

Enhancing Field Interventions In Emergency Cases Of Asphyxia: Best Practical Approaches For Paramedics At The Saudi Red Crescent Authority

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Abstract

Asphyxia represents a critical medical emergency requiring immediate and effective intervention by emergency medical personnel. This comprehensive review examines current evidence-based practices and emerging strategies for managing asphyxiation cases in pre-hospital settings, with specific focus on enhancing paramedic performance within emergency medical services frameworks. Through systematic analysis of contemporary literature and clinical protocols, this paper identifies key intervention strategies, common challenges, and practical solutions applicable to field emergency care. The research synthesizes findings from multiple international studies, clinical guidelines, and evidence-based protocols to establish a comprehensive framework for asphyxia management. Critical areas examined include initial assessment techniques, airway management strategies, ventilation protocols, advanced life support interventions, and scene safety considerations. The analysis reveals that successful outcomes in asphyxia cases depend heavily on rapid recognition, systematic assessment, and timely implementation of appropriate interventions. Furthermore, the research identifies significant gaps in current training programs and proposes enhanced educational approaches to improve paramedic competency. The findings emphasize the importance of regular skills maintenance, simulation-based training, and protocol adherence in optimizing patient outcomes. This paper provides actionable recommendations for emergency medical service providers, highlighting the necessity of continuous professional development, equipment standardization, and quality assurance mechanisms. The comprehensive approach presented offers practical guidance for paramedics managing asphyxia emergencies while contributing to the broader discourse on pre-hospital emergency care optimization.

Keywords: asphyxia, emergency medical services, paramedics, pre-hospital care, airway management, respiratory emergencies.

1. Introduction

Asphyxia constitutes one of the most time-sensitive emergencies encountered by pre-hospital emergency medical personnel, demanding immediate recognition and intervention to prevent irreversible tissue damage and mortality. The condition, characterized by inadequate oxygen delivery to vital organs, can result from various mechanisms including airway obstruction, respiratory depression, environmental oxygen deficiency, or interference with normal respiratory mechanics. Emergency medical service providers serve as the critical first line of medical intervention, and their ability to rapidly assess and manage asphyxiating conditions directly influences patient survival and neurological outcomes (Gräsner et al., 2021). The

complexity of asphyxia management in field settings presents unique challenges distinct from controlled hospital environments, requiring paramedics to make rapid clinical decisions often under suboptimal conditions with limited resources.

The epidemiological significance of asphyxia-related emergencies extends across diverse populations and settings, encompassing traumatic injuries, medical emergencies, occupational exposures, and environmental incidents. Data from emergency medical service systems worldwide demonstrate that respiratory emergencies, including asphyxiation, account for a substantial proportion of emergency calls, with mortality rates varying significantly based on response time, intervention quality, and underlying etiology (Soar et al., 2021). In regional contexts where environmental factors, industrial activities, or specific occupational hazards predominate, emergency medical personnel must maintain heightened preparedness for asphyxia-related incidents. The Saudi Red Crescent Authority, serving diverse geographical regions with varying risk profiles, exemplifies the need for comprehensive, evidence-based approaches to asphyxia management that can be effectively implemented across different operational contexts.

Contemporary emergency medical services increasingly emphasize evidence-based practice, systematic protocols, and continuous quality improvement to optimize patient outcomes. However, significant variability persists in paramedic training, available equipment, and implementation of current guidelines across different systems and regions (Panchal et al., 2020). This variability potentially contributes to inconsistent patient outcomes and highlights the necessity for standardized, practical approaches grounded in current scientific evidence. Furthermore, the evolving nature of emergency medical practice, driven by ongoing research and technological advancement, necessitates regular review and updating of clinical protocols and training methodologies. The integration of new evidence into practical field applications presents ongoing challenges for emergency medical service organizations, particularly in ensuring that front-line providers maintain current knowledge and competency.

The primary objective of this paper centers on examining current best practices for managing asphyxia emergencies in pre-hospital settings, with particular emphasis on practical implementation strategies for paramedics. Through comprehensive review of contemporary literature and clinical evidence, this research aims to establish a framework for optimizing field interventions that can be realistically applied within existing emergency medical service structures. The analysis encompasses assessment methodologies, intervention strategies, equipment considerations, training approaches, and quality assurance mechanisms. By synthesizing evidence from diverse sources and contexts, this work seeks to provide actionable guidance that enhances paramedic capability and ultimately improves patient outcomes in asphyxia emergencies.

2. Literature Review

2.1 Pathophysiology and Clinical Presentation of Asphyxia

Understanding the underlying pathophysiological mechanisms of asphyxia forms the foundation for effective clinical management. Asphyxia fundamentally represents a disruption in the oxygen-carbon dioxide exchange process, leading to hypoxemia and hypercapnia that, if uncorrected, progress to cellular dysfunction, organ failure, and death. The cascade of physiological responses to oxygen deprivation follows a predictable pattern, beginning with compensatory mechanisms including increased respiratory effort, tachycardia, and peripheral vasoconstriction, followed by decompensation characterized by bradycardia, hypotension, and eventual cardiopulmonary arrest (Berg et al., 2020). The time course of this progression varies significantly based on the degree of oxygen deprivation, underlying patient factors, and the specific mechanism of asphyxiation. Complete airway obstruction may lead to cardiac arrest within minutes, while partial obstruction or gradual oxygen depletion may allow for longer intervention windows.

The clinical presentation of asphyxia varies considerably depending on the underlying cause, severity, and duration of oxygen deprivation. Early signs typically include altered mental status, anxiety, dyspnea, and

increased work of breathing, manifested through accessory muscle use, nasal flaring, and paradoxical breathing patterns (Neumar et al., 2020). As hypoxemia worsens, patients may exhibit cyanosis, particularly in central locations such as the lips and mucous membranes, though the absence of cyanosis does not exclude significant hypoxemia. Progressive deterioration leads to decreased level of consciousness, ineffective respiratory efforts, and cardiovascular instability. The recognition of these progressive stages allows paramedics to assess severity, predict likely clinical course, and prioritize interventions accordingly. However, the presentation may be complicated by concurrent injuries, environmental factors, or underlying medical conditions that obscure typical signs or accelerate clinical deterioration.

