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Airway management success rate in prehospital EMS and hospital emergency departments- An Updated Review for Nursing, Emergency Professionals, and Dentists

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Abstract

Background: Airway management is a cornerstone of emergency and critical care practice, requiring deep knowledge of airway anatomy, physiology, device selection, and procedural strategies. Differences between adult and pediatric airways, along with disease-related anatomical variations, significantly influence intubation success and complication rates.

Aim: This review aims to update healthcare providers—including nurses, emergency personnel, and dentists—on modern airway management principles, devices, techniques, and complications across prehospital and hospital settings.

Methods: The article synthesizes evidence from current airway management literature, addressing anatomy, indications, contraindications, procedural steps, pharmacologic preparation, and team dynamics involved in effective airway management.

Results: Key findings reveal critical anatomical differences between pediatric and adult airways, influencing device choice and positioning techniques. Video laryngoscopy and cuffed pediatric tubes improve visualization and ventilation control. Preoxygenation, rapid-sequence induction, appropriate drug selection, and structured intubation steps enhance safety and first-pass success. Complications include esophageal intubation, airway trauma, respiratory failure, pneumothorax exacerbation, and right-mainstem intubation risk. A multidisciplinary team with coordinated roles is essential for reducing complications and improving outcomes.

Conclusion: Effective airway management requires comprehensive anatomical knowledge, structured techniques, advanced visualization tools, proper device selection, and coordinated team-based care. Recognition of difficult airway predictors and adherence to evidence-based practices significantly improve patient safety and clinical outcomes.

Keywords: Airway management, intubation, emergency care, pediatric airway, video laryngoscopy, rapid-sequence induction, complications, prehospital EMS.

Introduction

Proficiency in airway management requires a comprehensive and in-depth understanding of airway anatomy, physiology, and associated pathological variations that may compromise ventilation and oxygenation. Clinicians are expected to possess detailed knowledge of the structural and functional characteristics of the upper and lower airway, as these directly influence both routine and emergency airway interventions. A strong foundation in the principles underlying airway patency, respiratory mechanics, and potential disease-related alterations is essential for effective clinical decision making. Equally important is familiarity with the range of airway management devices and procedural techniques available in modern clinical practice, as the selection of an appropriate method is contingent upon patient condition, clinical setting, and operator expertise. Furthermore, clinicians must maintain a clear understanding of the indications that necessitate endotracheal intubation, as well as the contraindications that may render the procedure unsafe or inappropriate in certain clinical scenarios. Awareness of potential complications associated with endotracheal tube placement is also critical, as these may range from minor technical difficulties to severe life-threatening events if not promptly recognized and

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managed. In addition, the ability to accurately confirm correct endotracheal tube positioning is a fundamental competency, as incorrect placement may result in hypoxia, aspiration, or even mortality if undetected. Clinical competence further requires recognition of the anatomical and physiological differences among adult, pediatric, and neonatal airways, since these variations significantly influence airway resistance, device selection, and procedural approach. Effective airway management also demands advanced problem-solving skills and the ability to implement structured strategies when encountering difficult airway situations, ensuring patient safety and maintaining oxygenation under challenging conditions [1].

In the context of Advanced Cardiovascular Life Support, airway management decisions should be guided by a structured clinical assessment framework that ensures systematic evaluation of airway adequacy and intervention necessity. The initial consideration involves determining whether the patient's airway is patent, as airway obstruction represents an immediate threat to ventilation and requires urgent correction. Following this assessment, clinicians must evaluate whether the use of an advanced airway device is clinically indicated based on the patient's respiratory status, level of consciousness, and ability to maintain adequate oxygenation and ventilation through basic airway maneuvers. Subsequent to airway placement, it is essential to confirm the correct positioning of the airway device using reliable clinical and adjunct verification methods, as improper placement may lead to severe respiratory compromise and ineffective ventilation. Ongoing reassessment is equally important, as airway devices may become displaced or obstructed over time; therefore, clinicians must ensure that the tube remains securely positioned and that its placement is regularly verified throughout patient management. The integration of these evaluative steps supports a systematic and evidence-based approach to airway management within resuscitation settings, enabling clinicians to make timely and accurate decisions that optimize respiratory support and improve patient outcomes in critical care environments [1].

