

Difficult airway and difficult intubation in postintubation tracheal stenosis: a case report and literature review

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Abstract: Management of a "difficult airway" remains one of the most relevant and challenging tasks for anesthesiologists and pulmonary physicians. Several conditions, such as inflammation, trauma, tumor, and immunologic and metabolic diseases, are considered responsible for the difficult intubation of a critically ill patient. In this case report we present the case of a 46-year-old male with postintubation tracheal stenosis. We will focus on the method of intubation used, since the patient had a "difficult airway" and had to be intubated immediately because he was in a life-threatening situation. Although technology is of utter importance, clinical examination and history-taking remain invaluable for the appropriate evaluation of the critically ill patient in everyday medical life. Every physician who will be required to perform intubation has to be familiar with the evaluation of the difficult airway and, in the event of the unanticipated difficult airway, to be able to use a wide variety of tools and techniques to avoid complications and fatality.

Keywords: difficult airway, bronchoscopic intubation, predictive factors, predictive scales

Introduction

Failed or difficult endotracheal intubation is a significant cause of morbidity and mortality during anesthesia.¹ It has been estimated that inability to successfully manage a difficult airway has been responsible for as many as 30% of deaths attributable to anesthesia. Waiting too long before manipulation of the airway could increase the partial pressure of the volatile anesthetic in the body and result in apnea and bradycardia. The reported incidence of difficult intubation is one in every 65 patients. Fiberoptic bronchoscopes and laryngeal mask airways have contributed to a large extent to the management of difficult airway.² Several methods have been introduced to identify patients who are in danger of difficult intubation before the initiation of anesthesia.^{3,4} Not all cases can be identified before anesthesia, however, and many cases of difficult intubation arise after trying to find the vocal cords by direct laryngoscopy once unconsciousness has been induced and the skeletal muscles relaxed. The actual difficulties surrounding intubation can only be determined by grading the exposure of the vocal cords by conventional direct laryngoscopy.⁵

A number of devices are available to manage the difficult airway, including flexible fiberoptic bronchoscopes, the rigid optical stylet, light wands, rigid fiberscopes, the BullardTM laryngoscope, (BL, Gyrus ACMI, Southborough, MA), the Augustine Scope, (Augustine Biomedical + Design, Eden Prairie, MN), the intubation laryngeal mask airway, and the visualized endotracheal tube.⁶ Flexible fiberoptic bronchoscopy is immensely useful for the critical-care doctor in the management of difficult

tracheal intubations (DTIs), evaluation of the upper airway, verification of endotracheal tube placement, repositioning or checking of patency of endotracheal tubes, changing of endotracheal tubes, placement of double lumen tubes, and placement of endobronchial blockers. The flexible fiberoptic intubation bronchoscope gives the competent practitioner the unparalleled opportunity to secure almost any difficult airway encountered.⁷ The flexible fiberoptic bronchoscope is regarded as the gold standard in planning predicted difficult airway management, but numerous hours of training are necessary to optimize control of this device.^{8–10}

Case report

A 46-year-old man was admitted to the emergency department with exertional dyspnea, wheezing, and respiratory acidosis. Three days earlier he had been discharged from a tertiary hospital after being hospitalized for 15 days due to a labor accident. He had sustained bilateral pneumothorax, hemothorax, and rib fractures. Upon his admission at that time he was intubated for 5 (out of 15) days. He was discharged in a generally good condition. The patient was a lifetime nonsmoker and he was not receiving any medications. Nevertheless, he had morbid obesity, with a body mass index of >45.

On admission the patient had tachypnea (respiratory rate 35 breaths/minute), inspiratory stridor, and tachycardia (heart rate 135 beats per minute); use of accessory respiratory muscles was noticed and he was unconscious, responding only to painful stimuli. His arterial blood gas revealed respiratory acidosis: partial pressure of oxygen 48 mmHg, partial pressure of carbon dioxide 75 mmHg, pH 6.80, and bicarbonate 43 mmol/L, with on-air fraction of inspired oxygen of 21%. A chest X-ray revealed blunting of the left costophrenic angle and evidence of tracheal stenosis (Figure 1A). Therefore, a computed tomography scan of the thorax was performed and revealed narrowing of the trachea at the level of the thyroid gland (Figure 2B).

