

Review Article

Advanced Airway Assessment and Management: Contemporary Evidence, Emerging Technologies, And Clinical Applications

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Abstract: *Introduction:* Airway management continues to be a very important task of anesthesiologists, intensivists and emergency physicians. Blocking of the patent airway and failure to maintain it can cause rapid onset of symptoms of hypoxia, aspiration, neurological damage, cardiac arrest and death. Although considerable progress has been made in the maintenance of the airway using those devices and in monitoring techniques, the morbidity and mortality caused by complications related to the airway remain high. Adequate assessment of the airways is thus vital in the identification of patient at risk for difficult ventilation, laryngoscopy, intubation, extubation and emergency airway rescue. Traditional assessment methods for airways including Modified Mallampati Classification, Upper Lip Bite Test, thyromental distance, sternomental distance and neck circumference continue to be used but are not very useful when used alone. Most of the modern literature focuses on multimodal assessment of the airway, using multiple clinical predictors, in conjunction with cutting-edge technologies including airway ultrasonography. Airway Management has undergone recent innovations that have changed the way an airway is managed. For most known difficult airways, flexible bronchoscopic intubation is still the gold standard as video laryngoscopy has improved the visualization of the glottis and the first pass intubation success. Supraglottic airway devices still remain very important in rescue oxygenation and ventilation. The current guidelines of the American Society of Anesthesiologists (ASA) and the Difficult Airway Society (DAS) have been to ensure proper airway planning, ensure optimal oxygenation, rapidly utilize advanced airway devices, and become ready for emergency front-of-neck access. New technologies such as artificial intelligence, machine learning, high technology imaging, and augmented reality are promising to further enhance the ability to predict challenging airways and individualized airway management. This review discusses the current evidence on airway assessment, contemporary methods of airway management, difficult airway algorithms, human factors, simulation-based training and the future innovations pertinent to current anesthetic practice.

Keywords: Awake intubation, Airway ultrasound, Artificial Intelligence, Videolaryngoscopy, Difficult airway, Airway assessment

INTRODUCTION

Airway management is the backbone of the safe practice of anaesthetic and critical care. During anesthesia, emergency medicine and intensive care it is essential to establish and maintain adequate oxygenation and ventilation as a basis for patient survival. Despite extensive technological and educational advances, airway related adverse events remain an important cause of anesthesia associated morbidity and mortality.¹

Over the last few decades the definition of the difficult airway has changed dramatically. Conventionally, attention was focused upon the problems of difficult direct laryngoscopy and tracheal intubation². As of 2022, the American Society of Anesthesiologists (ASA) Difficult Airway Guidelines include as a difficult airway a clinical situation in which a trained clinician has difficulty with facemask ventilation (FMV), supraglottic ventilation with supraglottic airway device (SGA),

tracheal intubation, extubation or emergency invasive airway access.³

In about 5–10% of patients, a difficult laryngoscopy is encountered and in 1–8% of these, there will be a difficult tracheal intubation.⁴ There is a much greater incidence of airway difficulty in certain populations such as obese, pregnant women, critically ill and head and neck pathology.⁵

The results of the Fourth National Audit Project (NAP4) spurred many improvements in methods of assessing the airway, education, and creation of a standardized difficult airway algorithm.⁶

Conventional assessment techniques of the airway are still used, these include Modified Mallampati Classification, thyromental distance, sternomental distance and Upper Lip Bite Test. No one bedside test however is consistently predictive of all difficult airways

however. As a result, a multi-predictor method of assessment with the aid of technology, e.g. airway ultrasonography, is now considered more effective for contemporary practice.⁷

Video laryngoscopy is one of the most important advances for airway management in the last 20 years, and has increased the success rate of first pass intubation and better visualization of laryngeal components. At the same time, flexible bronchoscopy (FB) is proving to be a useful method in the assessment of the airway and for localisation of the cricothyroid membrane and confirmation of endotracheal tube placement in many anticipated difficult airways.⁸

Artificial intelligence (AI) and machine learning technologies recently have demonstrated potential in difficulty of airway identification and prediction by combining clinical, anatomical and imaging parameters⁹. These innovations are still to be investigated but could be a future development for airway management in individuals.¹⁰

The aim of this review is to provide a brief and evidence-based summary of current practice regarding airway assessment and management including current guidelines, advanced airway technologies, special patient populations, human factors, simulation-based airway education, and new advances that will shape the future of airway practice.

