OR 0.819). Thus, the patient's clinical symptoms of airway pathology, suggesting difficult intubation to the anesthesiologist, increased the risk of

difficult intubation 39.8-fold. Class 3 limited movement of the temporomandibular joint (mouth opening < 5 cm and inability to protrude the lower incisors beyond the upper incisors) meant a 10.2-fold higher risk of difficult intubation. If neck circumference was increased by 1 unit (cm), the likelihood of difficult intubation was 1.27 times higher. In contrast, a rise in TMD or IIG by 1 unit (mm) decreased the chance of difficult intubation by factors of 0.894 and 0.819, respectively.

Table 7. Logistic regression.

	odds-ratio	95%CI	<i>P</i>
Clinical symptoms	39.8	3.5–449.4	0.003
TM joint movement=class 3	10.2	2.1–49.2	0.004
Neck circumference (cm)	1.27	1.08–1.50	0.004
TMD	0.894	0.850–0.942	< 0.0001
IIG	0.819	0.741–0.905	< 0.0001

Nagelkerke R Square = 0.762

DISCUSSION

Although a previous history of difficult intubation is considered a predictive factor it was statistically insignificant in this study. This may be explained by inadequate history taking. In only a few cases, was it possible to ascertain whether the patient had been under anesthesia and the types of anesthesia and airway management. Previous difficult intubation has a great importance⁴.

Similarly, pathologies associated with difficult intubation have a predictive value⁴. However, all patients with diseases or traumas causing deformities or greatly limiting movement in the head and neck region were excluded from the study.

Clinical symptoms of airway pathology, that is feelings the anesthesiologist has concerning the patient's potential intubation, are a very important predictive factor. Although this parameter cannot be quantified it should

not be neglected in clinical practice⁴. Its predictive value is high but the ability to assess difficult intubation increases experience.

In common clinical practice, the Mallampati score is most widely used. However, this classification system is characterized by a high percentage of false-positive results. The actual predictive value is approximately 50% (ref.^{3,5}). In the literature, class 3 means up to 7.5–8 times higher risk for difficult intubation. But a 1992 German study showed that only 6.4% of class 4 patients were difficult to intubate^{3,5}.

Although ULBT is a statistically significant test, in some cases such as elderly patients with artificial dentition, it may be more difficult to understand and perform. Similarly, patients with a severely receding mandible deserve more attention from the intubating anesthesiologist. This parameter is even more important when combined with other tests^{6,11}.

Temporomandibular joint movement is assessed by a simple test consisting of two parts, full mouth opening and subluxation, i.e. forward protrusion of the lower incisors beyond the upper incisors. For patients, it is easier than ULBT. It showed to be an important predictor of difficult intubation in both this study and in the literature. This parameter is also a part of scoring systems such as the Arné or Wilson models^{4,8,12}.

Movement of the cervical spine also has its role. For instance, patients with a history of ankylosing spondylitis are usually automatically assumed to be difficult to intubate. According to Wilson, the range of cervical spine movement defined as anterior + posterior flexion should be more than 90° to predict easy intubation⁸. Interestingly, this range was not even achieved by some controls from the easy intubation group in the study. The range was 73.8–101.3°. Although we found the parameter to be statistically significant, its routine use in clinical practice is inhibited by both limited availability of equipment (a goniometer) and likely subjective error.

HLM is a metric parameter and if used on its own, it does not have much predictive value. Moreover, assessment using a measuring tape is usually influenced by the rater's error. Nevertheless, an HLM of at least 9 cm should guarantee easy intubation⁹.

As a single parameter, the neck circumference was not statistically significant, probably because the patients were matched by height and weight. However, logistic regression showed that an increase in one unit means that the likelihood of difficult intubation is 1.27 times higher. In most cases, greater neck circumference is associated with high body weight and some scoring models include weight as a risk factor for difficult intubation^{8,13–15}. We did not confirm that. In this context, the assessment of some our results (e.g. the value of neck circumference in predicting DI) must be done with caution. In the logistic regression analysis, there are more variables which affect each other, neck circumference being only one of them. The regression model deals with the issue of probability and prediction of membership of a given parameter (here the neck circumference) into a group with easy or difficult intubation, respectively. On the contrary, the significance

of the Student's t-test determines just the probability that the hypothesis of an identical neck circumference in easy and difficult intubation is rejected.

HMD is another metric parameter which was statistically significant. This is difficult to assess in overweight patients in whom the hyoid bone can hardly be identified. According to the literature, a distance of less than 4 cm is associated with difficult intubation.

SMD is a statistically significant metric parameter used in a large number of studies showing that a distance shorter than 13.5 cm is associated with difficult intubation^{3,12}.

TMD was defined by Patil as the distance from the thyroid notch to the mentum with the head extended. If TMD is shorter than 6 cm direct laryngoscopy usually cannot be performed. According to other authors, the distance is 6.5 or 7 cm^{3,10–12}. In this study, the cut-off was defined as 9.3 cm. Therefore, theoretically, a shorter distance may be associated with a more serious laryngoscopic picture and difficult intubation.

An IIG of at least 5 cm for tracheal intubation and 4 cm for inserting a laryngeal mask is another simple test with high predictive value^{3,12}. In this study, the cut-off was set at 4.2 cm, that is, patients with mouth opening less than 4.2 cm may experience difficulties with airway management.

Since the above parameters do not have high predictive value when used separately, various scoring systems have been described in the literature that increase the probability of difficult intubation predictions. An article by Naguib et al.¹⁶, published in *Anesthesia & Analgesia* in 2006, evaluated three scoring models for assessing difficult intubation: the Wilson (weight, cervical spine movement, temporomandibular joint movement, receding mandible and buck teeth), Arné (previous difficult intubation, diseases associated with difficult intubation, clinical symptoms of airway pathology, temporomandibular joint movement, cervical spine movement and the Mallampati score) and Naguib (height, IIG, TMD and the Mallampati score). However, not even the combination of examination methods is reliable. The Wilson and Arné models have a sensitivity of approximately 50% but relatively low positive predictive value. The Naguib model is relatively sensitive (81.4%) but its positive predictive value is even lower than that in the other two models (15.3%) (ref.¹⁶).

CONCLUSION

Statistical analysis of the results yielded three parameters with high predictive value – the maximum distance between the incisors (gums), thyromental distance measured with the mouth closed and head extended, and decreased temporomandibular joint movement. The examination itself is neither time-consuming nor technically demanding. Therefore, the next steps will be to validate the factors, assess them in anesthesiology clinic and subsequently, evaluate the laryngoscopic findings in airway management of the assessed patients.

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