Anatomy and Physiology

The structural and functional characteristics of the airway differ significantly between adults and children, and these variations have direct implications for airway management, particularly during endotracheal intubation. In adults, the narrowest segment of the airway is typically located at the level of the glottis. This anatomical configuration provides a relatively predictable pathway for tracheal intubation when standard techniques are applied. In contrast, the pediatric airway exhibits distinct anatomical properties that increase procedural complexity. In children, the narrowest portion of the airway is found at the subglottic region, and the larynx is positioned more cephalad and anteriorly compared to adults. These differences are clinically significant because they alter the angle and visualization of the airway structures during laryngoscopy, thereby increasing the technical difficulty of intubation in younger patients [2][3]. In pediatric patients aged twelve years or younger, the airway demonstrates additional anatomical immaturity that further complicates airway access. The cricothyroid membrane is notably smaller in size, limiting its utility in emergency surgical airway procedures. Moreover, the pediatric larynx is more compliant and exhibits a funnel-shaped configuration, which contrasts with the more cylindrical structure observed in adults. Its rostral positioning also contributes to alignment challenges during airway instrumentation. These structural characteristics must be carefully considered during airway planning, as failure to account for them can lead to increased risk of trauma, failed intubation, or airway obstruction. Another important anatomical factor is the disproportionate size of the occiput in children, combined with a relatively shorter neck length. This combination often results in a flexed neck position when the child lies supine, which complicates laryngoscopic visualization. Proper alignment of the oral, pharyngeal, and tracheal axes becomes more difficult under these conditions, thereby reducing the efficiency of direct laryngoscopy. To mitigate this issue, clinicians frequently utilize positioning strategies such as placing a folded towel or shoulder roll beneath the patient's shoulders. This adjustment helps achieve a neutral head and neck position, improving airway alignment and facilitating successful intubation. Recognition of these positional requirements is essential for optimizing airway access and minimizing procedural complications in pediatric populations [2][3][4].

The dimensions of the pediatric trachea vary according to both age and sex, reflecting ongoing growth and anatomical development throughout childhood and adolescence. This variability necessitates careful selection of endotracheal tube size to ensure adequate ventilation while minimizing airway trauma. Several age-based formulas are commonly used in clinical practice to estimate appropriate endotracheal tube internal diameter. The Cole formula, typically applied for uncuffed tubes, calculates tube size as internal diameter in millimeters equal to age in years divided by four plus four. For cuffed endotracheal tubes in children aged two years and older, the Motoyama formula is used, which estimates internal diameter as age divided by four plus 3.5. In children younger than two years, the Khine formula is applied, using age divided by four plus 3.0 to determine appropriate tube size. These mathematical approaches provide practical guidance in emergency settings where rapid decision making is required. In addition to formula-based estimation,

ultrasound assessment of the subglottic airway diameter has emerged as a more accurate method for predicting optimal endotracheal tube size in children aged one month to six years. This imaging-based approach allows direct visualization and measurement of airway dimensions, resulting in improved precision compared to traditional age- and height-based formulas. However, despite its accuracy, ultrasound may not be feasible in urgent or time-sensitive clinical scenarios, limiting its routine application in emergency airway management. As a result, clinicians must remain proficient in conventional sizing formulas to ensure rapid and effective decision making when advanced imaging is unavailable [3][4]. Cuffed endotracheal tubes are generally preferred in pediatric airway management due to their ability to minimize air leakage and reduce the risk of aspiration. They also allow for better control of ventilation pressures and may decrease the risk of pressure-related airway injury when appropriately monitored. However, their use must be balanced against potential complications, including the possibility of increased airway resistance due to the larger external diameter of the tube, which may contribute to laryngospasm during insertion. Despite this concern, modern cuffed tube designs have significantly improved safety profiles when used with appropriate technique and cuff pressure monitoring. Advancements in airway management technology have also contributed to improved clinical outcomes. Video-assisted laryngoscopy represents a significant development in this field, offering enhanced visualization of the airway structures compared to traditional direct laryngoscopy. This technology improves the clinician's ability to identify anatomical landmarks, increases first-attempt intubation success rates, and reduces the likelihood of airway trauma, particularly in anatomically challenging cases. The integration of such tools into clinical practice reflects an ongoing evolution in airway management strategies aimed at improving safety and procedural success across diverse patient populations [3][4].

Indications

Endotracheal intubation is indicated in a range of clinical scenarios where airway protection and adequate ventilation cannot be ensured through spontaneous respiratory function alone. One of the primary indications is the presence of respiratory failure, which may present in either hypoxemic or hypercapnic forms, both of which reflect an inability of the respiratory system to maintain sufficient gas exchange. Apnea also constitutes an absolute indication, as the absence of spontaneous breathing necessitates immediate airway control and mechanical ventilation to prevent hypoxic injury. A significantly reduced level of consciousness represents another critical indication for endotracheal intubation, particularly when protective airway reflexes are compromised. This is often operationalized clinically as a Glasgow Coma Scale score of eight or less, a threshold widely used to identify patients at high risk of airway obstruction and aspiration. In addition, rapid or fluctuating deterioration in mental status may necessitate preemptive airway securing to prevent sudden loss of airway patency and to ensure controlled ventilation. Airway compromise, whether actual or impending, is also a major indication for intubation. This includes conditions such as airway edema, obstruction, or structural injury that may progressively worsen and culminate in complete airway occlusion. Patients presenting with a high risk of aspiration require airway protection through intubation, particularly when gastrointestinal contents or secretions pose a threat to lower respiratory tract contamination. Furthermore, laryngeal trauma constitutes a significant indication for definitive airway management, especially in the context of penetrating injuries involving the neck, chest, or abdominal region. Such trauma may result in anatomical distortion, airway instability, or rapid deterioration of respiratory function, thereby necessitating early airway control to prevent catastrophic respiratory compromise. These clinical indications collectively underscore the importance of timely decision-making in securing the airway and preventing secondary hypoxic injury [5][6].