MATERIALS AND METHODS

This is a narrative review to summarise current evidence on airway assessment and management. Use of comprehensive literature search was done using Pub Med, Scopus, Google Scholar and Cochrane Library. The search terms "airway assessment", "difficult airway", "videolaryngoscopy", "airway ultrasound", "awake tracheal intubation", "supraglottic airway devices", "difficult airway guidelines", and "artificial intelligence in airway management" were used to identify relevant articles between 2000 and 2026. Further

references were manually searched for based on the articles selected and examined bibliographies.

The preference was for international guidelines, systematic review, meta-analysis, randomized controlled trials, and high quality observational studies. Special attention was given to the ASA 2022 guidelines on difficult airway and the latest recommendations of the Difficult Airway Society (DAS). The chosen literature was critically reviewed and synthesized to provide an evidence-based overview of current techniques of airway assessment, advanced airway technology, difficult airway algorithms, human factors and future developments in airway management.

Preop Airway Assessment Methods: Preoperative airway assessment continues to be the gateway of difficult airway prediction and preparation. While there is no single test that is certain to identify all difficult airways, a logical sequence of clinical parameters has been found to increase the chances of correct diagnosis and planning of the airway.¹¹

Modified Mallampati Classification

At present Modified Mallampati Classification is one of the most commonly used bedside airway assessment methods. Increased Mallampati grades are correlated with difficult laryngoscopy and intubation of the trachea.¹² However because of the relatively low sensitivity, and vast interobserver variation, it should not be used alone to predict difficult airway management.¹³

Advantages

- Simple and quick to perform
- Requires no specialized equipment
- Universally recognized and widely used
- Easily reproducible in routine clinical practice

Limitations

- Significant interobserver variability
 - Dependent on patient cooperation and positioning
 - Limited sensitivity when used alone
- Influenced by head position and examiner technique

Table 1. Modified Mallampati Classification

Class	Visible Structures	Predicted Difficulty
I	Soft palate, uvula, faucial pillars	Minimal
II	Soft palate and partial uvula	Mild
III	Soft palate and base of uvula	Moderate
IV	Hard palate only	Severe

Upper Lip Bite Test (ULBT)

The Upper Lip Bite Test assesses mandibular mobility and dental architecture by evaluating the patient's ability to bite the upper lip using the lower incisors.¹⁴

Table 2. Upper Lip Bite Test Classification

Class	Description	Airway Risk
I	Lower incisors bite above vermilion border	Low
II	Lower incisors bite below vermilion border	Intermediate
III	Unable to bite upper lip	High

Upper Lip Bite Test (ULBT)

The ‘Upper Lip Bite Test (ULBT) is a simple bedside assessment that evaluates mandibular mobility and the ability of the lower incisors to bite the upper lip. Several studies have demonstrated that the ULBT possesses higher specificity and positive predictive value for predicting difficult laryngoscopy and tracheal intubation compared with the Modified Mallampati Classification.¹⁵

Advantages

- Excellent reproducibility
- Simple and rapid bedside assessment
- Incorporates mandibular mobility and dental architecture

- Better interobserver reliability than the Mallampati test

Limitations

- Difficult to perform in edentulous patients
- Less reliable in patients with facial trauma
- Limited utility in temporomandibular joint disorders
- May be influenced by dental abnormalities.

Mouth opening Assessment

Adequate mouth opening is essential for insertion of laryngoscopes, supraglottic airway devices, oral airways, and bronchoscopic equipment. Inter-incisor distance is measured during maximal mouth opening.¹⁶

Table 3: Mouth Opening Assessment

Inter-incisor Distance	Interpretation
>4 cm	Normal
3–4 cm	Potential difficulty
<3 cm	Significant airway concern

Interpretation

Restricted mouth opening may occur due to temporomandibular joint disease, oral malignancy, facial trauma, radiation fibrosis, or previous surgery.¹⁷

Thyromental Distance

‘Thyromental distance (TMD) is measured from the thyroid notch to the mentum with the head fully extended. It estimates the available submandibular space required for displacement of the tongue during laryngoscopy.¹⁸

