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Recent Advances in Airway Management in Anesthesia: A Narrative Review

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Abstract: ***Airway management is one of the fundamental responsibilities of an anesthesiologist, and failure to establish or maintain adequate oxygenation can rapidly result in severe morbidity and mortality. The management of difficult airways has evolved substantially with the introduction of videolaryngoscopy, second-generation supraglottic airway devices, flexible bronchoscopic techniques, high-flow nasal oxygen, apneic oxygenation, airway ultrasonography and structured difficult-airway algorithms. Contemporary airway management emphasizes anticipation of difficulty, maintenance of oxygenation, first-pass success and early transition to rescue techniques rather than repeated attempts with a single device. Videolaryngoscopy has become an important component of routine and difficult airway management because it frequently provides an improved view of the glottis compared with conventional direct laryngoscopy. Awake tracheal intubation remains an important technique in patients with anticipated difficult ventilation or intubation. High-flow nasal oxygen and apneic oxygenation can prolong the safe apneic period during airway instrumentation. Point-of-care ultrasound provides additional information about airway anatomy and can assist in selected airway procedures and confirmation of tracheal tube placement. Simulation-based education further improves preparedness for uncommon but life-threatening airway emergencies. This narrative review summarizes recent developments in airway management and discusses their practical application in modern anesthetic practice.***

Keywords: Airway management; anesthesia; difficult airway; videolaryngoscopy; supraglottic airway; apneic oxygenation

1. Introduction

Airway management is an essential component of safe anesthesia practice. Establishment of a patent airway, adequate ventilation and maintenance of oxygenation are fundamental goals during general anesthesia. Although routine airway management is successful in most patients, unexpected difficulty may occur even when preoperative assessment does not identify obvious risk factors.

Difficult airway management may involve difficulty with face-mask ventilation, supraglottic airway placement, laryngoscopy, tracheal intubation or emergency rescue oxygenation. Repeated unsuccessful airway attempts can produce airway trauma, edema, bleeding and progressive hypoxemia. Therefore, modern airway management focuses not only on successful intubation but also on maintaining oxygenation throughout the procedure.

The American Society of Anesthesiologists (ASA) difficult-airway guidelines emphasize preoperative assessment, formulation of an airway strategy, consideration of awake airway management when appropriate, oxygenation, limitation of repeated attempts and timely transition to alternative techniques. [1]

The development of videolaryngoscopes, improved supraglottic airway devices, flexible bronchoscopes, high-flow nasal oxygen and point-of-care ultrasound has significantly expanded the anesthesiologist's airway-management options. This review summarizes these advances and their relevance to contemporary anesthesia practice.

2. Literature Search Methodology

A narrative literature review was performed using published literature relating to difficult airway management and recent advances in airway techniques.

Relevant articles were identified using databases and resources including PubMed/MEDLINE and Google Scholar. Search terms included “difficult airway,” “airway management,” “videolaryngoscopy,” “awake intubation,” “supraglottic airway,” “high-flow nasal oxygen,” “apneic oxygenation,” “airway ultrasound,” and “simulation airway management.”

Priority was given to international guidelines, consensus recommendations, systematic reviews, randomized trials and major review articles. Literature describing established airway-management techniques was also included where relevant. The available evidence was narratively synthesized according to major advances in airway assessment, oxygenation, intubation and rescue management.

3. Difficult Airway Assessment

Preoperative airway assessment remains an important component of anesthesia planning. Common clinical assessments include Mallampati classification, mouth opening, thyromental distance, neck mobility, mandibular protrusion and assessment of dentition.

However, no individual bedside test can reliably predict every difficult airway. The limitations of individual prediction tests mean that airway assessment should be considered as a combination of anatomical, physiological and procedural factors. [2]

Modern assessment should consider:
- Difficulty with face-mask ventilation
- Difficulty with supraglottic airway ventilation
- Difficulty with laryngoscopy
- Difficulty with tracheal intubation
- Risk of aspiration
- Rapid oxygen desaturation
- Limited physiological reserve
- Difficulty with emergency front-of-neck access

The patient's clinical condition and the anticipated consequences of airway difficulty are therefore as important as anatomical assessment.

4. Videolaryngoscopy

Videolaryngoscopy is one of the most important technological advances in airway management.