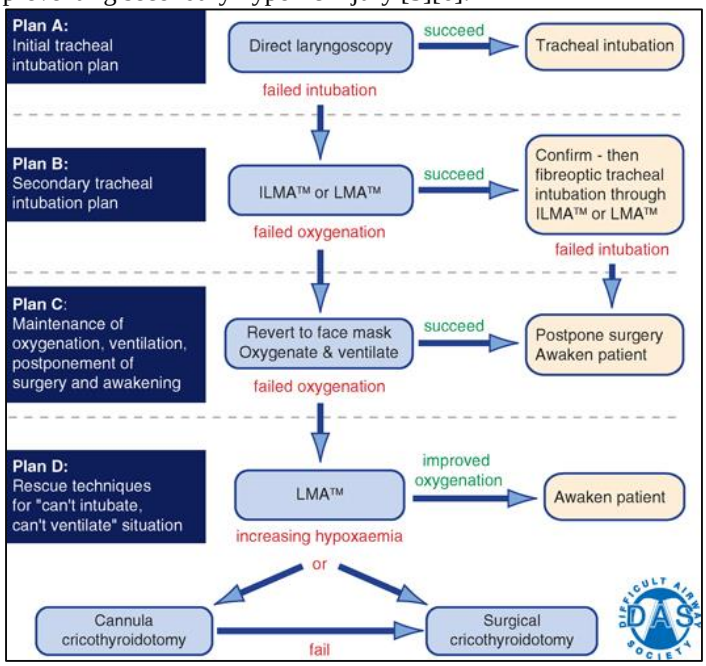

Fig. 1: Airway Management Protocol.

Contraindications

Endotracheal intubation is generally considered a life-saving intervention; however, it may be contraindicated in specific clinical circumstances where its execution is either unsafe or technically unfeasible. The most critical limitation arises in the presence of severe airway trauma or complete airway obstruction that precludes the safe passage of an endotracheal tube. In such situations, attempts at conventional intubation may exacerbate airway injury, worsen bleeding, or further compromise an already unstable airway, thereby necessitating alternative

airway strategies. When endotracheal tube placement cannot be successfully achieved and airway control remains essential, escalation to a surgical airway becomes mandatory. In adult patients, emergency surgical airway techniques such as cricothyrotomy or needle cricothyrotomy are considered appropriate rescue interventions when standard intubation fails. These procedures provide rapid access to the trachea and allow for oxygenation and ventilation in life-threatening scenarios. Once a surgical airway is established through cricothyrotomy, it is typically recommended that this temporary measure be converted to a formal tracheostomy as soon as the patient is stabilized, ensuring a more secure and long-term airway. In certain critical cases, an emergency tracheostomy, sometimes referred to as a "slash tracheostomy," may also be performed as an immediate definitive airway intervention when other methods are not viable [5][6][7].

The approach to surgical airway management in pediatric patients is significantly more complex and remains more conservative due to anatomical and developmental considerations. Cricothyrotomy is rarely performed in children who cannot be intubated with an endotracheal tube, as the procedure carries a higher risk of complications and anatomical injury in this population. Instead, emergent tracheostomy is often favored as a safer alternative for definitive airway access in pediatric emergencies. The only absolute contraindication to surgical cricothyrotomy in children is related to age and anatomical suitability, although this parameter remains variably defined across clinical literature. There is ongoing debate regarding the minimum age at which cricothyrotomy can be safely performed, with thresholds ranging between five and twelve years depending on the source, although patient size and anatomical development are considered more relevant than chronological age alone. Clinical guidelines such as those provided by Pediatric Advanced Life Support define the pediatric airway as encompassing children between one and eight years of age, further highlighting the variability in classification. In emergency pediatric airway management, needle cricothyrotomy combined with transtracheal ventilation is generally preferred over open surgical cricothyrotomy. This method allows temporary oxygenation until a definitive airway, typically a formal tracheostomy, can be established under controlled conditions [5][6][7].