Table 4: Thyromental Distance

Distance	Assessment
>6.5 cm	Favorable
6–6.5 cm	Intermediate
<6 cm	Increased risk

Interpretation: A short TMD may indicate a receding mandible, reduced submandibular space, or anteriorly positioned larynx.¹⁹ Sternomental distance: Sternomental distance is measured from the suprasternal notch to the mentum with maximal neck extension and mouth closure.²⁰

Table 5: Sternomental Distance

Distance	Assessment
>13.5 cm	Normal
12.5–13.5 cm	Intermediate
<12.5 cm	Increased risk

Interpretation: This measurement reflects cervical spine mobility and head extension, both essential for optimal laryngoscopy.²¹

Neck Circumference

Circumference of the neck has been identified as one of the factors that can predict difficult airway management especially in obese patients.²² Neck circumference is correlated with the difficult facemask ventilation, difficult laryngoscopy, difficult tracheal intubation and obstructive sleep apnea. Some research indicates that neck circumference > 40 cm is a risk factor for airway difficulties, and > 50 cm is a good predictor of difficult intubation.²³

Advantages

- Simple and rapid bedside measurement
- Particularly useful in obese patients
- Helps predict both difficult ventilation and intubation
- Correlates with the severity of obstructive sleep apnea

Limitations

- Influenced by obesity and body habitus
- Limited predictive value when used alone
- Lack of universally accepted cutoff values across populations

Neck Circumference-to-Thyromental Distance Ratio

A higher NC/TMD Ratio has been linked to the difficult laryngoscopy, difficult facemask ventilation, difficult tracheal intubation and obesity-related airway difficulties.²⁴ The NC/TMD Ratio combines two important anatomical airway parameters and may offer more predictive power than either alone. Its usefulness is supported in recent meta-analysis especially in the obese surgical population..²⁵

Advantages

- Integrates neck size and mandibular anatomy
- Improved predictive performance compared with individual measurements
- Particularly valuable in obese patients

Limitations

- Requires accurate measurement of two parameters
- Optimal cut-off values may vary among different populations
- Limited validation in some patient groups

Composite Airway Prediction Models

There are no bedside tests that are reliably good at predicting difficult airway management. The focus therefore has shifted towards using a combination of predictors to assess the airway in the present day to enhance the diagnostic accuracy. Variables generally used are Modified Mallampati Classification, Upper Lip Bite Test, thyromental distance, mouth opening, neck circumference, cervical spine mobility and history of difficult airway management. Multivariable prediction models have shown to offer better sensitivity, specificity and predictive performance than do individual tests of airway assessment, so a comprehensive airway assessment including multiple clinical predictors is recommended for more effective stratification and perioperative planning.²⁶

Airway Ultrasonography

Point-of-care airway ultrasonography has emerged as one of the most significant advances in modern airway assessment. It provides real-time visualization of upper airway anatomy and serves as a valuable adjunct to conventional bedside airway evaluation.²⁷ the technique is non-invasive, radiation-free, portable, repeatable, and can be performed rapidly at the bedside.

Advantages

- Non-invasive and radiation-free
- Portable and readily available
- Repeatable without patient risk
- Real-time bedside assessment
- Useful in both elective and emergency settings

Structures Visualized

- Tongue
- Epiglottis
- Vocal cords
- Cricothyroid membrane
- Trachea
- Esophagus

Sonographic Predictors of Difficult Airway

Skin-to-Epiglottis Distance

An increased skin-to-epiglottis distance has been associated with difficult laryngoscopy and tracheal intubation.²⁸

Tongue Thickness

Increased tongue thickness correlates with difficult laryngoscopy and is frequently observed in patients with obstructive sleep apnea.²⁹

Anterior Neck Soft Tissue Thickness

Greater soft tissue thickness at the hyoid bone, thyrohyoid membrane, and vocal cord levels has been shown to predict difficult airway management.³⁰

Identification of the Cricothyroid Membrane

Ultrasonography significantly improves identification of the cricothyroid membrane, particularly in obese patients, patients with distorted neck anatomy, and anticipated difficult airways.³¹ Accurate localization may facilitate emergency front-of-neck access when required.