Specific etiologies of asphyxia present distinct clinical patterns that may guide differential diagnosis and targeted intervention. Foreign body airway obstruction, a common cause of asphyxiation, typically presents with sudden onset during eating or play, often with the characteristic "choking" presentation of inability to speak, ineffective cough, and universal choking sign (Vaillancourt et al., 2020). Conversely, asphyxia related to drowning presents with a history of submersion, possible hypothermia, and aspiration of water or contaminants. Toxic inhalation or oxygen-deficient environments may affect multiple victims simultaneously and require scene safety assessment before patient approach. Traumatic asphyxia resulting from chest compression presents with distinctive findings including facial plethora, petechiae, and potential for associated injuries requiring comprehensive assessment.

2.2 Pre-hospital Assessment Strategies

Systematic patient assessment represents the cornerstone of effective emergency medical care, providing the foundation for clinical decision-making and intervention prioritization. The approach to asphyxia cases requires rapid yet thorough evaluation, balancing the need for comprehensive assessment against the urgency of intervention. Contemporary emergency medical service protocols typically employ a structured assessment framework beginning with scene safety evaluation, followed by primary survey addressing immediate life threats, and secondary survey identifying additional injuries or conditions (Olasveengen et al., 2020). In asphyxia cases, the primary survey assumes particular importance, focusing on airway patency, breathing adequacy, and circulatory status. The traditional ABCDE approach—airway, breathing, circulation, disability, and exposure—provides a systematic framework ensuring critical elements are not overlooked in high-stress situations.

Scene safety assessment, while universally applicable, assumes heightened significance in potential asphyxiation scenarios. Environmental hazards that caused patient asphyxiation may threaten responding personnel, requiring careful evaluation before patient approach. Toxic atmospheres, oxygen-deficient environments, unstable structures, or ongoing hazards necessitate specialized resources or environmental modification before safe patient access (Merchant et al., 2020). The failure to recognize scene hazards has resulted in secondary casualties among rescuers, emphasizing the critical nature of this assessment phase. Furthermore, scene assessment may provide crucial diagnostic information regarding the mechanism of asphyxiation, potential toxin exposures, or additional victims requiring assistance. The environmental context often informs clinical management decisions and resource allocation.

The primary survey in asphyxia cases demands rapid but systematic evaluation of airway and respiratory status. Airway assessment encompasses evaluation of patency, protective reflexes, and potential for deterioration. Observable signs of airway compromise include stridor, abnormal breath sounds, drooling, or inability to phonate normally (Benger et al., 2018). The assessment must identify both current obstruction and risk factors for deterioration, such as facial burns, inhalation injury, or progressive swelling. Breathing assessment evaluates respiratory rate, depth, symmetry, and effectiveness. Paramedics must recognize both obvious respiratory distress and subtle signs of inadequate ventilation. The integration of physical examination findings with objective measurements such as pulse oximetry and capnography provides comprehensive respiratory assessment, though technical limitations and environmental factors may affect measurement accuracy.

2.3 Airway Management Interventions

Airway management constitutes the most critical intervention in asphyxia cases, with the primary goal of establishing and maintaining a patent airway to facilitate adequate oxygenation and ventilation. The selection of specific airway management techniques depends on multiple factors including patient presentation, level of consciousness, presence of protective airway reflexes, anatomical considerations, and provider skill level. Contemporary pre-hospital airway management follows a graduated approach, beginning with basic maneuvers and progressing to advanced techniques as needed based on patient response and clinical requirements (Carlson et al., 2020). The concept of airway management as a continuum rather than discrete interventions reflects the dynamic nature of emergency care and the necessity for ongoing reassessment and technique modification.

Basic airway maneuvers form the foundation of pre-hospital airway management and frequently prove sufficient for establishing airway patency in unconscious patients. The head-tilt chin-lift maneuver, performed by placing one hand on the patient's forehead and gently tilting the head backward while lifting the chin with the other hand, effectively relieves upper airway obstruction caused by tongue displacement in non-trauma patients (Kleinman et al., 2018). In patients with potential cervical spine injury, the jaw-thrust maneuver provides airway opening while maintaining neutral cervical alignment. This technique requires positioning at the patient's head, placing fingers behind the angle of the mandible, and applying anterior displacement while avoiding head extension. The effectiveness of these basic maneuvers often surprises novice practitioners, as proper execution frequently establishes adequate airway patency without need for adjunctive devices.

Airway adjuncts provide mechanical support for maintaining airway patency and may facilitate ventilation in patients lacking protective airway reflexes. The oropharyngeal airway, inserted over the tongue to prevent posterior displacement, proves useful in unconscious patients without gag reflex (Soar et al., 2019). Proper sizing, achieved by measuring from the corner of the mouth to the angle of the jaw, ensures effective positioning without causing trauma or worsening obstruction. The nasopharyngeal airway offers an alternative in patients with intact gag reflex, trauma contraindications to oral airway placement, or trismus. This soft, flexible tube, lubricated and inserted along the floor of the nasal passage, provides a conduit from the nostril to the posterior pharynx. Selection between these devices depends on patient presentation, clinical contraindications, and anatomical factors, with paramedics requiring proficiency in both techniques to address varied clinical scenarios.

Advanced airway management techniques, particularly endotracheal intubation, remain controversial in pre-hospital settings despite widespread use. Endotracheal intubation provides definitive airway protection, secures the airway against displacement, and facilitates effective ventilation and oxygenation. However, the procedure requires significant skill, may cause complications, and demonstrates variable success rates across different provider groups and systems (Brown et al., 2018). Multiple studies have questioned the benefit of pre-hospital intubation compared to bag-valve-mask ventilation, particularly when intubation attempts delay transport or compromise oxygenation. Current evidence suggests that outcomes depend heavily on provider proficiency, first-pass success rates, and maintenance of oxygenation during attempts. Consequently, many systems have implemented strict protocols governing indications for intubation, limiting attempts, and mandating specific competency standards.

Supraglottic airway devices have emerged as alternatives to endotracheal intubation, offering improved ease of insertion while providing reasonable airway protection and ventilation capability. Devices such as the laryngeal mask airway, i-gel, and King LT demonstrate higher insertion success rates, particularly among less experienced providers, and may serve as primary airway management tools or rescue devices following failed intubation attempts (Jabre et al., 2018). These devices position above the glottis, creating a seal around the laryngeal inlet to facilitate ventilation. The relative ease of insertion, combined with acceptable ventilation performance and lower complication rates compared to endotracheal intubation, has led many emergency medical service systems to incorporate supraglottic airways into standard protocols.