Equipment

Airway Position and Clearance

Effective airway management begins with immediate restoration and maintenance of airway patency through appropriate positioning and clearance techniques. Upper airway obstruction can often be alleviated through basic manual maneuvers such as head tilt, chin lift, or jaw thrust, each of which functions to reposition the soft tissues of the upper airway and optimize airflow. These techniques are foundational interventions in both basic and advanced airway management, particularly in emergency settings where rapid restoration of ventilation is required. In pediatric populations, airway clearance requires additional caution due to anatomical vulnerability and heightened reflex sensitivity. Suctioning plays a central role in removing secretions, mucus, or foreign material that may compromise airway patency. In infants and young children, mechanical suction devices such as bulb syringes or other suction apparatuses are commonly utilized to facilitate airway clearance. When using a bulb syringe in infants, clinical technique must prioritize safety and sequencing, whereby the oral cavity is suctioned prior to nasal suctioning to reduce the risk of aspiration. The procedure involves compressing the bulb syringe prior to insertion into the oral cavity, followed by controlled suctioning of the mouth and subsequently the nasal passages. Infants are particularly susceptible to vagal stimulation during airway suctioning, which may result in significant physiological responses such as bradycardia. This heightened vagal reactivity necessitates strict procedural time limitations, with suctioning typically restricted to no more than ten seconds per attempt to minimize adverse cardiovascular effects. These considerations underscore the importance of precision, timing, and physiological awareness when managing pediatric airways in both emergency and controlled clinical environments [7].

Adjuvants to Upper Airway Obstruction

Adjunctive devices play a critical role in maintaining airway patency when manual maneuvers alone are insufficient to ensure adequate ventilation. Among the most commonly used adjuncts are the oropharyngeal airway and nasopharyngeal airway, both of which are designed to prevent airway collapse and facilitate unobstructed airflow in patients with compromised airway tone. The oropharyngeal airway is generally indicated in unconscious patients without an intact gag reflex, as its insertion may otherwise provoke gagging, vomiting, or aspiration of gastric contents. Consequently, its use is contraindicated in individuals with a strong gag reflex or significant oral trauma. These devices are manufactured in multiple sizes and are selected based on anatomical measurements, typically determined by the distance from the lips to the angle of the mandible. Clinically, oropharyngeal airways are particularly useful in patients who retain spontaneous respiratory effort but require assistance in maintaining airway patency, such as individuals experiencing obstructive sleep-related breathing disorders. The nasopharyngeal airway provides an alternative option in patients for whom oral airway insertion is contraindicated or poorly tolerated. It is especially useful in individuals with an

intact gag reflex, trismus, or oral and oropharyngeal trauma, as well as in those who have undergone surgical interventions involving the oral cavity where instrumentation should be minimized. Proper sizing of the nasopharyngeal airway requires consideration of both nasal passage anatomy and overall patient stature. In adult populations, standardized sizing correlates with sex and body habitus, with average male patients typically requiring a size 7 device and average female patients requiring a size 6 device. Larger individuals may require size adjustments, as a taller male patient may necessitate a size 8, while a taller female patient may require a size 7. This relationship reflects anatomical proportionality between patient height and midfacial airway length, particularly the anteroposterior dimension of the nasal cavity [7]. In pediatric patients, precise sizing is even more critical due to narrower anatomical structures and developmental variability. Evidence from clinical research involving 413 infants under twelve months of age demonstrated a significant correlation between patient height and the distance from the nares to the vocal cords, highlighting the importance of anthropometric measures in airway device selection [8]. In infants, correct insertion depth of the nasopharyngeal airway is generally guided by external anatomical landmarks, with optimal placement achieved when the insertion length is slightly shorter than the distance between the nasal tip and the earlobe. This approach minimizes the risk of trauma while ensuring adequate airway patency [7][8].

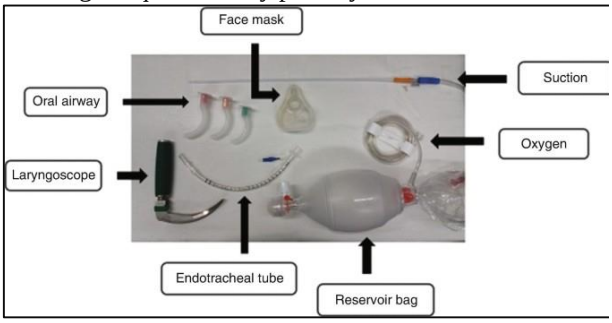

Fig. 2: Airway Management in Trauma Patients.

Bag-Mask Ventilation

Bag-mask ventilation represents one of the most essential and widely employed techniques in airway management, serving as both a primary resuscitative measure and a bridge to advanced airway intervention. Its effectiveness depends on the clinician's ability to maintain a proper seal and generate adequate tidal volumes to support oxygenation and ventilation. Both one-hand and two-hand techniques are utilized in clinical practice, with the choice of method determined by patient size, clinical condition, and operator experience. In adult patients, the two-hand technique is often preferred due to improved mask seal and ventilation efficiency, whereas in neonatal care, a one-hand technique is typically sufficient given the smaller facial dimensions and reduced airway resistance. During bag-mask ventilation, airway patency is maintained through a combination of manual maneuvers, including head tilt, chin lift, and jaw thrust, which work synergistically to reduce upper airway obstruction. The application of continuous positive airway pressure further enhances alveolar recruitment and oxygenation in patients with compromised respiratory function. Bag-mask ventilation is also a critical preparatory step prior to endotracheal intubation, ensuring adequate oxygen reserves and reducing the risk of hypoxemia during airway instrumentation [7][8].

