Kako napovedati težavno oskrbo dihalne poti

How to predict a difficult airway

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Izvleček

Težavna oskrba dihalne poti je po definiciji ameriškega anesteziološkega združenja klinična situacija, pri kateri ima izkušen anesteziolog težave s predihavanjem bolnika z masko in dihalnim balonom in/ali težave s prikazom grla z direktno laringoskopijo in vstavitvijo dihalne cevke. Strah pred neuspešno oskrbo dihalne poti spremlja vsakega zdravnika. Klinični pregled z oceno možnosti težavne oskrbe dihalne poti je obvezen pred vsako oskrbo dihalne poti tako pri otrocih kot pri odraslih. Z njim se izognemo nepričakovani težki oskrbi dihalne poti in posledičnim zapletom. Tveganje za težavno oskrbo dihalne poti ocenimo z anamnezo in pregledom medicinske dokumentacije ter usmerjenim kliničnim pregledom bolnika. Vsak test ali klinični znak, ki natančno oceni tveganje za težavno oskrbo dihalne poti, ima svojo senzitivnost in specifičnost za oceno tveganja težke oskrbe dihalne poti. Za vse teste ali klinične znake so značilne nizka

Abstract

According to The American Society of Anaesthesiologists Task Force, a difficult airway is defined as a clinical situation in which a conventionally–trained anaesthesiologist experiences difficulty with face mask ventilation and/or difficulty with tracheal intubation. Failing at efficient airway management is a source of major apprehension for physicians. Predicting difficult airway management is a mandatory part of clinical practice for paediatric and adult patients so as to avoid unexpected difficult airway management and adverse outcomes.
Predicting a difficult airway is based on a focused medical history, review of prior medical records, physical examination, and specific tests for airway assessment. Each feature or airway test has its own sensitivity and specificity for the prediction of a difficult airway. All airway assessment tests are characterised by

senzitivnost, zmerna specifičnost in nizka pozitivna napovedna vrednost. Na podlagi multivariantne analize je bilo razvitih veliko točkovnih modelov, v katere so bili vključeni različni testi in klinični znaki z namenom izboljšanja napovedi težavne oskrbe dihalne poti, vendar z zelo različno točnostjo napovedi težke oskrbe dihalne poti. Evropsko združenje za anesteziologijo priporoča sistematsko uporabo ocenjevalnega modela pred vsako oskrbo dihalne poti, ki vključuje: Mallampatijev test, thiromentalno razdaljo, oceno odpiranja ust z medzobno razdaljo, oceno gibljivosti vratu, oceno podajnosti mandibularnega prostora in oceno gibljivosti spodnje čeljusti.

low sensitivity, reasonable specificity, and a low positive predictive value. Several scoring system models have been developed by multivariate analysis with multiple different integrated tests or risk factors to improve the prediction of a difficult airway, but with considerably different effectiveness to predict a difficult airway.
According to the European Society of Anaesthesiology, systematic multimodal screening before airway management should include the Mallampati classification and thyromental distance, mouth opening or interincisor distance, range of motion of head and neck, compliance of the mandibular space, and the upper lip bite test.

INTRODUCTION

Failing efficient airway management in emergency departments and intensive care units or following the induction of general anaesthesia is a source of major apprehension for physicians in emergency departments and intensive care units as well as for anaesthesiologists.

According to The American Society of Anaesthesiologists Task Force, a difficult airway is defined as the clinical situation in which a conventionally–trained anaesthesiologist experiences difficulty with face mask ventilation and/or difficulty with tracheal intubation (1). Difficult mask ventilation (DMV) is defined as the inability of a trained anaesthesiologist to maintain oxygen saturation > 90% and prevent signs of inadequate ventilation using a face mask, 100% oxygen, and positive pressure ventilation (1). Difficult intubation is defined as the need for > 3 attempts for intubation of the trachea or > 10 minutes to achieve it (1).

The incidence of DMV is estimated to be between 0.9% and 5% (2, 3). The incidence of difficult intubation is estimated to be between 0.13% and 13% and failed tracheal intubation is estimated between 0.05% and 0.4% (4, 5). In pregnant women, trauma patients, and otorhinolaryngologic patients the incidence of difficult intubation and failed tracheal intubation is higher than the general population (6, 7). Fortunately, the incidence of difficult airways with a "can't intubate, can't ventilate" situation is very low, with an estimated incidence of 0.0001%–0.02% (8).