However, these devices provide less complete airway protection than endotracheal tubes and may prove inadequate in situations requiring high ventilation pressures or complete aspiration prevention.

2.4 Ventilation and Oxygenation Strategies

Effective ventilation and oxygenation represent parallel priorities alongside airway management, addressing the fundamental respiratory failure underlying asphyxia. The distinction between oxygenation and ventilation, though conceptually clear, becomes practically intertwined in emergency management. Oxygenation addresses oxygen delivery to the lungs and subsequently to tissues, while ventilation concerns the exchange of gases including carbon dioxide elimination. Both processes require attention in asphyxia cases, with the relative priority depending on the specific pathophysiology (Kleinman et al., 2020). Pure hypoxemia without ventilatory failure may respond to supplemental oxygen alone, while scenarios involving both hypoxemia and inadequate ventilation require assisted or controlled ventilation in addition to oxygen supplementation.

Supplemental oxygen administration represents a fundamental intervention in virtually all asphyxia cases, with delivery methods selected based on patient condition and requirements. High-flow oxygen via non-rebreather mask provides maximal oxygen concentration for spontaneously breathing patients capable of maintaining adequate ventilation. This approach delivers oxygen concentrations approaching ninety to one hundred percent when properly applied with adequate flow rates, though actual inspired oxygen concentration depends on patient respiratory pattern and mask seal (Soar et al., 2021). Nasal cannula offers an alternative for patients tolerating masks poorly or requiring lower oxygen concentrations, though the limited flow rates and oxygen delivery make this approach less suitable for critical asphyxia cases. The selection of oxygen delivery method balances the need for maximal oxygenation against patient tolerance, with many paramedics defaulting to high-flow non-rebreather masks in severe cases while accepting that some patients may require alternative approaches.

Assisted ventilation becomes necessary when patients demonstrate inadequate spontaneous respiratory effort, as evidenced by clinical signs of respiratory failure or objective measurements indicating hypoventilation. Bag-valve-mask ventilation represents the primary method for providing positive pressure ventilation in pre-hospital settings, offering immediate capability to support or replace spontaneous breathing (Perkins et al., 2018). Effective bag-valve-mask technique requires proper mask seal, appropriate ventilation volumes and rates, and coordination between bag compression and patient respiratory efforts when present. The two-person technique, with one provider maintaining mask seal using two hands while a second compresses the bag, generally produces superior ventilation compared to single-provider technique, though practical constraints often necessitate single-provider performance. Common errors in bag-valve-mask ventilation include excessive ventilation rates and volumes, inadequate mask seal allowing air leak, and failure to ensure airway patency before ventilation attempts.

Monitoring of ventilation effectiveness has improved substantially with the advent of quantitative capnography, which measures end-tidal carbon dioxide concentration to assess ventilation adequacy. End-tidal CO₂ monitoring provides real-time feedback on ventilation, helps confirm proper advanced airway placement, and may offer prognostic information in cardiac arrest scenarios (Wang et al., 2020). Normal end-tidal CO₂ values, typically thirty-five to forty-five millimeters of mercury in healthy individuals, indicate adequate ventilation and pulmonary blood flow. Values below twenty in cardiac arrest suggest inadequate perfusion or ventilation, while values above fifty may indicate hypoventilation or increased metabolic production. The integration of capnography into routine pre-hospital practice enhances clinical decision-making, though interpretation requires understanding of physiological principles and recognition of technical limitations.

2.5 Special Considerations in Asphyxia Management

Certain asphyxia scenarios present unique challenges requiring modified assessment or intervention approaches. Foreign body airway obstruction, particularly in conscious patients, demands immediate intervention using techniques specifically designed for this presentation. The Heimlich maneuver, performed by delivering abdominal thrusts aimed at creating sufficient intrathoracic pressure to expel the obstruction, remains the primary intervention for conscious choking adults and children over one year (Dyson et al., 2019). The technique requires proper hand positioning and sufficient force to generate adequate pressure while avoiding injury to underlying organs. Unconscious choking victims receive cardiopulmonary resuscitation with airway inspection before ventilation attempts, as chest compressions may generate sufficient pressure to relieve obstruction. Pediatric considerations include different techniques for infants, utilizing back blows and chest thrusts rather than abdominal thrusts to avoid injury.

Drowning represents another special category of asphyxia requiring specific management considerations. The primary pathophysiology involves surfactant washout, alveolar collapse, and ventilation-perfusion mismatch leading to severe hypoxemia. Initial management priorities include removal from water, assessment of cervical spine injury risk based on diving or trauma history, and immediate initiation of ventilation and oxygenation (Schmidt et al., 2017). Unlike other cardiac arrest scenarios, drowning victims benefit from ventilation prior to chest compressions when resources allow, as the primary problem involves respiratory rather than cardiac pathology. Special challenges include water-contaminated airways, hypothermia complicating assessment and resuscitation, and the potential for delayed deterioration even after initial recovery. Transport decisions must account for the risk of secondary drowning syndrome, warranting hospital evaluation even for apparently recovered patients.

Toxic inhalation and oxygen-deficient environments present assessment and management challenges alongside significant scene safety concerns. Common scenarios include smoke inhalation during fires, industrial exposures to toxic gases, and confined space incidents with oxygen displacement. Carbon monoxide poisoning deserves particular mention due to its frequency and specific treatment requirements (Rose et al., 2017). This colorless, odorless gas binds hemoglobin with much greater affinity than oxygen, producing tissue hypoxia despite normal oxygen saturation readings on standard pulse oximetry. Management requires high-flow oxygen administration and rapid transport for potential hyperbaric oxygen therapy. Paramedics must recognize that standard pulse oximetry cannot distinguish carboxyhemoglobin from oxyhemoglobin, potentially providing falsely reassuring readings in carbon monoxide poisoning. Clinical suspicion based on exposure history and presentation guides treatment decisions when specialized monitoring equipment remains unavailable.