Advanced Airway

Advanced airway devices encompass both supraglottic airway devices and endotracheal tubes, which are utilized when basic airway management techniques are insufficient to maintain adequate ventilation. Supraglottic devices include the laryngeal mask airway, laryngeal tube, and esophageal-tracheal devices, each designed to facilitate ventilation without requiring direct visualization of the vocal cords. These devices have become integral to modern airway management due to their relative ease of insertion and rapid deployment, particularly in emergency and prehospital environments. Among supraglottic devices, the classic and Pro-Seal laryngeal mask airways have demonstrated strong safety and efficacy profiles in pediatric populations. The use of a manometer is recommended to accurately monitor cuff inflation pressure, thereby reducing the risk of mucosal injury and ensuring optimal device performance. However, clinical evidence indicates that children with recent upper respiratory tract infections are at increased risk of respiratory complications when laryngeal mask airways are used, necessitating careful patient selection and risk assessment. In prehospital settings, devices such as the King tube are frequently favored over endotracheal intubation due to their simplicity and rapid insertion, particularly when managed by emergency medical personnel with limited airway training [7][8][9].

Esophageal-Tracheal Tube and Endotracheal Intubation

The esophageal-tracheal airway device is a supraglottic system designed primarily for esophageal insertion, enabling ventilation through a dual-cuff mechanism and dedicated ventilation ports. This design allows for effective airway control in emergency situations and is widely utilized by prehospital care providers due to its operational simplicity and reliability. Although available in multiple sizes, its use remains predominantly confined to adult populations, with limited application in pediatric airway management due to anatomical and safety considerations [8].

Oxygen

Oxygen administration is a fundamental component of airway management and plays a critical role in both preoxygenation and peri-intubation care. Adequate preoxygenation strategies are essential to extend safe apnea time and reduce the risk of

desaturation during airway manipulation. Various delivery methods are employed depending on patient condition and clinical urgency, including nasal cannula systems, facemask oxygen delivery, high-flow oxygen therapy, and bilevel positive airway pressure systems. These modalities aim to optimize oxygen reserves prior to definitive airway intervention, thereby enhancing procedural safety and patient outcomes [7][8][9].

Bougie

The bougie is a semi-rigid, flexible introducer commonly utilized as an adjunct in difficult airway management and as part of primary intubation strategies in selected cases. It functions as a guiding device that facilitates endotracheal tube placement, particularly in situations where direct visualization of the vocal cords is limited or suboptimal. Its tactile feedback and directional control make it a valuable rescue tool in challenging airway scenarios, improving first-pass intubation success rates and reducing the likelihood of failed airway attempts [7][8][9].

Personnel

Effective endotracheal intubation requires a coordinated multidisciplinary team to ensure procedural safety and optimize patient outcomes. Ideally, the primary physician responsible for airway management should be supported by at least two additional trained staff members who can assist throughout the procedure. These supporting personnel play a critical role in administering medications, preparing and operating bag-mask ventilation, and continuously monitoring the patient's physiological status, including oxygen saturation, heart rate, and hemodynamic stability. A well-structured airway team typically includes a physician, respiratory therapist, registered nurse, nursing technician, paramedic, and advanced practice provider. Each member contributes specialized expertise that enhances procedural efficiency and reduces the risk of complications. The respiratory therapist assists with ventilation and airway equipment, while nursing staff support drug preparation and patient monitoring. Paramedics and advanced practitioners contribute to rapid decision-making and technical support. This collaborative structure ensures timely intervention, improved communication, and safe airway management in critical care environments [9].

Preparation

Airway preparation prior to endotracheal intubation requires a structured and systematic approach aimed at optimizing oxygenation, minimizing aspiration risk, and ensuring safe tracheal tube placement. Following adequate preoxygenation, additional protective and stabilizing measures such as cricoid pressure and in-line cervical stabilization are commonly applied, particularly in trauma or suspected cervical spine injury cases. These interventions aim to reduce the risk of gastric content aspiration while maintaining spinal alignment and preventing secondary neurological injury. Rapid-sequence induction, followed by direct laryngoscopy, is widely regarded as the most effective and controlled method for securing the airway in critically ill patients, as it minimizes the interval between loss of spontaneous respiration and definitive airway protection. Successful airway management requires a detailed understanding of anatomical predictors of difficulty, commonly summarized as the four Ds of a difficult airway, which include distortion, disproportion, dysmobility, and dentition. Airway distortion refers to anatomical abnormalities or trauma that alter normal airway landmarks. Disproportion describes mismatch in anatomical dimensions that complicate visualization or tube passage. Dysmobility reflects reduced cervical spine or temporomandibular joint mobility that limits optimal positioning for intubation. Dentition relates to the presence of abnormal, protruding, or fragile teeth that may obstruct laryngoscope insertion or be damaged during the procedure. Recognition of these factors during pre-intubation assessment is essential for anticipating difficulty and selecting appropriate airway strategies [7][8][9].