Predicting difficult airway management is a mandatory part of clinical practice prior to any airway management (1, 9). The purpose of pre–operative airway evaluation is to identify patients with a difficult airway, warn and alert physicians, avoid unexpected difficult airway management, and mitigate and prevent the likelihood of adverse outcomes.

The principal adverse outcomes associated with a difficult airway include damage to the teeth, airway trauma, an unnecessary tracheostomy, aspiration, hypoxemia, hypotension, brain injury, cardiopulmonary arrest, and death (10–12). Between 1999 and 2005, difficult airway was the cause of 50 of 2211 (2.3%) anaesthesia–related deaths in the US (6). Between 2008 and 2009, there were 16 airway–related deaths reported during 2.9 million general anaesthetic procedures in the UK (10–13). Airway management outside of the operating theatre in UK is even more hazardous; specifically, there were 46 reports of death or brain damage amongst 184 reports, 22 of which were associ-

Table 1: Components of the pre–operative airway physical examination

Airway Examination Component	Findings that give cause for concern
face inspection	beard, size of nose, mouth and tongue, jaw protrusion, jewellery
patency of nares	masses inside nasal cavity, deviated nasal septum
teeth	relatively long upper incisors or canines, protruding teeth, lack of teeth, an edentulous state
relation of maxillary and mandibular incisors during normal jaw closure	maxillary incisors anterior to mandibular incisors
relation of maxillary and mandibular incisors during voluntary protrusion of lower jaw	inability to protrude the lower jaw and mandibular incisors beyond the upper incisors
temporomandibular joint movement	interincisor distance less than 3 cm
visibility of uvula	not visible
shape of palate	highly arched or very narrow
compliance of mandibular space	stiff, indurated, occupied by mass
shape of neck	thick and short (sternomental distance below 12 cm)
voice	presence of hoarse voice or stridor
scars	presence of signs of previous tracheostomy
range of motion of head and neck	patient cannot touch tip of chin to chest or cannot extend neck, more than 35°
assessment of submandibular space	hyomental distance less than 3 cm thyromental distance less than three ordinary finger breadths or less than 6.5 cm
assessment of body habitus	pregnancy, obesity, snoring

ated with care in intensive care units, 19 with anaesthesia care, and 5 with care in emergency departments (10–12). During difficult airway management the physicians have to pay attention to ventilation because the patient does not die from a failure to intubate, but from a failure to ventilate (14).

Evaluation of the airway

The prediction of a difficult airway is based on a focused medical history, review of prior medical records, physical examination, and specific tests for airway assessment.

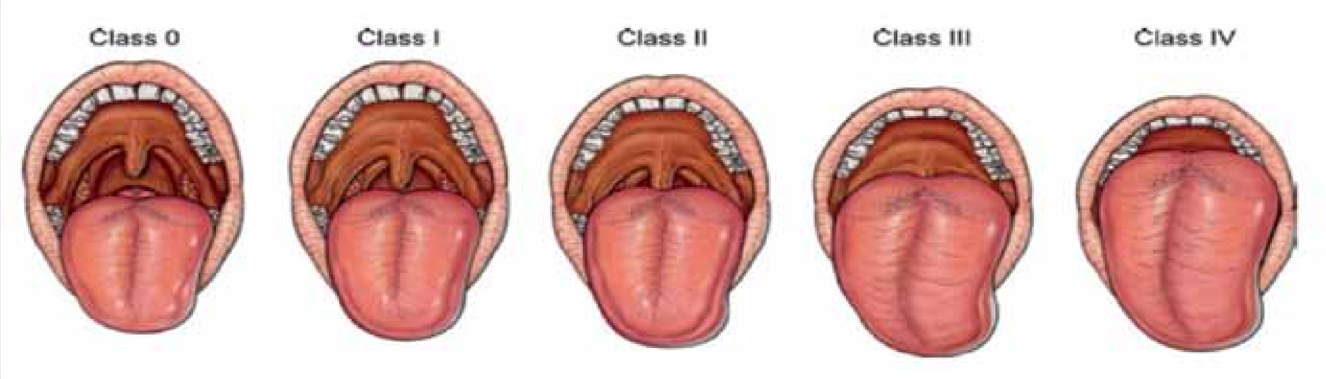
1. **Focused bedside medical history and review of prior medical records**
   By compulsively reviewing the medical history and the scope of medical records we can detect congenital (anatomic personal facial characteristics, neck and airway, micrognathia, Pierre–Robin syndrome, Treacher–Collins syndrome, Goldenhar syndrome, Down's syndrome, and Klippel–Feil syndrome), acquired (airway infections, obesity, acromegaly, goiters, ankylosing spondylitis, rheumatoid arthritis, amyloidosis, head and neck benign tumours or malignant tumours, and surgical or radiation therapy to the head and neck), or traumatic disease states (facial and airway injuries, burns, haematomas, cervical spine injuries, and foreign bodies), which may indicate the presence of a difficult airway. Medical history should also contain data of previous difficult airway management, alcohol or drug abuse, duration of fasting, and pregnancy.
2. **Physical Examination**
   An airway physical examination should be conducted, whenever feasible, prior to initiating airway management in all patients. The components of the pre–operative airway physical examination are described in Table 1.
3. **Specific tests for airway assessment**
   - The submandibular space is estimated using three measurements (Table 1):
     - Hyomental distance is defined as the distance between the mentum and the hyoid bone and is normally > 3 cm.