2.6 Training and Competency Maintenance

The effectiveness of paramedic interventions in asphyxia cases depends critically on initial training quality and ongoing competency maintenance. Traditional education approaches emphasizing didactic instruction and limited practical experience have demonstrated inadequate preparation for the complex, high-stress reality of emergency field work (Laudit et al., 2018). Contemporary emergency medical education increasingly incorporates simulation-based training, scenario-based learning, and deliberate practice of critical skills to enhance learner preparation and confidence. High-fidelity simulation allows trainees to experience realistic clinical scenarios, practice decision-making under pressure, and develop technical skills without risk to actual patients. The evidence supporting simulation-based training demonstrates improved skill acquisition, better knowledge retention, and enhanced performance in real clinical situations compared to traditional educational methods.

Competency maintenance presents ongoing challenges for emergency medical service systems, as skills decay occurs without regular practice and reinforcement. Studies examining paramedic skill retention have documented significant deterioration in both cognitive knowledge and psychomotor skills within months of initial training, particularly for infrequently performed procedures like advanced airway management (Dyson et al., 2017). This finding emphasizes the necessity for structured continuing education, regular skills practice, and competency verification programs. Various approaches to competency maintenance

include mandatory continuing education hours, periodic skills testing, simulation sessions, and case review processes. The optimal approach likely combines multiple methods, ensuring both knowledge currency and practical skill maintenance through varied learning experiences and regular reinforcement.

Quality assurance mechanisms provide crucial feedback on actual field performance, identifying areas requiring improvement and verifying that established protocols are followed appropriately. Systematic data collection on key performance indicators including response times, intervention success rates, patient outcomes, and protocol adherence enables objective assessment of system performance (Jensen et al., 2019). Case review processes, examining both routine cases and critical incidents, offer learning opportunities and identify systemic issues requiring attention. The implementation of electronic patient care reporting systems has facilitated more comprehensive data collection and analysis, though challenges persist regarding data quality, completeness, and meaningful utilization of collected information. Creating a non-punitive quality improvement culture that views performance review as educational rather than disciplinary encourages honest reporting and constructive engagement with improvement processes.

3. Methods

This comprehensive review employed systematic literature search and analysis methodologies to identify, evaluate, and synthesize current evidence regarding pre-hospital asphyxia management. The research approach combined elements of systematic review methodology with narrative synthesis to provide both comprehensive coverage of available evidence and practical interpretation applicable to field emergency medical services. The selection of this hybrid approach reflected the dual objectives of establishing a thorough evidence base while generating actionable recommendations for clinical practice. Unlike purely systematic reviews focused on answering specific, narrowly defined questions, this work aimed to provide broader understanding of asphyxia management across multiple dimensions including pathophysiology, assessment, intervention, training, and quality assurance.

The literature search strategy utilized multiple electronic databases including PubMed, CINAHL, Cochrane Library, and Google Scholar to ensure comprehensive coverage of relevant publications. Search terms combined controlled vocabulary and free-text keywords related to asphyxia, emergency medical services, paramedics, pre-hospital care, airway management, and respiratory emergencies. The search strategy employed Boolean operators to combine concepts appropriately, with typical search strings including terms such as "asphyxia OR asphyxiation" AND "emergency medical services OR paramedic OR pre-hospital" AND "airway management OR resuscitation OR intervention." Additional searches targeted specific topics including foreign body airway obstruction, drowning, toxic inhalation, and carbon monoxide poisoning to ensure comprehensive coverage of relevant scenarios. Reference lists of identified articles provided supplementary sources through backward citation searching, while forward citation searching identified more recent publications citing seminal works.

The inclusion criteria prioritized peer-reviewed publications from reputable journals, clinical guidelines from recognized emergency medical organizations, and evidence-based protocols from established emergency medical service systems. The temporal scope focused primarily on publications from the past seven years, reflecting the emphasis on current evidence and contemporary practice while including older landmark studies where historically significant or still clinically relevant. Publication types considered included original research articles, systematic reviews and meta-analyses, clinical guidelines, case series, and expert consensus statements. Exclusion criteria eliminated publications lacking peer review, those focused exclusively on in-hospital management without pre-hospital relevance, and those addressing pediatric populations exclusively given the focus on general adult emergency medical services. Language restrictions limited inclusion to English language publications, acknowledging this as a limitation but reflecting practical constraints and the predominance of emergency medical literature published in English.

Quality assessment of included studies employed established critical appraisal tools appropriate to publication type. Original research articles underwent evaluation using validated assessment instruments

considering study design, methodology, statistical analysis, and conclusion validity. Clinical guidelines received assessment regarding development methodology, evidence grading systems, and recommendations clarity. The quality assessment process informed the weight assigned to different sources during synthesis, with higher quality evidence receiving greater emphasis in developing recommendations. However, the practical nature of emergency medical services sometimes necessitates reliance on expert opinion and consensus where high-quality research evidence remains limited, particularly regarding specific field procedures or operational considerations.

Data extraction focused on capturing information relevant to the research objectives including assessment techniques, intervention approaches, success rates, complications, training methods, and outcome measures. Information synthesis employed narrative approaches given the heterogeneity of included studies and the broad scope of topics addressed. The synthesis process involved identifying common themes, recognizing areas of consensus and controversy, and integrating findings from multiple sources to develop comprehensive understanding. Where quantitative meta-analysis proved inappropriate due to study heterogeneity, qualitative synthesis identified patterns across studies and generated practical recommendations based on collective evidence. The synthesis specifically aimed to translate research findings into actionable guidance applicable in real-world emergency medical service operations.

4. Results

The comprehensive literature search and subsequent synthesis revealed substantial evidence supporting specific approaches to pre-hospital asphyxia management while identifying areas where evidence remains limited or conflicting. The results presented here organize findings according to major themes including assessment strategies, intervention effectiveness, equipment considerations, training approaches, and quality assurance mechanisms. The integration of evidence from diverse sources provides both broad overview and specific guidance applicable to emergency medical service operations.

4.1 Assessment and Recognition

Current evidence strongly supports systematic assessment approaches in identifying asphyxia and determining intervention priorities. Multiple studies have demonstrated that structured assessment protocols improve recognition of respiratory emergencies and reduce the likelihood of missed diagnoses or delayed interventions. The traditional ABCDE approach maintains widespread acceptance and effectiveness, though emerging evidence suggests potential benefit from modified frameworks emphasizing simultaneous rather than strictly sequential assessment when multiple providers are available (Olasveengen et al., 2020). Scene safety assessment receives universal emphasis across reviewed guidelines and research, with multiple case reports documenting secondary casualties among rescuers who failed to recognize environmental hazards before patient approach. The identification of specific asphyxia etiologies through history and scene assessment influences management decisions and resource allocation, emphasizing the importance of thorough scene evaluation beyond immediate patient assessment.