Upon discharge the patient was given painkillers and anticoagulant treatment with low-molecular-weight heparin. Systemic corticosteroids (methylprednisolone) and inhaled treatment with nebulizer (bronchodilators ipratropium bromide and budesonide) were administered.

The patient was ventilated with an Ambu face mask (DIGAS GEORGE & Co., Thessaloniki, Greece) during his transport to the hospital and during the radiologic examination. Noninvasive ventilation was applied with a bilevel positive airway pressure model of inspiratory positive airway pressure of 12 and expiratory positive airway pressure of

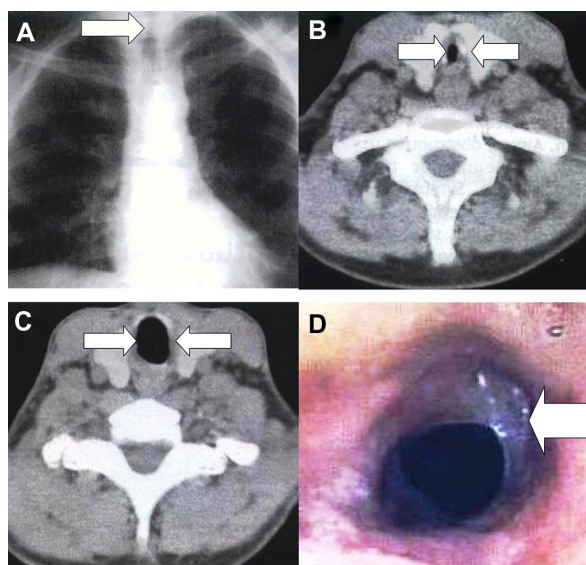


Figure 1 (A) Chest X-ray upon admission. (B) Computed tomography scan of neck upon admission. (C) Computed tomography scan of neck post-laser intervention and systemic treatment. (D) Bronchoscopic findings demonstrating (web-like) fibrotic stenosis.

6, and titration was applied according to the arterial blood gas, but the patient continued to have respiratory acidosis. Attempting to intubate the patient to sustain ventilation revealed edema of the oropharyngeal structures.

Since all attempts to intubate with lighted stylet failed, we decided to apply a laryngeal supraglottic steel handle mask. The patient was admitted into the intensive care unit and, with the use of a fiberoptic bronchoscope (model 11301ABN1, Storz insertion cord diameter 2.8 mm, insertion cord length 500 mm, working channel 1.2 mm; Karl Storz GmbH & Co. KG, Tuttlingen, Germany), an endotracheal tube of 7.5 mm (high-volume, low-pressure; Well Lead Medical Co, Guangzhou, China) was inserted. A red stomach tube (Levin's type) of 18 (Fr/Ch) or 6.7 mm (size OD; Well Lead Medical Co) was firstly applied throughout the bronchoscope and was inserted into the laryngeal mask to be used as a guide for the endotracheal tube that we intended to use (Figures 2 and 3). The fiberoptic bronchoscope revealed a membranous web-like stenosis of the trachea (Figure 1D). The Levin tube was placed and the fiberoptic bronchoscope was removed. The endotracheal tube was then applied with the Levin tube as a guide. All laboratory findings were normal. The patient was ventilated with an Evita 2 Dura ventilator (Dräger Medical GmbH, Lübeck, Germany) (Figure 4). We attributed the formation of the membranous tissue and consequently the tracheal stenosis to the former intubation period. Endoscopic treatment with laser incision and systematic steroid administration provided the solution (Figure 1C). The arterial blood