- Thyromental distance or the Patil sign is defined as the distance between the mentum and the thyroid cartilage, while the patient's neck is fully extended and is normally > 6.5 cm, or 3 ordinary finger breadths, which is less accurate (15).
- The ratio of height to thyromental distance lower than 22.24 (16).

- A neck circumference to thyromental distance ratio > 5.0 predicts a difficult airway (17)
- The sternomental distance is defined as the distance between the mentum and the sternum, while the patient's neck is fully extended. The normal distance is > 12.5 cm.
- Modified Mallampati test:
  The modified Mallampati test assesses the size of the base of the tongue relative to the oral cavity and oropharynx.

The Mallampati test is performed with the patient in the sitting position, with the head in a neutral position, the mouth wide open, and the tongue protruding to its maximum. Classification is assigned based on the extent to which the base of the tongue is able to mask the visibility of pharyngeal structures into three classes (18). Samsoon and Young (19) modified the Mallampati test classification with the addition of a fourth class and Ezri et al. (20) added the zero class (Figure 1). The third and fourth classes in the Mallampati classification predict a difficult airway. When used alone, the Mallampati test has limited accuracy in the prediction of a difficult airway (21, 22). The modified Mallampati test is also useless in uncooperative or unconscious patients (23).

- The upper lip bite test (ULBT) evaluates the patient's ability to reach or completely cover the upper lip with the lower incisors (24).
- Direct laryngoscopy visualisation of the larynx, according to Cormack and Lehane (14), who defined four grades of direct laryngoscopic visualisation of the larynx (Figure 2; 14). Grades III and IV predict difficult orotracheal intubation.
- Radiographic assessment and computerized facial analysis
  Craniocervical X–ray films, CT and MRI scans, or digital photographs are required for measuring the distance, angle, and relationship between anatomic structures from which difficult mask ventilation and orotracheal intubation might be predicted (25, 26). These assessments exceed the pre–operative bedside airway evaluation and are required for some special diagnostic and airway evaluations.



0. Class: visualisation of the epiglottis, soft palate, fauces, uvula, anterior and the posterior pillars; I. Class: visualisation of the soft palate, fauces, uvula, anterior and the posterior pillars; II. Class: visualisation of the soft palate, fauces and uvula; III. Class: visualisation of soft palate and base of uvula; IV. Class: visualisation of only hard palate