Physical examination findings demonstrate variable sensitivity and specificity for identifying asphyxia severity. While obvious signs such as cyanosis, altered mental status, and respiratory distress clearly indicate significant pathology, subtle presentations may escape recognition, particularly in early stages or with complicating factors such as dark skin pigmentation affecting cyanosis visibility (Neumar et al., 2020). The respiratory rate, though widely taught as a vital sign, demonstrates surprising unreliability when measured during brief field assessments, with studies documenting poor inter-rater reliability and frequent measurement errors. Conversely, clinical gestalt impressions by experienced paramedics regarding overall severity often prove accurate, suggesting value in systematic training that develops pattern recognition alongside technical assessment skills. The integration of objective measurements including pulse oximetry and capnography with clinical assessment enhances accuracy, though technical limitations and artifact must be recognized and managed appropriately.

Table 1. Key Assessment Parameters in Asphyxia Evaluation

Assessment Component	Clinical Indicators	Objective Measurements	Limitations
Airway Patency	Stridor, abnormal sounds, inability to speak, positioning	Direct visualization, auscultation	May be intermittent, position-dependent
Breathing Adequacy	Respiratory rate, depth, symmetry, work of breathing	Pulse oximetry, capnography, respiratory rate	Artifact, measurement error, delayed changes
Circulation Status	Heart rate, blood pressure, perfusion, skin signs	Vital signs, capillary refill	Compensatory mechanisms mask early shock
Neurological Status	Consciousness level, responsiveness, agitation	Glasgow Coma Scale, AVPU scale	Confounded by hypoxia, intoxication, trauma
Environmental Factors	Scene hazards, mechanism, number of victims	Gas detection if available	Requires specific equipment, delayed availability

4.2 Airway Management Effectiveness

The evidence regarding specific airway management techniques reveals both clear consensus on fundamental principles and ongoing controversy regarding advanced interventions. Basic airway maneuvers including head-tilt chin-lift and jaw-thrust demonstrate consistent effectiveness in establishing airway patency in unconscious patients, with success rates exceeding ninety percent when performed correctly (Kleinman et al., 2018). The simplicity and immediate availability of these techniques support their role as first-line interventions, though proper technique proves crucial to effectiveness. Studies examining paramedic performance of basic maneuvers have identified common errors including inadequate head extension, insufficient jaw displacement, and premature abandonment of basic techniques in favor of more complex interventions. Educational programs emphasizing proper basic airway management technique and prioritization of these interventions before advancing to adjuncts or devices demonstrate improved patient outcomes.

Airway adjunct devices including oropharyngeal and nasopharyngeal airways show good effectiveness when appropriately selected and sized, though complications occur with improper use. Oropharyngeal airways, while simple in concept, require careful sizing and insertion technique to avoid worsening obstruction or causing trauma (Soar et al., 2019). The common teaching to insert the airway upside down and rotate during placement may actually increase trauma risk, with some evidence supporting direct insertion without rotation using a tongue depressor to control the tongue. Nasopharyngeal airways generally demonstrate better patient tolerance and lower complication rates, though contraindications including basilar skull fracture must be recognized. Comparative studies between airway adjunct types show similar effectiveness in maintaining airway patency, suggesting that provider familiarity and appropriate selection based on patient presentation matter more than inherent device superiority.

Advanced airway management, particularly endotracheal intubation, generates substantial controversy within pre-hospital emergency medical literature. While intubation provides definitive airway control, multiple studies have failed to demonstrate consistent outcome benefit compared to bag-valve-mask ventilation or supraglottic airway devices (Carlson et al., 2020). A large systematic review examining pre-hospital intubation outcomes found substantial heterogeneity in success rates, ranging from fifty to ninety-

five percent depending on provider training, experience, and system factors. First-pass success rates prove particularly important, as multiple intubation attempts correlate with worse outcomes, likely reflecting both prolonged hypoxemia during attempts and airway trauma. Systems implementing strict protocols limiting intubation attempts, requiring continuous pulse oximetry monitoring during attempts, and mandating specific competency standards demonstrate better outcomes than those without such safeguards.

Supraglottic airway devices have emerged as viable alternatives to endotracheal intubation, with evidence suggesting similar or superior outcomes in many pre-hospital scenarios. Multiple randomized controlled trials comparing supraglottic airways to endotracheal intubation in cardiac arrest found equivalent or better outcomes with supraglottic devices, attributed to higher first-attempt success rates and shorter time to ventilation initiation (Jabre et al., 2018). The relative ease of insertion, combined with adequate ventilation performance and lower complication rates, has led many emergency medical service systems to adopt supraglottic airways as primary advanced airway management tools. Device-specific considerations including insertion technique, ventilation characteristics, and limitations must be understood, as different supraglottic airway models demonstrate variable performance characteristics. The evidence supports supraglottic airways as appropriate first-line advanced airway interventions, with endotracheal intubation reserved for situations where supraglottic devices prove inadequate or contraindicated.

Table 2. Comparative Effectiveness of Airway Management Techniques

Intervention	First-Pass Success Rate	Ventilation Adequacy	Complication Rate	Time to Implementation	Skill Maintenance
Basic Maneuvers	>90%	Adequate with proper technique	Minimal	Immediate	Easily maintained
Airway Adjuncts	85-95%	Good when properly sized	Low to moderate	<1 minute	Easily maintained
Supraglottic Devices	75-95%	Adequate for most scenarios	Low to moderate	1-2 minutes	Moderate difficulty
Endotracheal Intubation	50-95%	Excellent when successful	Moderate to high	2-5 minutes	Difficult to maintain
Bag-Valve-Mask	Variable	Adequate with two-person technique	Low	Immediate	Moderate difficulty

4.3 Ventilation and Oxygenation Outcomes

The literature examining ventilation strategies in pre-hospital asphyxia management emphasizes several key principles that influence patient outcomes. Supplemental oxygen administration, while nearly universal in asphyxia treatment, requires attention to delivery method and flow rate to ensure adequate oxygenation. High-flow oxygen via non-rebreather mask achieves inspired oxygen concentrations of eighty-five to ninety-five percent when properly applied, though actual delivery depends on mask seal and patient respiratory pattern (Soar et al., 2021). Studies examining oxygen administration in emergency medical services have identified common problems including inadequate flow rates, poor mask seal, and premature oxygen discontinuation based on improving pulse oximetry readings despite persistent hypoxemia risk. The emphasis should remain on maximizing oxygen delivery in acute asphyxia cases, with concerns about oxygen toxicity or hyperoxia generally irrelevant given the short transport times typical of pre-hospital care.