A key anatomical landmark in direct laryngoscopy is the vallecula, which plays a central role in successful visualization of the glottic opening. Accurate identification of this structure is fundamental for clinicians performing oral tracheal intubation, as it guides proper blade placement and facilitates optimal exposure of the vocal cords. When using a Macintosh laryngoscope with a curved blade, the instrument is advanced along the tongue until it reaches the vallecula, where upward and forward pressure is applied to elevate the epiglottis indirectly and expose the glottic opening. Failure to correctly position the blade within the vallecula significantly increases the risk of esophageal intubation and subsequent ventilation failure. In contrast, the Miller straight blade follows a different anatomical pathway, being advanced beyond the vallecula to directly lift the epiglottis. This technique provides direct visualization of the vocal cords and is particularly useful in pediatric airway management or in cases where indirect epiglottic elevation is insufficient. Regardless of blade type, endotracheal tube insertion should only proceed once the glottic opening and vocal cords are clearly visualized, ensuring accurate placement and reducing complications such as hypoxia or airway trauma [8][9].

Video laryngoscopy represents a significant advancement in airway visualization techniques, incorporating a camera system mounted on a curved blade to enhance glottic exposure. This technology allows indirect visualization of the airway structures on a monitor, improving success rates in difficult airway scenarios and reducing the need for extensive

neck manipulation. During insertion, the blade is positioned near the vallecular space to achieve optimal visualization of the vocal cords. If initial visualization is inadequate, gradual withdrawal and repositioning of the blade is recommended until the epiglottis or laryngeal structures come into view, enabling reassessment of anatomical orientation and improving intubation success. Preparation for intubation also requires the availability of essential equipment to ensure accurate placement and post-procedural verification. Standard equipment includes a functional laryngoscope, carbon dioxide detectors, continuous waveform capnography devices, and materials required for securing the endotracheal tube. Post-intubation imaging, particularly chest radiography, is often utilized to confirm correct tube depth and exclude complications such as mainstem bronchial intubation. Capnography plays a critical role in real-time confirmation of tracheal placement and is considered a gold standard for verifying successful intubation [9].

Pharmacological preparation is equally important in rapid-sequence induction, involving the administration of sedative and neuromuscular blocking agents to facilitate optimal intubation conditions. Commonly used induction agents include etomidate at doses ranging from 0.3 to 0.4 mg/kg, fentanyl at 2 to 10 mcg/kg, midazolam at 0.1 to 0.3 mg/kg, propofol at 1 to 2.5 mg/kg, and thiopental at 3 to 5 mg/kg. These medications are selected based on patient hemodynamic status, comorbidities, and clinical urgency. Neuromuscular blockade is achieved using agents such as succinylcholine at 1 to 2 mg/kg, rocuronium at 0.6 to 1.2 mg/kg, and vecuronium at 0.15 to 0.25 mg/kg, all of which facilitate complete muscle relaxation and improve laryngoscopic visualization. The combined use of appropriate pharmacologic agents, structured airway assessment, and advanced visualization techniques ensures a controlled and efficient intubation process, minimizing complications and enhancing patient safety in critical care environments [9].

Technique or Treatment

Endotracheal intubation follows a structured and highly standardized sequence designed to optimize oxygenation, minimize aspiration risk, and ensure rapid and secure airway access in critically ill or injured patients. The process begins with adequate preoxygenation, which serves to increase oxygen reserves and extend the safe apnea period during airway manipulation. This is followed by the administration of rapid-sequence induction medications, combining sedative and neuromuscular blocking agents to achieve unconsciousness and complete muscle relaxation, thereby facilitating optimal intubating conditions. In many clinical scenarios, cricoid pressure is applied during induction to reduce the risk of passive regurgitation and aspiration of gastric contents, although its use may vary depending on institutional protocols and clinical judgment. In addition, in-line cervical stabilization is implemented when cervical spine injury is suspected, ensuring that airway manipulation does not exacerbate potential spinal damage. Once these preparatory steps are completed, laryngoscopy is performed using either a direct or indirect approach, with the goal of achieving clear visualization of the vocal cords and facilitating accurate placement of the endotracheal tube. Collectively, this sequence represents a controlled and systematic approach that is widely regarded as the safest and most effective method for airway protection in emergency and critical care settings [8][9][10].