Confirmation of Endotracheal Tube Placement

Airway ultrasonography can rapidly confirm correct tracheal intubation by demonstrating:

- Tracheal expansion during tube placement
- Bilateral lung sliding
- Diaphragmatic movement

This technique is particularly valuable in emergency medicine, critical care, and situations where capnography may be unreliable or unavailable.³²

Table 6: Common Predictors of Difficult Airway

Predictor	Increased Risk
Mallampati Class III–IV	Difficult laryngoscopy
ULBT Class III	Difficult tracheal intubation
Mouth opening < 3 cm	Difficult airway instrumentation
Thyromental distance < 6 cm	Difficult laryngoscopy
Sternomental distance < 12.5 cm	Difficult tracheal intubation
Neck circumference > 40 cm	Difficult facemask ventilation and intubation
Limited cervical spine mobility	Difficult laryngoscopy
Previous difficult airway history	Strong predictor of future airway difficulty

Advanced Airway Management: Safety and success with tracheal intubation has been enhanced significantly by advances in the technology of the airway. Modern airways are focussed on optimising oxygenation, first-pass success, minimising airway trauma and readiness to rescue. It is now good practice to use advanced airway devices early in difficult airways protocols.³³

VIDEO LARYNGOSCOPY

Video laryngoscopy (VL) is one of the greatest developments in airway management in the last 20 years. Video laryngoscopes are laryngoscopes that have a small camera with the blade that shows the glottis magnified on a monitor, rather than directly.³⁴ Videolaryngoscopy has been proven to be superior to direct laryngoscopy in multiple RCTs and systematic reviews in terms of better glottic visualization, higher first-attempt intubation rates and fewer failed intubation attempts.³⁵ For this reason, videolaryngoscopy has become a cornerstone of modern airway management practice..

Advantages of Video Laryngoscopy

- Improved glottic visualization
- Higher first-pass intubation success rates
- Reduced airway trauma from repeated attempts
- Shared airway view for assistants and trainees
- Reduced cervical spine movement during intubation
- Valuable educational and training tool

Video laryngoscopy is particularly beneficial in patients with obesity, cervical spine pathology, trauma, restricted neck mobility, and anticipated difficult laryngoscopy.³⁶

Types of Video Laryngoscopes

Macintosh-Style Video Laryngoscopes

Common examples include:

- C-MAC
- McGrath MAC
- King Vision Standard Blade

Advantages

- Familiar blade design and intubation technique
- Short learning curve
- Ability to perform both direct and indirect laryngoscopy
- Easier transition for operators experienced in direct laryngoscopy

Limitations

- Endotracheal tube delivery may be challenging despite an adequate glottic view
- Stylet shaping is often required
- Greater operator experience may be necessary for successful tube placement

Current Role in Difficult Airway Management

Evidences and the guidelines from international airway associations have recently recommended videolaryngoscopy as the first-line intubation technique in many anticipated and unanticipated difficult airway

scenarios which facilitates visualisation, first attempt intubation success, and reduces attempts at repeated intubation and laryngoscopy. Consequently, many institutions switched to videolaryngoscopy as the primary device to use for tracheal intubation, as soon as a difficult airway management is suspected.³⁷

FLEXIBLE BRONCHOSCOPIC INTUBATION

Flexible bronchoscopic intubation (FBI) remains the gold-standard technique for the management of many anticipated difficult airways. It allows tracheal intubation while maintaining spontaneous ventilation and preserving protective airway reflexes, thereby enhancing safety in selected high-risk patients.³⁸

Indications

- Anticipated difficult airway
- Limited mouth opening
- Cervical spine instability or restricted neck movement
- Airway tumors or upper airway masses
- Facial trauma
- Previous failed intubation
- Congenital airway abnormalities

Technique

Flexible bronchoscope can be inserted through the mouth or nose. With direct visualization, the bronchoscope is passed down the oropharynx, epiglottis, vocal cords, and the trachea sequentially until the point of the carina is located. The endotracheal tube then is passed over the bronchoscope into the trachea with ongoing visualization.³⁹

Advantages

- Maintenance of spontaneous ventilation
- Preservation of airway reflexes
- Excellent visualization of airway anatomy
- Minimal cervical spine movement
- High success rates in anticipated difficult airways
- Particularly useful in patients with distorted airway anatomy