Assisted ventilation technique significantly influences outcomes, with multiple studies documenting the challenges of effective bag-valve-mask ventilation. Proper technique requires adequate mask seal, appropriate ventilation volumes and rates, and maintenance of airway patency during ventilation. Common errors include excessive ventilation rates causing gastric insufflation and reduced venous return, inadequate tidal volumes failing to achieve adequate oxygenation, and poor mask seal allowing air leak (Perkins et al., 2018). The two-person bag-valve-mask technique demonstrates superior performance compared to single-person technique in multiple studies, though practical constraints often necessitate single-provider ventilation. Training programs incorporating deliberate practice of bag-valve-mask technique, feedback on performance through quantitative capnography, and simulation-based scenarios demonstrate improved provider skill and patient outcomes.

Capnography monitoring has become increasingly standard in pre-hospital care, providing valuable information on ventilation adequacy and physiological status. End-tidal carbon dioxide monitoring confirms adequate ventilation, verifies advanced airway placement, and offers prognostic information in cardiac arrest (Wang et al., 2020). Paramedics require training in capnography interpretation beyond simple numeric values, understanding waveform morphology, trend analysis, and correlation with clinical presentation. Studies examining capnography implementation in emergency medical services demonstrate improved ventilation management, earlier recognition of airway problems, and reduced complications from excessive ventilation. However, technical issues including sensor contamination, sampling errors, and device malfunction require recognition and troubleshooting capability to ensure reliable information.

The debate regarding optimal ventilation rates and volumes in different clinical scenarios continues, with evolving evidence suggesting that traditional teaching may have promoted excessive ventilation. Current guidelines recommend ventilation rates of ten to twelve breaths per minute for adults with advanced airway in place, substantially lower than rates historically taught and often delivered in practice (Kleinman et al., 2020). Excessive ventilation rates have been associated with worse outcomes in cardiac arrest, likely through mechanisms including reduced venous return, decreased coronary perfusion, and increased intrathoracic pressure. The implementation of quantitative capnography allows real-time feedback on ventilation rate and effectiveness, helping providers maintain appropriate parameters. Training programs must address the natural tendency toward excessive ventilation during high-stress resuscitation, emphasizing controlled, measured ventilation delivery.

4.4 Special Population and Scenario Considerations

Foreign body airway obstruction management demonstrates high success rates with proper technique application, though challenges exist in recognition and intervention selection. The Heimlich maneuver, when performed correctly on appropriate patients, shows success rates of seventy to eighty-five percent for relieving complete airway obstruction (Dyson et al., 2019). The technique requires sufficient force to generate adequate intrathoracic pressure while avoiding injury to underlying organs, a balance that proves challenging particularly in obese patients or those with anatomical variations. Studies examining paramedic performance of choking relief techniques have identified common errors including incorrect hand placement, inadequate thrust force, and premature abandonment of conscious choking interventions in favor of invasive airway procedures. The transition from conscious to unconscious choking victim requires recognition and appropriate modification of intervention approach, emphasizing chest compressions and airway inspection rather than continued abdominal thrusts.

Drowning cases present unique management challenges with specific evidence-based approaches differing from other asphyxia scenarios. The modified resuscitation sequence beginning with ventilations rather than chest compressions reflects the respiratory nature of the primary pathology, with evidence from multiple studies supporting this approach (Schmidt et al., 2017). The practical challenge of initiating ventilation in water or immediately upon removal often necessitates immediate chest compressions while establishing capability for ventilation, though the goal remains early ventilation provision when feasible. Cervical spine immobilization decisions in drowning victims require risk assessment based on mechanism, with diving

injuries and falls clearly warranting precautions while simple submersions without trauma history generally not requiring immobilization. The potential for delayed deterioration following successful initial resuscitation emphasizes the importance of hospital transport for observation even in apparently recovered patients.

Toxic inhalation scenarios including carbon monoxide poisoning require specific assessment and management approaches. Carbon monoxide poisoning, occurring in fire exposures, vehicle exhaust exposure, and faulty heating systems, produces tissue hypoxia despite potentially normal pulse oximetry readings (Rose et al., 2017). The management priority involves removing the patient from exposure, administering high-flow oxygen, and rapid transport for potential hyperbaric oxygen therapy. Studies examining outcomes in carbon monoxide poisoning consistently demonstrate benefit from early high-flow oxygen administration, with delayed treatment correlating with worse neurological outcomes. The recognition that standard pulse oximetry cannot reliably exclude carbon monoxide poisoning emphasizes the importance of exposure history and clinical suspicion in guiding treatment decisions. Co-oximetry capable of measuring carboxyhemoglobin when available provides definitive diagnosis, though treatment should not be delayed pending specialized testing.

Table 3. Evidence-Based Interventions for Specific Asphyxia Scenarios

Scenario	Primary Pathology	Key Interventions	Success Factors	Common Errors	Evidence Strength
Foreign Body Obstruction	Complete or partial airway blockage	Heimlich maneuver, direct laryngoscopy, chest compressions	Proper technique, adequate force, persistence	Premature abandonment, incorrect hand position	Moderate
Drowning	Surfactant washout, V/Q mismatch	Early ventilation, high-flow oxygen, maintain normothermia	Rapid ventilation, avoid hyperventilation	Delayed ventilation, unnecessary immobilization	Moderate to High
Carbon Monoxide	Tissue hypoxia, cellular toxicity	Remove from exposure, high-flow oxygen, rapid transport	Early oxygen, high flow rates, hyperbaric referral	Relying on pulse oximetry, delayed oxygen	High
Anaphylaxis with Airway	Angioedema, bronchospasm	Epinephrine, high-flow oxygen, airway management	Rapid epinephrine, repeated doses if needed	Delayed epinephrine, inadequate dosing	High
Trauma with Airway	Obstruction, aspiration risk	Airway clearance, positioning, definitive airway	Rapid sequence, minimize attempts	Excessive intubation attempts, delayed transport	Moderate

4.5 Training and Education Effectiveness

The evidence examining paramedic training approaches reveals substantial benefit from simulation-based education, scenario-based learning, and deliberate practice methodologies. Traditional didactic education combined with limited hands-on practice demonstrates inferior outcomes compared to comprehensive simulation programs incorporating realistic scenarios, immediate feedback, and repeated practice

opportunities (Laudit et al., 2018). High-fidelity simulation allows learners to experience the stress, time pressure, and complexity of actual emergencies while developing both technical skills and non-technical competencies including communication, teamwork, and decision-making. Multiple studies have documented improved skill acquisition, better knowledge retention, and enhanced real-world performance among paramedics trained through simulation-based programs compared to traditional educational approaches.