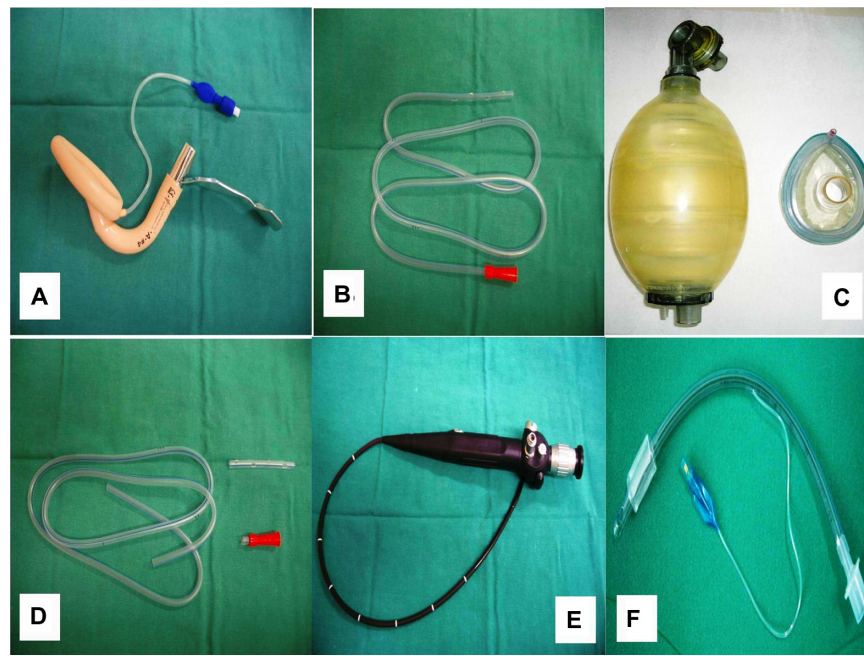


Figure 2 (A–C) Application of the Levin tube through the bronchoscope (steps). **(D)** Demonstration of the laryngeal mask with the bronchoscope and Levin tube. **(E)** Levin tube within the laryngeal steel handle mask. **(F)** Endotracheal tube with the Levin tube inserted as a guide.

gas on air after the endoscopic treatment was partial pressure of oxygen 82 mmHg, partial pressure of carbon dioxide 37 mmHg, pH 7.42, and bicarbonate 22 mmol/L.

Discussion

The difficult airway has been defined as “the clinical situation in which a conventionally trained anesthetist experiences

difficulty with mask ventilation of the upper airway, tracheal intubation, or both.”¹⁰ DTI accounts for 17% of respiratory-related injuries and results in significant morbidity and mortality.¹ In fact, up to 28% of all deaths associated with anesthesia are due to the inability of a mask to ventilate or intubate.¹ The American Society of Anesthesiologists defines a difficult airway as the existence of clinical factors