Limitations

- Requires specialized equipment and expertise
- Longer procedure time compared with conventional intubation
- Visualization may be impaired by blood, secretions, or edema
- Higher equipment and maintenance costs

Flexible bronchoscopic intubation remains to be an irreplaceable part of the difficult airway armamentarium. Videolaryngoscopy is now the first choice for a lot of difficult airways but flexible bronchoscopy remains an important tool for challenging airway situations, especially for the awake intubation or for the maintenance of spontaneous ventilation.⁴⁰

AWAKE TRACHEAL INTUBATION

Difficult tracheal intubation and difficult facemask ventilation are rare occurrences that are usually best dealt

with by Awake tracheal intubation (ATI). By keeping the airway open prior to general anesthesia, ATI helps reduce the risk of losing the airway and catastrophic hypoxia.⁴¹

The Difficult Airway Society (DAS) 2020 guidelines focus on the awake intubation, with particular attention to pre-planning, topicalizing the airways, oxygenation, sedation and maintenance of spontaneous ventilation during the procedure.⁴²

Indications: Awake tracheal intubation should be considered in patients with.

- Severe airway distortion
- Head and neck tumors
- Previous failed intubation
- Cervical spine instability
- Severe obesity with anticipated airway difficulty
- Post-radiation fibrosis of the airway
- Predicted impossible or difficult facemask ventilation
- Anticipated difficult airway with a high risk of failed intubation

The sTOP Principle

The DAS guidelines advocate the **sTOP** approach to optimize patient safety and procedural success:⁴²

- **s – Sedation:** Careful titration to maintain patient cooperation
- **T – Topicalization:** Effective local anesthesia of the airway
- **O – Oxygenation:** Continuous oxygen delivery throughout the procedure
- **P – Performance:** Skilled execution by a trained operator

This structured framework improves intubation success rates, enhances patient comfort, and reduces complications.

Airway Topicalization

Effective airway anesthesia is fundamental to successful awake intubation. Common techniques include:⁴³

- Nebulized lidocaine
- Atomized lidocaine
- Lidocaine sprays
- Transtracheal lidocaine injection
- Superior laryngeal nerve block
- Combined topicalization techniques

Adequate topical anesthesia improves patient tolerance, suppresses airway reflexes, and facilitates atraumatic intubation.

Sedation

Sedation should provide patient comfort while preserving spontaneous ventilation, airway patency, protective airway reflexes, and responsiveness. Commonly used agents include.

- Dexmedetomidine
- Remifentanyl
- Midazolam
- Fentanyl

No single sedative agent has proven superior in all clinical situations. Regardless of the drug selected, careful titration is essential, as excessive sedation remains a major cause of airway obstruction, hypoventilation, and failed awake intubation.

Awake tracheal intubation remains a cornerstone of modern difficult airway management and should be considered whenever airway assessment suggests a significant risk of failed intubation, failed ventilation, or both.⁴⁴

SUPRAGLOTTIC AIRWAY DEVICES: Supraglottic airway devices have transformed contemporary airway management and are integral components of modern difficult airway algorithms. These devices provide effective oxygenation and ventilation without entering the trachea and frequently serve as rescue airway devices during difficult or failed intubation scenarios.⁴⁵

First-Generation Supraglottic Airway Devices

Common examples include:

- Classic Laryngeal Mask Airway (LMA)
- Flexible LMA

Second-Generation Supraglottic Airway Devices

Common examples include:

- ProSeal LMA
- i-gel
- Supreme LMA

Advantages

- Integrated gastric drainage channels
- Higher oropharyngeal seal pressures
- Improved efficacy during positive-pressure ventilation
- Reduced risk of gastric insufflations and aspiration
- Enhanced safety profile compared with first-generation devices

Owing to these advantages, second-generation supraglottic airway devices are now recommended by most contemporary difficult airway guidelines and algorithms.⁴⁶

Role in Difficult Airway Management

Supraglottic airway devices play several important roles in airway management:

- Rescue oxygenation devices during failed intubation
- Rescue ventilation devices in difficult airway situations
- Conduits for flexible bronchoscopic or guided tracheal intubation
- Primary airway devices for selected surgical procedures
- Essential components of difficult airway rescue strategies

Timely insertion of an appropriately selected supraglottic airway device can rapidly restore oxygenation and ventilation, preventing progression to severe hypoxemia and reducing the risk of airway-related morbidity and mortality.⁴⁷

The widespread availability and high success rates of second-generation SADs have made them indispensable

tools in modern airway management and a critical bridge between failed intubation and definitive airway rescue.