Skill decay represents a significant challenge in maintaining paramedic competency, particularly for infrequently performed procedures. Studies examining retention of airway management skills have documented substantial deterioration within three to six months of initial training, with some complex skills showing degradation even sooner (Dyson et al., 2017). The decay affects both psychomotor skills such as intubation technique and cognitive knowledge including assessment frameworks and decision algorithms. Regular skills practice, refresher training, and competency verification programs help maintain capabilities, though optimal frequency and format remain debated. Some evidence suggests that distributed practice with frequent short sessions proves more effective than infrequent marathon review sessions, though practical constraints often limit implementation of ideal training schedules.

Competency assessment methodologies range from simple skills checklists to comprehensive evaluation frameworks examining multiple performance dimensions. Objective structured clinical examinations, incorporating standardized scenarios with specific assessment criteria, demonstrate good reliability and validity for evaluating clinical competency (Jensen et al., 2019). However, the resource intensity of comprehensive competency assessment limits practical application in many systems, leading to reliance on simpler evaluation methods that may not adequately capture actual performance capability. The integration of field performance data through case review and quality assurance processes provides real-world assessment complementing simulation-based evaluation, though challenges exist in obtaining complete, accurate data on field interventions and outcomes.

The effectiveness of different educational modalities varies based on learning objectives and content. Technical skills such as airway management benefit from hands-on practice with immediate feedback, while cognitive knowledge including assessment frameworks may be effectively delivered through multiple modalities including online learning, classroom instruction, and case-based discussion (Laudit et al., 2018). Blended learning approaches combining different methods show promise in optimizing educational efficiency while addressing diverse learning needs. The emerging use of virtual reality and augmented reality technologies in emergency medical education offers potential advantages including realistic scenario exposure without resource intensity of traditional simulation, though evidence regarding effectiveness remains limited as these technologies are relatively new to the field.

5. Discussion

The synthesis of current evidence regarding pre-hospital asphyxia management reveals both substantial consensus on core principles and ongoing evolution in specific techniques and approaches. The fundamental priority of rapid assessment, immediate oxygenation, and appropriate ventilation support remains consistent across all guidelines and research, emphasizing that basic principles effectively applied generally outweigh perfect execution of complex procedures. The evidence supports a systematic approach beginning with scene safety assessment, progressing through structured patient evaluation, and implementing interventions matched to identified pathology and patient response. The variability in specific technique effectiveness across different studies and systems suggests that success depends heavily on provider training, system support, and appropriate patient selection rather than inherent superiority of particular approaches.

The controversy surrounding advanced airway management deserves particular attention given its prominence in pre-hospital emergency care. The accumulated evidence fails to demonstrate consistent benefit from endotracheal intubation compared to alternative approaches, particularly when intubation

attempts compromise oxygenation or delay transport. This finding does not negate the value of advanced airway capability but rather emphasizes the importance of appropriate indications, high first-pass success rates, and recognition that simpler approaches may prove adequate or superior in many scenarios. The growing adoption of supraglottic airways as primary advanced airway devices reflects this evidence, offering reasonable airway management with higher success rates and lower complication risks than endotracheal intubation. Systems must critically evaluate their advanced airway protocols, training programs, and performance data to ensure that complex procedures provide actual benefit rather than simply representing traditional practice patterns.

The integration of technology including pulse oximetry and capnography into routine pre-hospital care enhances assessment and intervention quality when properly utilized. However, technology implementation requires appropriate training in both device operation and data interpretation to realize potential benefits. The tendency to over-rely on technology while neglecting clinical assessment represents a recognized risk, with multiple case reports documenting missed diagnoses or inappropriate treatments based on misleading monitor data. Education must emphasize the complementary nature of technology and clinical assessment, developing provider capability to integrate multiple information sources while recognizing limitations and artifacts. Furthermore, technology implementation must account for practical field constraints including environmental conditions, patient factors, and resource limitations that may affect device performance or applicability.

Training and education emerge as critical determinants of effective asphyxia management, with evidence consistently demonstrating that provider capability influences outcomes more than specific protocol details or available equipment. The shift toward simulation-based education, scenario-based learning, and competency-based assessment reflects growing recognition that traditional educational approaches inadequately prepare providers for field emergency care complexity. However, the resource requirements of comprehensive simulation programs present challenges for many emergency medical service systems, particularly smaller or rural services with limited budgets and training infrastructure. Creative approaches including regional training centers, mobile simulation programs, and technology-enhanced learning may help address these challenges, though sustained organizational commitment and resource allocation remain necessary for effective implementation.

The special considerations in different asphyxia scenarios emphasize the importance of comprehensive provider education addressing diverse clinical presentations and etiologies. While core principles remain consistent, specific management approaches vary based on underlying pathology, requiring paramedics to recognize distinctive features and modify interventions accordingly. The evidence regarding scenario-specific management generally supports existing guideline recommendations, though gaps persist in areas where research has been limited. Foreign body obstruction management, drowning resuscitation, and toxic inhalation treatment demonstrate the importance of mechanism-based assessment guiding intervention selection. Training programs must ensure adequate coverage of these varied scenarios through diverse case exposure, either through actual field experience supplemented by simulation or primarily through simulation given the relative infrequency of some presentations.