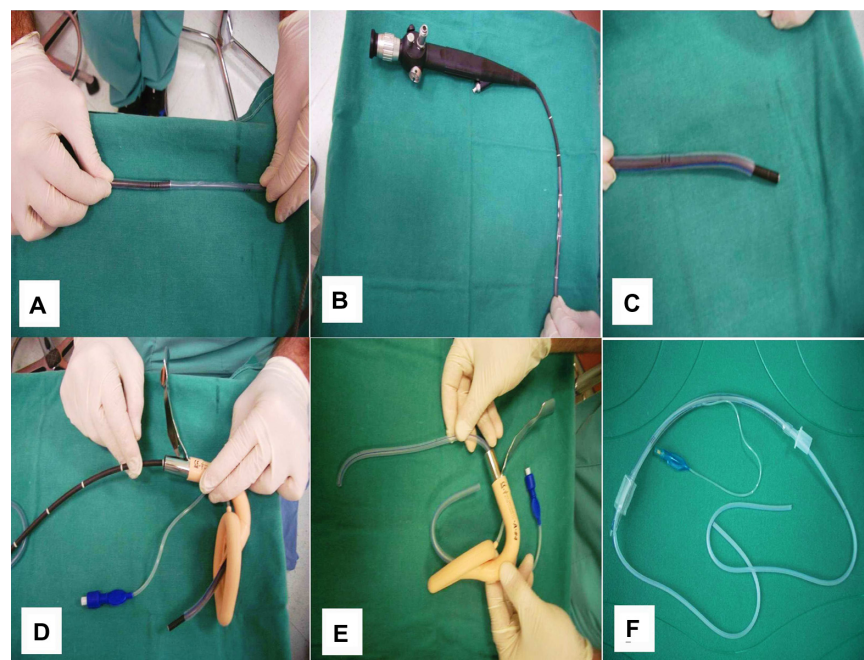


Figure 3 (A) Laryngeal steel handle mask. **(B)** Levin tube. **(C)** Ambu face mask. **(D)** Levin tube with the edges cut off. **(E)** Bronchoscope. **(F)** Endotracheal tube.



Figure 4 Evita 2 Dura (Dräger, Medical GmbH, Lübeck, Germany).

that complicate both ventilation administered through a face mask and intubation performed by an experienced person. The difficult airway algorithm of the American Society of Anesthesiologists was developed to guide clinicians in the management of the patient who is either predicted to have a difficult airway or whose airway cannot be adequately managed after induction of anesthesia.¹⁰

Though the American Society of Anesthesiologists' taskforce did not attempt to enumerate the features that identify those patients who may prove difficult to manage, it did recognize that an airway evaluation should be performed. Difficult ventilation is defined as the inability of a trained anesthesiologist to maintain oxygen saturation >90% using a face mask, with a goal of oxygen fraction of 100%. Difficult intubation is defined as the need for more than three attempts for intubation of the trachea or more than 10 minutes to achieve it, a situation that occurs in between 1.5% and 8% of general anesthesia procedures.^{11,12} Greater degree of difficulty in intubation is associated with greater incidence and severity of complications.¹³

Up to 30% of anesthetic deaths can be attributed to a compromised airway.¹⁴ This has generated the need for highly predictive tests for the identification of an airway

with assumed intubation difficulty, to be applicable in all anesthetic and surgical procedures.^{10,15}

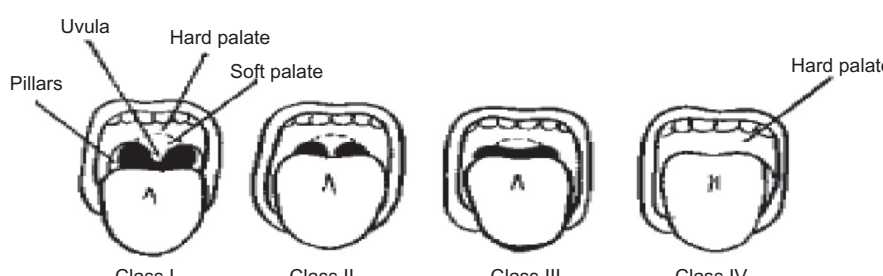
There are several factors that may cause tracheal stenosis, including traumatic conditions, inflammatory diseases, benign and malignant lesions, collagen vascular diseases, and congenital conditions. Of these causes the leading cause of tracheal stenosis still continues to be endotracheal intubation, despite technological improvements such as the introduction of high-volume low-pressure cuffs and better patient care. Local inflammation and ischemia caused by an endotracheal tube can result in the upregulation of the fibrinolytic pathway, including C and S proteins locally, resulting in the creation of membranous-like stenosis.¹⁶ Two studies, the first by Spittle and Beavis¹⁶ and the second by Spittle and McCluskey,¹⁷ present data that elucidate the underlying mechanism when a cuff pressure greater than 30 mmHg exceeds a critical point in the mucosal capillary perfusion pressure, causing mucosal ischemia leading to ulceration, chondritis of the tracheal cartilages, and, ultimately, development of irreversible fibrotic tissue. The endotracheal tube cuff causes circumferential erosion of the mucosa, which heals with a concentric (web-like) stenosis. It has been reported that based on the length of tracheal stenosis, the depth of the tracheal wall involvement, and the presence or not of tracheomalacia, postintubation tracheal stenosis falls into three categories: short, "complex", and "pseudoglottic".¹⁸