Table 7. Comparison of Advanced Airway Devices

Device	Main Advantage	Limitation
Video Laryngoscope	Improved glottic view	Tube passage may be difficult
Flexible Bronchoscope	Gold standard for anticipated difficult airway	Requires expertise
Awake Intubation	Maintains spontaneous ventilation	Patient discomfort
Second-generation SAD	Rescue oxygenation and ventilation	Does not definitively secure airway

CURRENT GUIDELINE RECOMMENDATIONS

The guidance for contemporary difficult airway management is mainly based on ASA 2022 Difficult Airway Guidelines and the Difficult Airway Society (DAS) Adult Difficult Airway Guidelines (DAS) 2025. Both the guidelines advocate a holistic approach towards airways assessment and maintenance of oxygenation, early use of advanced airway equipment, minimizing multiple airway interventions, and readiness for emergency airway rescue.

American Society of Anesthesiologists (ASA) 2022 Difficult Airway Guidelines (DAG).⁴⁸

The ASA 2022 guidelines advocate for a systematic approach that is dependent on predicted airway challenges. Clinicians should consider the risk of difficult laryngoscopy, difficult mask ventilation, difficult supraglottic airway ventilation, risk of aspiration and the ability to gain emergency access to the airway.

The key changes for 2022 guidelines are greater focus on awake intubation, early videolaryngoscopy use, ongoing oxygenation, cognitive aids, and team communication, and planned extubation.

The **2022 ASA Practice Guidelines for Management of the Difficult Airway** are the latest official ASA guidelines and emphasize decision-making, awake intubation, oxygenation, limiting attempts, and early transition to invasive airway access when necessary.

Step	Clinical Situation	Recommended Action
1. Airway Assessment	Anticipated or unanticipated difficult airway	Evaluate difficulty with laryngoscopy, mask ventilation, supraglottic airway (SGA), aspiration risk, and front-of-neck access
2. Consider Awake Intubation	Difficult intubation with risk of difficult ventilation, aspiration, rapid desaturation, or difficult emergency airway access	Awake fiberoptic bronchoscopy, videolaryngoscopy, or combined techniques
3. Induction and Intubation Attempt	After induction of anesthesia	Optimize position, oxygenation, and use appropriate device (VL/DL/FOB)
4. Confirm Ventilation	Failed intubation	Assess ability to ventilate with facemask
5A. Non-Emergency Pathway	Ventilation adequate	Call for help, optimize conditions, change device/operator, consider SGA-guided intubation or awakening patient
5B. Emergency Pathway	Inadequate ventilation and oxygenation	Immediate rescue with SGA, optimize oxygen delivery
6. Emergency Invasive Airway	Cannot Intubate, Cannot Oxygenate (CICO)	Cricothyrotomy or other front-of-neck airway technique
7. Extubation Strategy	Difficult airway successfully managed	Plan extubation carefully, consider airway exchange catheter, extubation over guide, or delayed extubation

Key Recommendations of ASA 2022

Recommendation	Guideline Statement
Awake Intubation	Strongly consider when difficult intubation and difficult ventilation are anticipated
Oxygenation	Continuous oxygen administration throughout airway management
Videolaryngoscopy	Early use encouraged to improve first-pass success
Number of Attempts	Limit repeated airway attempts to prevent trauma and hypoxia
Team Communication	Call for help early and use cognitive aids/checklists
Capnography	Mandatory confirmation of tracheal tube placement
CICO Situation	Early recognition and prompt front-of-neck airway access
Extubation	Extubation strategy should be planned before induction

DIFFICULT AIRWAY SOCIETY (DAS) APPROACH

DAS Adult Difficult Airway Algorithm (2025) :