Confirmation of correct endotracheal tube placement is a fundamental aspect of airway management and is essential for preventing life-threatening complications. Direct visualization of the tube passing through the vocal cords using a laryngoscope remains the most definitive method of confirming placement and is considered the gold standard. However, multiple adjunctive techniques are routinely employed to enhance diagnostic accuracy and ensure ongoing verification. Measurement of end-tidal carbon dioxide is a critical tool, with continuous waveform capnography being strongly recommended by the American Heart Association as the most reliable method for confirming tracheal placement and monitoring ongoing ventilation. A normal capnography waveform with end-tidal carbon dioxide values typically ranging between 35 and 45 mm Hg indicates correct tracheal placement, whereas a flat waveform or a value of zero suggests possible esophageal intubation. Additional confirmatory modalities include chest radiography, which is frequently used to assess tube depth and verify positioning relative to the carina, with the ideal endotracheal tube placement approximately 2 cm above the carina. Bedside ultrasound has also emerged as a valuable adjunct in certain emergency settings, allowing rapid visualization of tracheal placement in real time. Clinical assessment remains essential and includes bilateral chest auscultation to confirm equal breath sounds and exclusion of gastric insufflation [7].

Malposition of the endotracheal tube is a significant complication of airway management and may manifest as either esophageal intubation or right mainstem bronchial intubation. Blind intubation techniques are particularly associated with the risk of right mainstem placement due to the more vertical orientation and wider diameter of the right main bronchus. In cases of malposition, clinical and technical indicators guide immediate correction. Right mainstem intubation is typically identified by diminished or absent breath sounds on the left hemithorax, whereas esophageal intubation presents with absent bilateral breath sounds, absence of chest rise, and the presence of gastric insufflation sounds in the epigastric region during ventilation. In both scenarios, oxygen desaturation occurs rapidly if corrective action is not taken. Once correct placement

of the endotracheal tube has been confirmed, it must be securely fastened to prevent accidental displacement, which can lead to catastrophic loss of airway control. Continuous monitoring is then maintained using waveform capnography and pulse oximetry to ensure ongoing ventilation adequacy and early detection of complications. In pediatric critical care settings, the use of cuffed endotracheal tubes is generally preferred over uncuffed tubes, as they provide improved control of ventilation, reduce air leakage, and allow for more accurate delivery of tidal volumes while minimizing the risk of aspiration [8][9].

Airway management in trauma patients represents a particularly high-risk and time-sensitive component of emergency care. Trauma remains a leading cause of morbidity and mortality globally, particularly among individuals aged 15 to 50 years, and is recognized as the second most common cause of death, accounting for approximately 8 percent of all global fatalities. According to the World Health Organization, traumatic injuries resulting from motor vehicle accidents, drowning, poisoning, falls, burns, and interpersonal violence contribute to more than 5 million deaths annually, with a significantly larger number of survivors experiencing long-term disability and functional impairment. Early intervention and rapid transport to specialized trauma centers are strongly associated with improved outcomes in severely injured patients. However, the role of prehospital intubation remains controversial within emergency medical services literature due to variability in operator skill, environmental constraints, and potential delays in definitive care. As a result, protocols governing field intubation are typically determined by medical directors of emergency medical services systems, who define the clinical indications and training requirements for paramedic-led airway interventions. Despite these controversies, emergency transport teams continue to play a vital role in ensuring rapid stabilization and safe transfer of critically injured patients to trauma facilities [10].

Surgical airway access represents the final rescue intervention in failed airway scenarios when conventional intubation techniques are unsuccessful or contraindicated. Cricothyroidotomy is the most commonly employed surgical airway procedure in emergency settings; however, its use in pediatric populations remains highly restricted. The only absolute contraindication to surgical cricothyroidotomy is related to patient age and anatomical suitability, although this threshold is not uniformly defined in the literature. Reported lower age limits vary between five and twelve years depending on clinical guidelines and institutional practices. Pediatric Advanced Life Support frameworks classify the pediatric airway as applicable to children between one and eight years of age, reflecting the anatomical and physiological differences that increase procedural risk in younger patients. In pediatric emergencies where surgical airway access is required, needle cricothyroidotomy with transtracheal ventilation is generally preferred as a temporizing measure until a definitive airway, such as a formal tracheostomy, can be established under controlled conditions [8][9].

Complications

Complications associated with endotracheal intubation encompass a broad spectrum of mechanical, physiological, and procedural failures that may significantly compromise patient safety. One of the most critical complications is the inability to successfully secure the airway, which can rapidly lead to severe hypoxemia and subsequent cardiac arrest if not promptly corrected. Esophageal intubation represents another major adverse event, in which the endotracheal tube is inadvertently placed within the esophagus rather than the trachea, resulting in ineffective ventilation, gastric insufflation, and rapid oxygen desaturation. Respiratory failure, whether hypoxic or hypercapnic, may also occur during or after the procedure, particularly in cases of prolonged attempts, inadequate preoxygenation, or unrecognized tube misplacement, and may progress to respiratory arrest if not immediately addressed. Traumatic complications are also clinically significant and may involve injury to the oropharyngeal or laryngeal structures. Such injuries can result from repeated laryngoscopy attempts, poor visualization, or difficult airway anatomy, and may manifest mucosal bleeding, soft tissue edema, or direct damage to the vocal cords. These injuries not only complicate ventilation but may also contribute to long-term sequelae such as hoarseness or airway stenosis. In patients with underlying thoracic trauma, additional life-threatening complications may arise. Intubation in individuals with chest injuries can precipitate or exacerbate conditions such as tension pneumothorax or significant air leaks secondary to bronchial injury. In cases where pneumothorax is already present, chest tube placement prior to intubation is often recommended to prevent further respiratory compromise. When bronchial injury exists, positive pressure ventilation following intubation may worsen air leakage, leading to inadequate ventilation and hemodynamic instability. In such complex scenarios, the use of a bronchial blocker may be necessary to isolate the injured lung segment and reduce ongoing air escape, thereby improving ventilatory control and stabilizing gas exchange [9][10][11].