Assessment of a difficult airway begins with a comprehensive medical history, and physical and regional examination. There are several key elements for the clinician to check: (1) variations in normal anatomy; (2) pathologic conditions; (3) a small mouth opening; (4) protruding upper teeth; (5) a large tongue; and (6) immobility of the head, neck, and jaw. Variations in "normal" anatomy and characteristic airway anatomy resulting from pathologic conditions can result in problems despite proper positioning and equipment (Tables 1 and 2).


Moreover, several conditions have been reported to predispose patients to difficult airway intubation. These conditions include infections, trauma, obesity, endocrine factors, foreign body, tumors, inflammatory conditions, congenital problems, and physiologic conditions (Table 2).¹⁰ Difficult airway intubation can result in numerous complications (Table 3). Infections such as epiglottitis, abscesses, croup, bronchitis, and pneumonia can affect airway management.¹⁹ Radiological methods such as a computed tomography scan or a lateral neck radiograph may be helpful as an initial management of the underlying condition and should

Table 1 Most valuable scales/distances used in the prediction of difficult airway


	Technique classification	
1. Mallampati scale	Patient seated with head in complete extension, carrying out phonation and with the tongue within the mouth	Class I: visibility of soft palate, uvula, and amygdaline pillars Class II: visibility of soft palate and uvula Class III: visibility of soft palate and base of uvula Class IV: impossibility of visualizing soft palate
2. Patil–Aldrete scale (thyromental distance)	Patient seated, head extended and mouth closed; distance that exists between the thyroid cartilage (upper recess) and the lower border of the chin is evaluated	Class I: >6.5 cm (endotracheal laryngoscopy and intubation without difficulty) Class II: 6–6.5 cm (laryngoscopy and intubation with a certain level of difficulty) Class III: <6 cm (very difficult laryngoscopy and intubation)
3. Sternomental distance	Patient seated, head in complete extension and mouth closed; distance of a straight line going from the superior border of the manubrium of the sternum to the point of the chin is evaluated	Class I: >13 cm Class II: 12–13 cm Class III: 11–12 cm Class IV: <11 cm
4. Cormack–Lehane classification	Direct laryngoscopy is carried out; grade of difficulty achieving endotracheal intubation according to visualized anatomic structures is evaluated	Grade I: Glottic ring is observed in total (intubation very easy) Grade II: commissure or upper half of glottic ring is observed (difficult) Grade III: Only epiglottis is observed with visualization of the glottic opening (very difficult) Grade IV: impossible to visualize the epiglottis (intubation only possible with special techniques)




Class I Class II Class III Class IV




Scale 2



Scale 1



Grade I Grade II Grade III Grade IV



Scale 3

5. Atlanto Occipital (AO) joint extension	Patient faces front with head erect and extends the head maximally; the angle traversed by the occlusal surface of the upper teeth is measured with agoniometer	Grade I: >35 Grade II: 22°–34° Grade III: 12°–21° Grade IV: <12
6. Mandibulo-hyoid distance	Measurement from chin to hyoid	At least 4 cm or 3 finger breadths
7. Inter-incisor distance	Distance between upper and lower incisors	Normal: >4.6 cm Difficult airway: <3.8 cm

be tried, where possible.¹⁰ Trauma also alters the airway structures. The ABC (airway, breathing, and circulation) rule should be followed in this situation. Indications for tracheal intubation include protection of the airway, airway obstruction, positive pressure ventilation, tracheal toilet, and a decreased level of consciousness. Alternatively,

orotracheal intubation may be contraindicated or may not be possible in the patient with massive facial, laryngeal, or tracheal trauma.²⁰ A surgical airway may be necessary instead.¹ Moreover, obesity (body mass index ≥ 25 kg/m²) alters respiratory pathophysiology and distorts upper airway anatomy.^{5,21}