In conventional direct laryngoscopy, successful visualization of the glottis depends on alignment of the oral, pharyngeal and laryngeal axes. Videolaryngoscopes use a camera positioned near the distal portion of the blade to provide an indirect view of the glottis.

Advantages:
- Improved visualization of the glottis
- Reduced requirement for alignment of airway axes
- Better visualization in selected difficult airways
- Useful rescue capability after unsuccessful direct laryngoscopy
- Shared visualization between anesthesiologist and assistant
- Educational advantages during airway training

However, visualization of the glottis does not always translate into successful tube delivery. Passage of the tracheal tube may remain difficult because of altered airway geometry, secretions, blood, limited mouth opening or inappropriate stylet selection.

Therefore, appropriate blade selection, patient positioning, stylet shaping and operator familiarity are important.

Videolaryngoscopy should be considered an integral part of an airway strategy rather than simply a replacement for direct laryngoscopy. [1,3]

5. Awake Tracheal Intubation

Awake tracheal intubation is an important technique for patients in whom difficulty with airway management is anticipated.
Maintaining spontaneous ventilation and protective airway reflexes during intubation can provide an important safety advantage in selected patients.
Awake intubation may be performed using:
- Flexible bronchoscopy
- Videolaryngoscopy
- Combined techniques

The Difficult Airway Society recommends awake tracheal intubation when there is an increased likelihood of difficult airway management together with factors such as anticipated difficulty with ventilation or intubation, increased risk of aspiration or intolerance of apnea. [4]

Successful awake intubation requires adequate preparation, oxygen supplementation, topicalization of the airway and appropriate sedation when necessary.

Awake videolaryngoscopy has also emerged as an alternative technique in selected patients, particularly where expertise with the device is available.

6. Supraglottic Airway Devices

Supraglottic airway devices have transformed airway management in modern anesthesia.

They are widely used during elective anesthesia and are also important rescue devices during difficult airway management.

Second-generation supraglottic devices generally provide improved seal pressures and incorporate features intended to reduce aspiration risk compared with earlier devices.

Clinical applications include:
- Elective airway management
- Rescue oxygenation
- Short surgical procedures
- Selected difficult airway situations
- Conduit for tracheal intubation with appropriate devices

Despite their advantages, supraglottic devices should not be considered interchangeable with tracheal intubation in every patient. Surgical requirements, aspiration risk, airway anatomy and patient physiology should guide device selection.

7. High-Flow Nasal Oxygen and Apneic Oxygenation

A major development in airway management is the increasing emphasis on oxygenation throughout airway intervention.

Conventional preoxygenation increases the oxygen reservoir in the lungs and delays the development of critical hypoxemia during apnea.

Apneic oxygenation can further prolong the period before oxygen desaturation during airway instrumentation.

High-flow nasal oxygen provides heated and humidified oxygen at high flow rates and has become increasingly useful for preoxygenation and airway management, particularly in patients at risk of rapid desaturation.

Recent difficult-airway recommendations emphasize adequate preoxygenation and the use of nasal oxygen or high-flow nasal oxygen during airway management when appropriate. [5]

The importance of oxygenation is particularly evident in patients with obesity, pregnancy, severe respiratory disease or reduced functional residual capacity, where oxygen reserve may be limited.

8. Flexible Bronchoscopy

Flexible bronchoscopy remains an important tool in difficult airway management.
It is particularly useful for:

- Awake tracheal intubation
- Limited neck movement
- Cervical spine disease
- Upper airway abnormalities
- Selected anticipated difficult airways

The major limitations include dependence on operator expertise, difficulty with significant blood or secretions and the need for effective topical airway anesthesia during awake procedures.

Despite the increasing use of videolaryngoscopy, flexible bronchoscopy remains an essential component of difficult-airway equipment.

9. Airway Ultrasound

Point-of-care ultrasound has become increasingly relevant in anesthetic airway assessment.

Potential applications include:

- Identification of the cricothyroid membrane
- Assessment of anterior neck anatomy
- Identification of tracheal structures
- Assessment of vocal cord movement
- Confirmation of tracheal tube placement
- Assessment of gastric contents in selected clinical settings

Ultrasound may be particularly useful when surface anatomical landmarks are difficult to identify.

However, ultrasound should complement established clinical examination and capnographic confirmation rather than replace them.

10. Capnography and Confirmation of Tracheal Intubation

Correct confirmation of tracheal tube placement is an essential component of airway management.