Figure 1. *Classification according to the modified Mallampati test (18–20)*

Table 2: *Statistical terms and definitions*

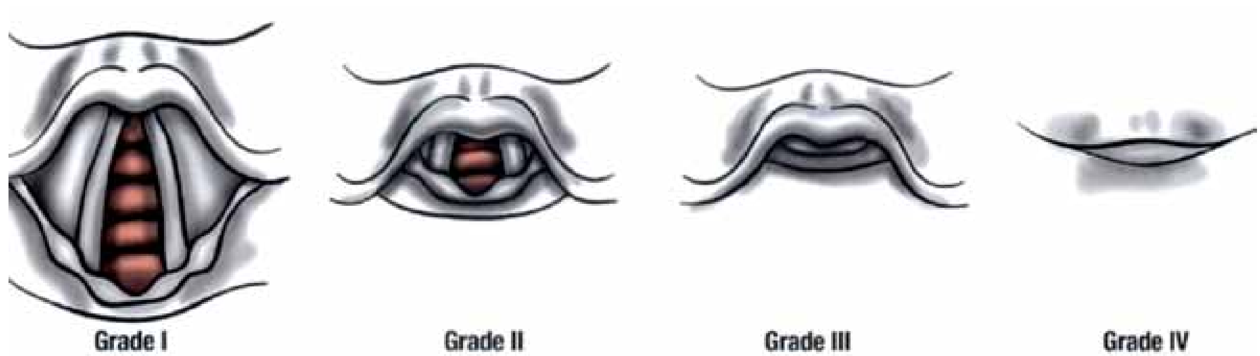
True positive (TP) a difficult laryngoscopy that had been predicted to be difficult; False positive (FP) an easy laryngoscopy that had been predicted to be difficult; True negative (TN) an easy laryngoscopy that had been predicted to be easy; False negative (FN) a difficult laryngoscopy that had been predicted to be easy
Sensitivity or true positive rate (TPR) the percentage of correctly predicted difficult laryngoscopies as a proportion of all laryngoscopies that were truly difficult: TPR = (TP/(TP + FN) Specificity (SPC) or True Negative Rate the percentage of correctly predicted easy laryngoscopies as a proportion of all laryngoscopies that were truly easy: SPC = (TN/(TN + FP)
Positive predictive value (PPV) or precision the percentage of correctly predicted difficult laryngoscopies as a proportion of all predicted difficult laryngoscopies: PPV = (TP/(TP + FP) Negative predictive value (NPV) the percentage of correctly predicted easy laryngoscopies as a proportion of all predicted easy laryngoscopies: NPV = (TN/(TN + FP)
Accuracy of the percentage of correctly predicted easy or difficult laryngoscopies as a proportion of all laryngoscopies: Accuracy = (TP + TN)/(TP + FP +TN + FN)

Interpretation of the airway assessment

Each feature or test is characterized by a sensitivity and specificity for the prediction of a difficult airway. Statistical terms and definitions, which are described in Table 2, are required to evaluate and understand the accuracy of a feature or airway test in predicting a difficult airway.

A test to predict a difficult airway should have high sensitivity to identify most patients with difficult airways, high specificity to correctly predict easy airway management, and a high level of accuracy to identify truly difficult and easy airway management (Table 2). There are numerous studies involving the evaluation of the accuracy of single and multiple airway tests with very different results (Tables 3 and 4; 22, 26, 30–40, 42).

There is insufficient published evidence to evaluate the predictive value of a bedside medical history and individual features of the airway physical examination



Grade I: visualisation of entire laryngeal aperture; Grade II: visualisation of the posterior commissure of the laryngeal aperture only; Grade III: visualisation of the epiglottis only; Grade IV: visualisation of the soft palate only.

Figure 2. *Direct laryngoscopic visualisation of the larynx according to Cormack and Lehane (14).*