Table 2 Congenital and acquired compromising conditions

Congenital:
Pierre Robin syndrome: micrognathia, macroglossia, cleft soft palate
Treacher-Collins syndrome: auricular and ocular defects, malar and mandibular hypoplasia
Goldenhar syndrome: auricular and ocular defects, malar and mandibular hypoplasia
Down syndrome: poorly developed or absent bridge of the nose, macroglossia
Klippel-Feil syndrome: congenital fusion of a variable number of cervical vertebrae, restriction of neck movement
Goiter: compression of trachea, deviation of larynx/trachea
Acquired:
Infections
Supraglottitis: laryngeal edema
Croup: laryngeal edema
Abscess (intraoral): distortion of the airway and trismus retropharygeal
Ludwig's angina: distortion of the airway and trismus
Arthritis
Rheumatoid arthritis: temporomandibular joint ankylosis, cricoarytenoid arthritis, deviation of larynx, restricted mobility of cervical spine
Ankylosing spondylitis: ankylosis of cervical spine, less commonly ankylosis of temporomandibular joints, lack of mobility of cervical spine
Benign tumors
Cystic hygroma, stenosis or distortion of the lipoma, adenoma, goiter airway, fixation of larynx or adjacent tissues secondary to infiltration or fibrosis from irradiation
Malignant tumor, edema of the airway
Facial injury, hematoma, unstable fraction(s) of the cervical spine injury, maxillae, mandible and cervical laryngeal/tracheal trauma vertebrae
Obesity
Short, thick neck, redundant tissue in the oropharynx, sleep apnea
Acromegaly
Macroglossia, prognathism
Acute burns
Edema of airway

In addition, patient age >55 years and lack of teeth has also been associated with DTI.²⁵ Finally, acromegaly, tumors, gastric reflux, and pregnancy are included among the factors predisposing a patient to DTI, either through morphologic and anatomic differentiations or pathogenic mechanisms of the underlying condition.^{26–28}

Failure to intubate the trachea occurs in one in 2000 patients in the nonobstetric population and one in 300 patients in the obstetric population.²² The need for equipment other than a direct laryngoscope may also help define DTI, although devices such as the gum elastic bougie (introducer) may or may not be viewed as part of standard technique. Therefore, the intubation difficulty scale is used, incorporating seven variables to calculate a score. An intubation difficulty scale score of 5 has been used to define DTI and, in a large study, occurred in 8% of patients.^{23,24}

No single airway test can provide a high index of sensitivity and specificity for prediction of difficult airway. Therefore,

Table 3 Difficult airway complications

Laceration of soft tissues
Laryngospasm
Vocal cord paralysis
Dislocation of the arytenoid cartilages or mandible
Perforation of the trachea or the esophagus
Endobronchial or esophageal intubation
Dental damage
Hemorrhage
Aspiration of gastric contents or foreign bodies
Increased intracranial or intraocular pressure
Hypoxemia, hypercarbia
Fracture or dislocation of the cervical spine
Spinal cord damage
Trauma to the eyes

a combination of multiple tests is used. The grading tools and scales most commonly used to assess difficult intubation are presented in Table 1.¹³ They provide accuracy in assessment of preoperative stable patients. Emergency patients are more difficult to assess because of coexisting stress factors, hypoxemia, hypotension, and hypertension, and require intubation under less than optimal conditions. Furthermore, some patients with a difficult airway will remain undetected despite the most careful preoperative airway evaluation. Thus, anesthesiologists must always be prepared with a variety of preformulated and practiced plans for airway management in the event of an unanticipated difficult airway (Table 4).