Clinical Significance

Airway management represents a fundamental component of critical care and emergency medicine, requiring comprehensive knowledge of anatomical variations, physiological principles, and procedural strategies to ensure effective patient outcomes. A central consideration is

the anatomical and functional distinction between pediatric and adult airways, as these differences significantly influence device selection, intubation technique, and complication risk. Pediatric airways are smaller, more anteriorly positioned, and more prone to obstruction, necessitating modified approaches compared to adult patients. Selection of the appropriate airway management strategy is another essential factor, requiring clinicians to evaluate patient condition, anticipated difficulty, and available resources. Rapid-sequence induction remains a key technique in emergency airway control, and its success depends on correct selection and administration of induction agents and neuromuscular blocking medications. Accurate assessment of a potentially difficult airway is critical, as early recognition of risk factors allows for timely modification of the airway plan and reduces the likelihood of failed intubation. Alternative airway techniques, including supraglottic devices and surgical airway interventions, serve as essential backup strategies when conventional intubation fails. The use of airway adjuvants such as bougies, stylets, and video-assisted laryngoscopy further enhances success rates in challenging cases. Special clinical circumstances, particularly penetrating trauma, require individualized airway approaches due to anatomical distortion, bleeding, and rapidly evolving airway compromise [10][11]. Effective airway management also depends on adequate training and continuous skill development, particularly among prehospital personnel responsible for pediatric airway interventions. Regular exposure to simulation-based training improves procedural competence and decision-making accuracy. Furthermore, clinicians must maintain a clear understanding of the indications, contraindications, and potential complications of endotracheal intubation to ensure safe practice. Reliable confirmation of endotracheal tube placement remains a critical safety step, typically achieved through waveform capnography and clinical assessment [11].

Enhancing Healthcare Team Outcomes

Optimal airway management outcomes are strongly dependent on coordinated interprofessional collaboration involving physicians, advanced practice providers, nurses, respiratory therapists, and emergency medical personnel. A team-based approach ensures that each stage of airway management, from preparation and preoxygenation to intubation and post-procedural monitoring, is performed with precision and efficiency. Effective communication within the team is essential for early identification of difficult airway predictors and for timely adjustment of the airway management strategy when challenges arise. This proactive approach significantly reduces the incidence of failed intubation and associated complications, thereby improving overall patient survival and recovery outcomes. Continuous training and skill refinement are fundamental to maintaining high standards of airway management. Regular practice, whether in clinical environments or simulation-based laboratories, enhances procedural confidence and technical proficiency across all healthcare disciplines. Evidence indicates that structured training programs substantially improve intubation success rates and reduce mortality, regardless of the clinician's primary specialty area. Emergency physicians often rely on length-based or weight-based formulas to estimate appropriate endotracheal tube size, particularly in pediatric populations where anatomical variability is pronounced. Technological advancements have also contributed to improved airway management outcomes. Camera-assisted or video laryngoscopy has demonstrated superior performance compared to direct laryngoscopy in difficult airway scenarios, particularly in achieving higher first-pass success rates. This improvement is attributed to enhanced visualization of airway structures and reduced need for extensive manipulation of the cervical spine. The integration of such technologies, combined with structured team coordination and ongoing professional development, strengthens the overall effectiveness of airway management systems and contributes to improved clinical safety and patient outcomes [9][10][11].

Conclusion:

Airway management remains a vital intervention in emergency and critical care, demanding proficiency in anatomy, device selection, procedural technique, and rapid decision-making. The article highlights substantial differences between pediatric and adult airways, reinforcing the need for tailored approaches based on patient age and anatomical considerations. Successful intubation depends on structured preparation, appropriate pharmacologic agents, and the integration of advanced tools such as video laryngoscopy. Complications—including esophageal intubation, trauma, and respiratory deterioration—underscore the necessity of continuous reassessment, capnographic confirmation, and diligent tube securing. A coordinated interprofessional team enhances safety, communication, and procedural effectiveness. Ultimately, ongoing training, adherence to evidence-based protocols, and recognition of difficult airway predictors remain foundational to improving outcomes and reducing morbidity in both prehospital and hospital environments.

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