Plan	Objective	Key Actions
Plan A: Tracheal Intubation	Secure definitive airway	Airway assessment, optimal positioning, preoxygenation, videolaryngoscopy when available, intubation by most experienced operator, limit attempts (3+1 rule)
Plan B: Supraglottic Airway Device (SAD)	Restore oxygenation and ventilation	Insert second-generation SAD, confirm ventilation with capnography, optimize device position
Plan C: Face Mask Ventilation	Maintain oxygenation	Facemask ventilation using airway adjuncts, two-person technique, neuromuscular blockade optimization if indicated
Plan D: Emergency Front-of-Neck Airway (eFONA)	Rescue oxygenation in CICO situation	Emergency cricothyroidotomy using scalpel-bougie-tube technique (preferred)

Key Principles of DAS 2025 Guidelines

Principle	Recommendation
Oxygenation	Prioritize oxygenation over intubation
Airway Attempts	Limit repeated laryngoscopy attempts (maximum 3 + 1 by expert)
Teamwork	Call for help early and use clear communication
Confirmation	Use continuous waveform capnography to confirm tracheal tube placement
Human Factors	Employ cognitive aids, role allocation, and situational awareness
Physiologically Difficult Airway	Consider hypoxaemia, obesity, cardiovascular instability, and aspiration risk during planning
Emergency Airway	Early recognition of CICO and prompt transition to eFONA

The DAS algorithm prioritizes oxygenation above all other objectives and advocates progression through a structured Plan A–D framework.⁴⁹

Special Situations in Difficult Airway Management

Airway Management in Obese Patients

Obesity is becoming a common problem in anesthetic practice and is certainly linked to poor airway management. Anatomic challenges include excess pharyngeal soft tissue, increased neck circumference and a high prevalence of obstructive sleep apnea, while physiological challenges include decreased functional residual capacity, increased oxygen consumption and shorter safe apnea time.^{50,51} The ramped position, with the external auditory meatus at the same level as the sternal notch, provides better visualization of glottis, better oxygenation, better respiratory mechanics, and better success rate of first pass intubation. Videolaryngoscopy is generally used due to the better laryngeal view and success of intubation.^{52,53}

Obstetric Difficult Airway

Physiologic and anatomic changes occur during pregnancy that make breathing even harder. Rapid oxygen desaturations occur during airway interventions as a result of airway edema, weight gain and breast enlargement, decreased pharyngeal size, increased oxygen consumption, decreased functional residual capacity, and increased risk of aspiration. Current guidelines include careful airway evaluation, early videolaryngoscopy, access to second-generation supraglottic airways, restricted number of attempts and preparedness for front-of-neck access. The main aim

during the management of the airways is to ensure good maternal oxygenation.^{54,55}

Pediatric Difficult Airway

The airways of children have special anatomical features that involve a relatively large tongue, more cephalad larynx, narrow airway and a floppy epiglottis. In congenital syndromes like Pierre Robin sequence, Treacher Collins syndrome, Goldenhar syndrome and Down syndrome, difficult airway management can be especially challenging. Pediatric videolaryngoscopy and flexible bronchoscopy have been greatly advanced in recent years and have greatly improved the management of difficult pediatric airways.^{56,57}

Physiologically Difficult Airway and ICU Airway Management

The "physiologically difficult airway" acknowledges that the difficult airway can result from a state of physiologic instability even if there is no anatomic cause. Pre-intubation risk factors include severe hypoxemia, hypotension, metabolic acidosis, pulmonary hypertension and right ventricular dysfunction. All of these fallacies are more pertinent in critically ill patients who are often shocked, have respiratory failure and multiorgan dysfunction and are at risk of aspiration. The principles of modern day airway management strategies were refined in order to optimize physiology prior to intubation and to use state-of-the-art oxygenation

modalities to increase time to unsafe apnoea and minimise hypoxia, such as the use of high-flow nasal oxygen, continuous positive airway pressure and non-invasive ventilation. Rapid sequence intubation (RSI) is central to the management of the potentially difficult airway and a large number of important outcomes depend on first-pass success.^{58,59,60}

Extubation of the Difficult Airway

It is now becoming accepted that the time of extubation is a key stage of airway management. Major airway complications are common during emergence and recovery, especially in patients with obesity, OSA, airway tumours, surgery on the cervical spine, prolonged intubation and/or surgery to the head and neck. Current guidelines include: Extubation should be considered an elective procedure and should be carefully planned with appropriate oxygenation, haemodynamic stability, difficult airway equipment available and a clear plan for reintubation. Airway exchange catheters may be useful in certain high-risk patients to allow for quick reintubation in case of respiratory compromise after extubation.^{61,62,63}