The most widely used scale is the Mallampati test, which originally categorized patients into three grades according to the ability to visualize the soft palate, fauces, uvula, and anterior and posterior pillars.³ In 1987, Samssoon and Young added a fourth grade.²² Cormack and Lehane also provided a grading system of four grades according to exposure of the larynx at laryngoscopy.⁵ Their classification also underwent modification by Cook, who subdivided grade II into IIa and IIb, and grade III into IIIa and IIIb.²⁹ Wilson developed a scoring system that was based on body weight (<90 kg, 90–110 kg, >110 kg), head and neck movement, jaw movement, mandibular recession, and the presence or absence of protruding (“buck”) teeth.³⁰ Arne et al³¹ developed a scoring system with seven individual predictive factors, including not only anatomical factors and scales but clinical symptoms and pathologies associated with difficult intubation and history of difficult intubation. Sensitivity ranged from 90% to 94%, and specificity was 66% and 96% for cancer and general surgery, respectively; nevertheless the positive predictive value was low (34%). In conclusion, the Mallampati test was more accurate than the other predictive factors. The LEMON airway assessment method (Table 5)

Table 4 Accuracy indexes of prognostic tests for difficult airway

Prognostic tests	Types of test characteristics	Sensitivity (%)	Specialty (%)	Positive prognostic value (%)
Mallampati test	Category 3	44–64	66–89	21
Savva test	<6 cm	7	99	38
	<6.5 cm	62–64	25–81	16
Petil test	<12.5 cm	82	88	27
Head extension	<80°	11	98	30
Mouth opening	<4 cm	26	95	25

was assessed in two studies, which showed that patients in the difficult intubation group scored higher than those in other groups.^{32,33}

Despite the advances in available devices, most airway practitioners tend to resort to the surgical airway approach when facing difficulty in intubation, although the ACLS (advanced cardiac life support) guidelines include a variety of alternatives when tracheal intubation is not achieved.¹⁰ There are two key parameters for the management of the difficult airway: (1) practitioner experience, and (2) clinical setting. During the last 10 years, many researchers agreed that the flexible fiberoptic endoscope is the single most useful tool when facing a difficult airway. Direct visualization of the upper airway, vocal cords, and tracheal placement ensures correct placement of the endotracheal tube. In some studies, the success rates were as high as 93.9%.^{11,34} The simplest and easiest approach to intubating using a flexible endoscope is that the larynx is in view and the bronchoscope passes through it. Then the operator can rotate the scope and bend its tip when navigating through a difficult airway. This method of intubation allows the practitioner to have a wide variety of choices regarding whether to intubate with the patient awake or asleep, or whether to use an oral or nasal pathway. Most experts agree that awake intubation in an informed adult patient is the safest choice, using local anesthesia and sedation when necessary, whereas children are more difficult to intubate awake. Awake intubation provides for spontaneous respiration and maintenance of upper airway tone.^{35,36}

Table 5 The LEMON assessment method

L	Look externally (facial trauma, large incisors, beard or moustache, large tongue)
E	Evaluate the 3-3-2 rule (incisor distance 3 finger breadths, hyoid mental distance 3 finger breadths, thyroid-to-mouth distance 2 finger breadths)
M	Mallampati (Mallampati score \geq 3)
O	Obstruction (trauma, epiglottitis, peritonsillar abscess)
N	Neck mobility

Conclusion

Despite the variety of prediction tests for the difficult airway, none can provide an accurate assessment, so every patient has to be considered as possibly having a difficult airway upon performing an intubation. A combination of scales could be used for early identification of difficult airway intubation with higher sensitivity and specificity results. In most cases the airway has to be maintained for a long period of time with adequate oxygenation and ventilation, and the intubation attempts have to be minimized to avoid injury and complications. Although the conventional laryngoscopic technique remains the standard with a high success rate, every physician who will be required to perform intubation has to be familiar with the process of evaluating a difficult airway and, in the event of the unanticipated difficult airway, be able to use a wide variety of tools and techniques to avoid complications and fatality. The flexible fiberoptic bronchoscope is the gold standard to predict difficult airway and to ensure tube position. Limitations involve purchasing and maintenance costs and skill development.

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All authors contributed equally to the preparation of the manuscript.

Disclosure

Written informed consent was obtained from the patient upon discharge for publication of this case report and all accompanying images. The authors report no conflicts of interest in this work.

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