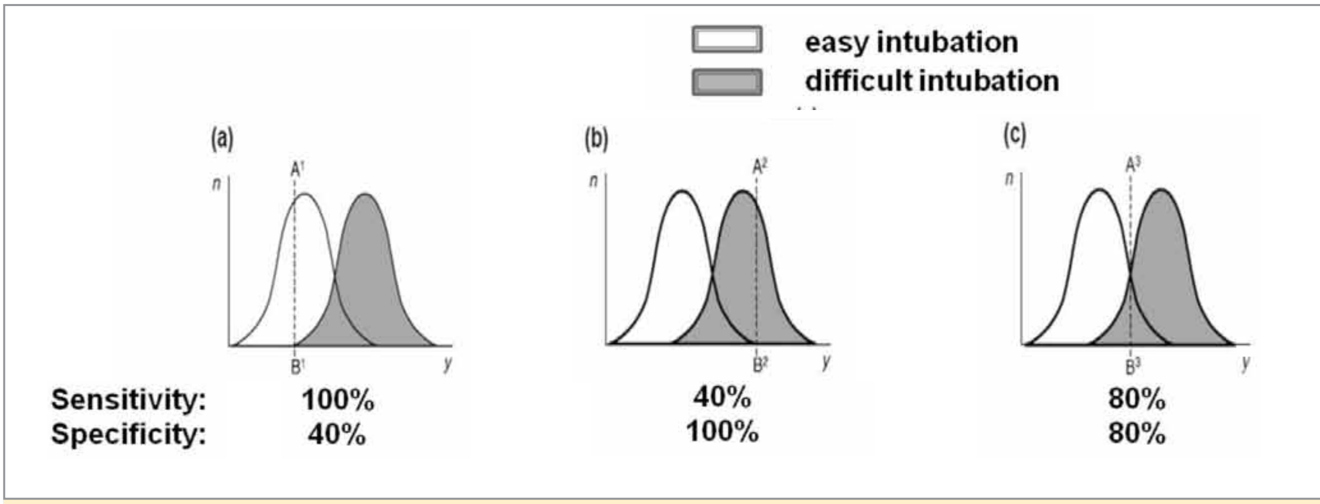


Figure 3. Schematic representation of a population of patients separated into two overlapping groups by measuring a specific feature. The dotted lines are cut–off values (27).

or multiple features in predicting the presence of a difficult airway. However, the prediction of a difficult airway may be improved by a focused medical history and the assessment of a single feature of the airway physical examination. The prediction is even more accurate by the airway assessment with multiple features (1).

There are two major problems in the statistical evaluation of the tests to predict difficult airways (27). First, where to place the cut–off value for Ax–Bx to separate populations with easy and difficult orotracheal intubations according to the results of the test to predict difficult intubations has not been established (Figure 3). The cut–off value for A1–B1 (Figure 3a) correctly identifies all patients with difficult intubations, but a shortcoming of 100% sensitivity is the large number of false–positive results, and therefore the corresponding low specificity. To avoid a large number of false–positive results and unnecessary preparation for difficult airway management, the cut–off value should be moved to a new position (A2–B2; Figure 3b). The test now correctly identifies all of the patients with easy intubation (100% specificity), but there is a large number of false–negative results and low sensitivity. Thus, one might be unprepared for difficult airway management.

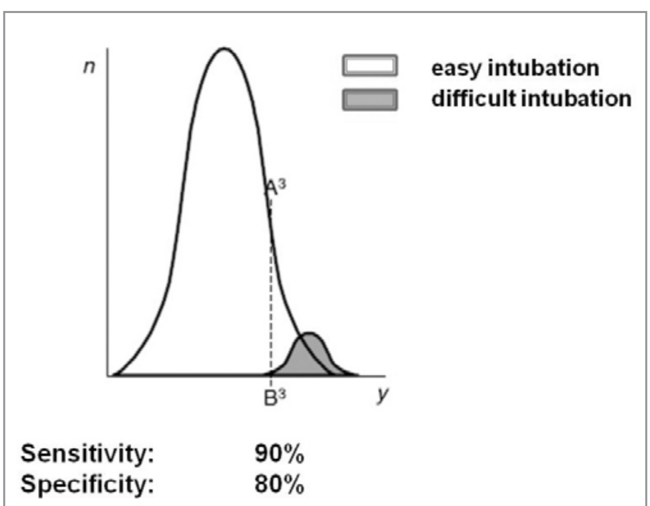


Figure 4. Schematic representation of a population of patients separated into two overlapping groups by measuring a specific feature. The dotted lines are cut–off values (27).

It is reasonable that a compromise might be the cut–off value position, A3–B3 (Figure 3c), but there is a second major statistical problem; specifically, a low incidence of difficult airways and a high incidence of easy airway management (Figure 4).