Quality assurance and continuous improvement processes represent essential components of effective emergency medical service systems but demonstrate variable implementation across different organizations. The evidence regarding quality assurance approaches emphasizes the value of systematic data collection, objective performance measurement, and structured review processes in identifying improvement opportunities and verifying protocol adherence. However, the implementation of effective quality assurance requires organizational culture supporting transparency, learning from errors, and continuous improvement rather than punitive approaches to performance deficiencies. The balance between accountability and education, between individual responsibility and system factors, proves challenging but critical to creating environments where quality assurance drives improvement rather than defensive practice and data concealment.

System-level considerations including equipment standardization, protocol development, and resource allocation significantly influence field performance but receive less attention in research literature than individual provider skills. The evidence suggests that consistent equipment across response units, clear protocols that providers understand and accept, and adequate resource availability contribute substantially to effective emergency care. However, the practical challenges of implementing system-wide changes, particularly in diverse organizations serving large geographical areas, should not be underestimated. Successful implementation requires stakeholder engagement, adequate resource commitment, and realistic timelines acknowledging the complexity of organizational change.

The application of evidence-based practice in emergency medical services faces unique challenges compared to hospital-based care. The time pressure, environmental constraints, limited resources, and isolation from immediate specialist consultation that characterize field emergency care create context-specific considerations affecting research applicability. Furthermore, the evidence base itself demonstrates substantial gaps, with many common field practices based more on tradition and expert opinion than rigorous research. The emergency medical services community must continue advocating for research addressing field-specific questions, supporting practice-based research networks, and critically evaluating how hospital-based evidence applies in pre-hospital contexts.

The geographical and cultural context of emergency medical service delivery influences both the types of asphyxia cases encountered and the practical approaches to management. Regional variations in industrial hazards, environmental risks, cultural practices, and healthcare infrastructure create diverse operational environments requiring locally adapted protocols and training. While core evidence-based principles remain universally applicable, their specific implementation must account for local context including available resources, provider training levels, transport times, and receiving facility capabilities. The development of locally appropriate protocols based on international evidence represents an ongoing challenge requiring clinical expertise, understanding of local context, and willingness to adapt rather than simply adopt external protocols.

Looking toward future directions in pre-hospital asphyxia management, several promising developments warrant attention. Technological advances including improved monitoring devices, video laryngoscopy, and point-of-care testing offer potential to enhance field assessment and intervention capability. However, technology adoption must be evidence-based and practical, avoiding the pitfall of acquiring expensive equipment providing marginal benefit or proving unreliable in field conditions. Educational innovations including virtual reality training, mobile learning applications, and artificial intelligence-enhanced feedback systems show promise in improving training effectiveness and accessibility. The integration of telemedicine capabilities allowing field providers to consult with emergency physicians or specialists may enhance decision-making, particularly in complex or unusual cases, though implementation challenges including connectivity, workflow integration, and liability considerations require resolution.

The limitations of this review merit acknowledgment. The reliance on published literature necessarily creates publication bias toward positive findings and may not capture negative results or unpublished experiences. The heterogeneity of included studies regarding design, quality, and context complicates synthesis and limits the strength of some conclusions. The focus on English language publications excludes potentially relevant research published in other languages. The rapidly evolving nature of emergency medical practice means that some included evidence may become outdated relatively quickly, emphasizing the need for ongoing literature monitoring and periodic review updates. Despite these limitations, the comprehensive synthesis of available evidence provides valuable guidance for emergency medical service providers and identifies areas requiring further research and development.

6. Conclusion

Effective management of asphyxia emergencies in pre-hospital settings requires integration of evidence-based assessment techniques, appropriate interventions, skilled providers, and supportive systems. The

evidence consistently demonstrates that fundamental principles including rapid recognition, systematic assessment, immediate oxygenation, and appropriate ventilation support form the foundation of successful outcomes. Basic airway management techniques including positioning, airway adjuncts, and bag-valve-mask ventilation prove effective in most scenarios when properly performed, with advanced interventions reserved for situations where basic approaches fail or specific indications exist. The controversial role of endotracheal intubation in pre-hospital care reflects the importance of balancing procedural capability against success rates, complication risks, and availability of effective alternatives.

The critical importance of provider training and competency maintenance emerges clearly from the evidence, with simulation-based education, scenario-based learning, and regular skills practice demonstrating superior outcomes compared to traditional educational approaches. Emergency medical service systems must commit adequate resources to initial training, ongoing education, and competency verification to ensure that paramedics maintain capability to perform effectively in the high-stress, time-pressured environment of field emergency care. The integration of technology including pulse oximetry and capnography enhances care when properly implemented, though success requires appropriate training and recognition of both capabilities and limitations.

Special considerations in specific asphyxia scenarios including foreign body obstruction, drowning, and toxic inhalation emphasize the importance of mechanism-based assessment and scenario-appropriate interventions. Training programs must ensure adequate coverage of diverse presentations through varied case exposure, simulation scenarios, and focused education on distinctive features of different etiologies. Quality assurance processes incorporating systematic data collection, performance measurement, and structured review provide essential feedback for continuous improvement but require organizational culture supporting learning and development rather than punitive responses to performance variations.

System-level factors including equipment standardization, protocol clarity, and resource availability significantly influence field performance and deserve attention alongside individual provider capabilities. The development and implementation of evidence-based protocols must balance international research findings with local context including available resources, provider training, and operational environment. The ongoing evolution of emergency medical practice, driven by continuing research and technological advancement, necessitates regular review and updating of protocols, training programs, and operational procedures.

Future directions in pre-hospital asphyxia management include technological innovations, educational advances, and enhanced integration with hospital-based care systems. However, successful implementation of innovations requires careful evaluation of evidence, practical feasibility, and actual benefit rather than simply adopting new technologies or approaches because they are available. The emergency medical services community must continue supporting research addressing field-specific questions, developing and validating evidence-based protocols, and evaluating implementation effectiveness in diverse operational contexts.

The ultimate goal of enhanced field interventions in asphyxia emergencies centers on improved patient outcomes through rapid, effective, evidence-based care delivered by skilled, confident providers supported by well-designed systems. Achievement of this goal requires sustained commitment from individual paramedics, emergency medical service organizations, educational institutions, and healthcare systems to continuous improvement, evidence-based practice, and patient-centered care. The evidence synthesized in this review provides a foundation for such efforts, though ongoing research, evaluation, and refinement remain necessary as knowledge advances and practice evolves.

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