Human Factors, Crisis Resource Management and Simulation

Many serious airway incidents have been traced back to problems of communication, team working, leadership, situational awareness and decision making as well as technical failure, and have been identified from major airway audits. Therefore, the principles of crisis resource management: good leadership skills, delegation of tasks, utilisation of resources, and closed loop communication have become a part and parcel of airway practice. Simulation-based training also provides additional benefits for improving technical skills, decision-making, team performance, and readiness for uncommon but life-threatening operations like a CICO and emergency access in front of the neck.^{64,65}

AI in Airway Management

Artificial intelligence and machine learning are newly-ripened technologies that have the potential to be used in the assessment and management of airways. Difficult airway prediction, automated airway assessment, ultrasound interpretation, risk stratification, clinical decision support and videolaryngoscopy assistance are currently or potential applications. A demographic, anatomical, ultrasonographic and imaging-based machine-learning model could be more accurate than each bedside airway assessment for prediction of difficult laryngoscopy. Future developments may include automated identification of airway landmarks, localization of the cricothyroid membrane, real-time guidance of procedures and intelligent videolaryngoscopy systems. While preliminary results are hopeful, large multicenter validation studies are needed before it will be broadly adopted in clinical practice.^{66,67}

Recommendations

Based on the current evidence, contemporary difficult airway guidelines, and recent advances in airway management.

- Comprehensive preoperative airway assessment should be performed in all patients.
- Video laryngoscopy should be readily available and considered early in anticipated difficult airways.
- Awake tracheal intubation should be considered in selected high-risk patients.
- Adequate oxygenation should remain the primary objective throughout airway management.
- Airway ultrasound may be incorporated as an adjunct to conventional airway assessment.
- Human factors, teamwork, and effective communication should be emphasized during airway management.
- Regular simulation-based training should be encouraged to improve airway skills and crisis management.
- Artificial intelligence-assisted airway assessment tools may enhance difficult airway prediction in the future.
- Institutions should establish standardized difficult airway protocols and emergency airway carts.

FUTURE DIRECTIONS

Incoming years will likely see near-future changes in airway management as a result of rapid technological advances. Three-dimensional (3-D) airway imaging could help to create individual airway maps, better predict difficult airways and aid in individual airway planning. Augmented reality (AR) system can augment assessment of the air way, navigation using bronchoscopy, ultrasound guidance of airway intervention and emergency access to front of the neck. Such clinical decision-support systems are now more frequently incorporating artificial intelligence, advanced imaging and predictive analytics. A patient's particular anatomical and physiological features may permit personalizing airway management strategies using these technologies. While there is much that is still experimental about robotic airway intervention, future advancements could help ensure precision during difficult airway interventions and offer increased opportunity for remote airway support. As these new technologies appear, extensive research and clinical validation will be needed prior to large scale implementation.

CONCLUSION

The importance of airway management for safe anesthetic, critical care and emergency medicine practice will never change. Although there have been great advances in airways devices and management, airways related complications still play a major role in perioperative morbidity and mortality.

The Modified Mallampati Classification, the Upper Lip Bite Test, thyromental distance and sternomental distance are all important tools for air way assessment, and continue to be useful for assessing airways preoperatively. However, none of these tests is a reliable predictor of a difficult airway; and that is the reason why it is important to carry out a multimodal assessment.

Airway safety has dramatically improved over the years with the introduction of wide-spread use of videolaryngoscopy, technological advances in flexible bronchoscopy, improvement in supraglottic airway devices, and the development of evidence-based airway algorithms. Current guidelines focus on careful planning, optimising oxygenation, minimising failed attempts at re-intubation, dealing with failed airways and team working.

New technology like artificial intelligence, machine learning, advanced imaging, and augmented reality have promise in helping to better assess airways and provide individual patient care. However, good clinical judgment, careful preparation, ongoing education, effective communication and applying evidence to practice are critical to a successful airway management procedure.

In order to optimize patient safety and improve outcomes in contemporary perioperative and critical care medicine, it is necessary to have a detailed understanding of airway assessment, difficult airway algorithms, advanced airway technologies, human factors and future innovations.

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