Despite the specificity of a test, there will always be false–positives results in the absence of 100% specificity. Even the small proportion of the large easy intubation group indicates that the number of false–positive results will be large compared to the number of

Table 3: *Statistical predictive values for the prediction of difficult orotracheal intubation from several studies (22, 30–34, 42)*

Test	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Accuracy (%)
Mallampati test	32–82	61–97	8–65	94–98	61–94
Upper lip bite test	17–76	89–97	29–35	91–98	85–90
Interincisor distance	23–68	77–93	8–13	98	76
Thyromental distance	7–17	25–99	5–18	98	82
Sternomental distance	13–84	71–96	8–13	98	71
Micrognathia	6	99	50	84	—
Limited mouth opening	10–47	95–98	50	84	—
Abnormal teeth	13	78	11	82	—
Limited neck extension	10–17	92–99	5–67	84–98	—
Ratio of height to thyromental distance	71	98	78	97	96
Neck circumference to the thyromental distance ratio	88	83	45.5	97.8	—

true–positive results in the small difficult intubation group, resulting in low specificity and a positive predictive value.

No single feature or airway test can provide a high index of sensitivity and specificity for the prediction of a difficult airway (Table 3, Figure 4; 28, 29). All airway assessment tests are characterized by low sensitivity, reasonable specificity, and a low positive predictive value (Table 3). Therefore, the effective prediction of difficult mask ventilation and orotracheal intubation requires a combination of tests to evaluate the airway (1).

Several scoring system models were developed by multivariate analysis with multiple different integrated tests or risk factors to improve the prediction of difficult airways, but with very different effectiveness to predict difficult airways accurately (Table 4; 22, 26, 30–40, 42).

There are several reasons for the large variability and poor performance of the tests and models to predict difficult intubation, including the rarity of difficult intubation, multifactorial etiology and varying definitions of difficult airway, interobserver variability in test results, the variability of validation study methodologies and statistical analyses, the variability of anaesthesia induction techniques, and the inadequacy of the tests and models themselves.

Difficult airway management:

Difficult airway management may result from different underlying mechanisms and can be divided into the following categories:

- patient–related
- airway–related
- technique–related (drug–related, inappropriate equipment, lack of knowledge and experience to manage a difficult airway)

The independent risk factors significantly associated with DMV include age > 55 years, BMI > 26 kg/m2, lack of teeth, history of snoring, third and fourth classes according to the Mallampati classification, limited ULBT, and the presence of a beard (41). In the case of DMV, the risk of difficult orotracheal intubation increases four–fold (2).

El–Ganzuri et al. (42) identified several independent predictors of difficult intubation, as follows: mouth opening < 4 cm; thyromental distance < 6 cm; Mallampati class III or higher; neck movement < 80%; in-

Table 4: Sensitivity and specificity of scoring models (26, 35–40)

Assessment model	Tests integrated in model	Sensitivity (%)	Specificity (%)
Wilson model	weight neck mobility temporomandibular joint movement receding mandible buck teeth	75	88
Arne model	previous difficult intubation diseases associated with difficult intubation clinical symptoms of airway pathology temporomandibular joint movement cervical spine movement the interincisor gap the Mallampati score	94	96
Naguib model	height thyrosternal distance thyromental distance the Mallampati score	95.4	91.2
Connor model	computerised analysis of facial structure thyromental distance	90	85
Basaranoglu model	the Mallampati score sternomental distance thyrosternal distance the interincisor gap atlanto–occipital extension	21	92
Karkouti model	mouth opening chin protrusion atlanto–occipital extension	86.8	96
Simplified Predictive Intubation Difficulty Score (SPIDS) model	pathology associated with difficult intubation mouth opening ratio of height to thyromental distance maximum range of head and neck movement the Mallampati score	65	76

ability to advance the mandible; body weight > 110 kg; and a positive history of difficult intubation.

According to the European Society of Anaesthesiology, systematic multimodal screening for difficult intubation should include the Mallampati classification and thyromental distance, mouth opening or interincisor distance, range of motion of head and neck, compliance of the mandibular space, and the ULBT (6).

CONCLUSION

Further multicentre studies with large sample sizes in different populations should be conducted to determine the most accurate model of airway assessment to predict difficult airways and confirm the model in clinical practice.

Until then, the clinical value of bedside screening tests and models for predicting difficult intubation remains a mandatory part of clinical practice before airway management.

Despite careful pre–operative airway evaluation, some patients with a difficult airway will remain undetected; therefore, it is necessary to have knowledge of "can't intubate, can't ventilate" protocol skills to manage the airway and ventilate the patient and the equipment for difficult airway management.

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