Direct visualization of the tube passing through the vocal cords is helpful but is not sufficient as the sole method of confirmation.

Continuous waveform capnography provides objective confirmation of effective ventilation through the tracheal tube and is regarded as the standard method for confirming tracheal intubation in appropriate circumstances.

This is particularly important during difficult airway management because clinical signs such as chest movement or auscultation can be misleading.

11. Crisis Management and Limiting Repeated Attempts

One of the most important principles of difficult airway management is recognizing when the initial technique has failed.

Repeated attempts using the same technique may worsen airway trauma and edema while progressively reducing oxygenation.

An effective difficult-airway strategy should therefore include:

- Recognition of failed technique.
- Maintenance of oxygenation.
- Calling for additional assistance.
- Changing device or technique.
- Considering supraglottic rescue.
- Proceeding to emergency front-of-neck access when appropriate.

The 2022 ASA guidelines emphasize limiting attempts by the same operator and changing technique when an initial approach is unsuccessful. [1]

The principle can be summarized as: “Oxygenation first, repeated attempts second.”

12. Simulation-Based Airway Training

Airway emergencies are relatively uncommon but potentially catastrophic. This creates a challenge for clinical training because trainees may have limited exposure to real-life “cannot intubate, cannot oxygenate” scenarios.

Simulation allows anesthesiologists and trainees to practice:

- Difficult mask ventilation
- Videolaryngoscopy
- Supraglottic airway rescue
- Failed intubation
- Emergency front-of-neck access
- Crisis communication
- Team leadership
- Allocation of airway equipment

Simulation also allows deliberate practice without exposing patients to unnecessary risk.

Regular airway simulation can therefore complement clinical experience and improve familiarity with airway equipment and emergency algorithms.

13. Recent Developments in Difficult Airway Algorithms

Modern airway guidelines increasingly emphasize structured decision-making rather than prolonged attempts at one technique.

Important principles include:

- Identification of difficult airway risk before induction
- Appropriate positioning
- Adequate preoxygenation
- Consideration of awake airway management
- Use of videolaryngoscopy when appropriate
- Limiting repeated attempts
- Early use of rescue supraglottic devices
- Continuous assessment of oxygenation
- Early recognition of failure
- Emergency front-of-neck access when indicated

The 2025 All India Difficult Airway Association guideline provides an updated framework for unanticipated difficult airway management in adults and emphasizes preoxygenation, apneic oxygenation, videolaryngoscopy, capnography and structured rescue strategies. [5]

14. Limitations of Current Evidence

Although airway-management technology has advanced rapidly, important limitations remain.

Studies evaluating airway devices frequently differ in patient populations, operator experience, definitions of difficult intubation and clinical endpoints. Improved glottic visualization does not necessarily translate into improved patient-centered outcomes.

Many airway techniques are also strongly dependent on operator skill and institutional resources.

Therefore, the availability of advanced equipment should not replace basic airway skills, appropriate patient assessment, preparation and team training.

15. Future Perspectives

Future airway management is likely to involve greater integration of technology with clinical decision-making.

- Potential developments include:
- Artificial intelligence-assisted airway prediction
- Advanced videolaryngoscopy
- Improved airway imaging
- Portable ultrasound
- Integrated airway monitoring
- Augmented and virtual reality simulation
- More sophisticated oxygen-delivery systems
- Personalized difficult-airway algorithms

The future of airway management is therefore likely to focus on early prediction, prevention of hypoxemia, first-pass success and rapid rescue rather than simply improving visualization of the larynx.

16. Conclusion

Airway management has evolved from a predominantly direct-laryngoscopy-based approach to a comprehensive strategy incorporating advanced visualization, oxygenation techniques, supraglottic rescue devices, ultrasound and structured difficult-airway algorithms.

Videolaryngoscopy, awake tracheal intubation, high-flow nasal oxygen, apneic oxygenation, flexible bronchoscopy and airway ultrasound have expanded the anesthesiologist's options for managing difficult airways.

The most important principle of contemporary airway management remains maintenance of oxygenation. Early recognition of difficulty, appropriate preparation, avoidance of repeated unsuccessful attempts and timely transition to rescue techniques are essential for patient safety.

Technology should therefore be viewed as an extension of clinical expertise rather than a replacement for fundamental airway skills. Regular simulation and structured team training can further improve preparedness for rare but life-threatening airway emergencies.

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