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Anaesthetic Priorities In Prehospital Trauma Care: A Paramedic Perspective

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ABSTRACT

Trauma remains a leading cause of mortality and morbidity worldwide, with prehospital care playing a pivotal role in improving survival during the critical "golden hour." Paramedics are at the forefront of this response, delivering advanced interventions including airway management, analgesia, sedation, hemodynamic stabilization, and rapid transport. This review explores anaesthetic priorities in prehospital trauma care from a paramedic perspective, examining historical evolution, scope of practice variations, legal and ethical considerations, and interprofessional collaboration. Emphasis is placed on airway management strategies, analgesic and sedative choices, and physiologic stabilization, particularly in special trauma populations such as pediatric, geriatric, pregnant, and polytrauma patients. Evidence indicates that paramedics, when adequately trained and supported by structured protocols, can safely perform advanced anaesthetic procedures with outcomes comparable to physician-led teams. Challenges remain regarding skill retention, adverse event prevention, and balancing on-scene interventions with rapid transport. Future directions include innovations in monitoring, telemedicine, new pharmacologic protocols, and expanded critical care paramedic roles. Addressing knowledge gaps through high-quality research is essential to optimize outcomes, standardize practices, and further integrate anaesthetic priorities into global prehospital trauma systems.

Keywords: Prehospital anaesthesia; Trauma care; Paramedics; Airway management; Analgesia; Sedation; Rapid sequence induction (RSI); Prehospital emergency medicine; Hemodynamic stabilization; Critical care paramedics

INTRODUCTION

Trauma remains a major global health challenge and a leading cause of mortality and morbidity worldwide. According to recent global burden of disease estimates, traumatic injuries are responsible for millions of deaths annually and contribute significantly to disability-adjusted life years (DALYs). For example, in 2021, traumatic amputations affected over 445 million individuals globally, with a considerable burden in terms of years lived with disability despite declining age-standardized incidence

rates. Injuries account for a large proportion of deaths, notably in younger populations, and worldwide trauma mortality continues to pose a public health crisis driven by factors such as road traffic collisions, falls, violence, and occupational hazards. The demographic transition of aging populations and population growth further complicate trauma epidemiology, increasing absolute numbers of trauma cases even as prevention and treatment improve (Wei et al., 2025).

Effective prehospital trauma care is critical in determining patient outcomes by reducing preventable deaths and limiting complications. The initial minutes to hours after injury constitute a "golden hour" during which timely interventions can halt or slow physiological deterioration caused by airway compromise, hemorrhage, and respiratory failure—the primary causes of early trauma mortality. Prehospital care extends beyond immediate life-saving interventions to include stabilization measures such as spinal immobilization, wound management, oxygen support, and early recognition of traumatic brain injury. Evidence supports that prompt and skilled emergency medical services (EMS) interventions enhance survival and functional recovery by attenuating secondary injury cascades (Suárez et al., 2024).

Paramedics are frontline providers in the prehospital setting, delivering advanced trauma care essential for bridging the gap to definitive hospital treatment. Their responsibilities encompass rapid trauma assessment, triage, airway management (including intubation and ventilation), hemorrhage control, analgesia, and resuscitation. Paramedics also coordinate transport logistics to trauma centers and liaise with hospital teams to optimize outcomes. Their scope of practice has evolved with expanded protocols and technology, enabling administration of advanced airway techniques, sedation, intravenous access, and monitoring in challenging environments. Studies show that paramedic-led prehospital critical care significantly improves survival rates in trauma patients compared to standard ambulance care (Watson et al., 2012).

Anaesthetic management in the prehospital setting involves applying fundamental anaesthetic principles such as airway protection, analgesia, sedation, and haemodynamic stabilization outside controlled hospital environments. This includes securing a patent airway through rapid sequence intubation, providing sedation and analgesia to reduce patient distress and physiological stress, and managing circulation to maintain perfusion. The complexity of delivering safe anesthesia in austere, resource-limited, and dynamic prehospital contexts requires specialized skills, continuous training, and protocols adapted for out-of-hospital conditions. Agents like ketamine are frequently utilized due to their safety profiles and versatility. The integration of anesthetic care into trauma management is vital for improving prehospital patient comfort, facilitating procedures, and optimizing survival (Youn et al., 2015).

Given the expanding role of paramedics as primary resuscitation providers in prehospital trauma care, focusing on their perspective brings insights into practical challenges, decision-making, training needs, and protocol development. Paramedics operate at the interface of emergency response and hospital care, making their experience pivotal to identifying priorities for anesthetic interventions tailored to prehospital environments. Exploring anesthesia from a paramedic viewpoint highlights the realities of prehospital trauma management including limited resources, time constraints, patient variability, and the need for autonomy balanced with guideline adherence. Such focus is crucial for developing educational frameworks, evidence-based protocols, and innovations that enhance paramedic capability in delivering safe, effective anesthetic care in traumatic emergencies.

This review aims to comprehensively analyze anaesthetic priorities in prehospital trauma care with a dedicated focus on the paramedic perspective. It will synthesize current evidence on global trauma burden, prehospital trauma principles, and paramedic roles, with an emphasis on anesthesia-related interventions. The review will address airway management, analgesia, sedation, hemodynamic support, and challenges unique to out-of-hospital care environments. Additionally, it will explore emerging technologies, protocols, and training strategies that empower paramedics to optimize anaesthetic care in trauma. The findings aim to guide future research, policy, and clinical practice improvements to reduce trauma mortality and morbidity through enhanced prehospital anesthetic management.

Historical Perspective

The role of paramedics in trauma care has evolved significantly from its early origins. Historically, prehospital care was limited primarily to basic life support and rapid transport of injured individuals to hospitals. The foundation of modern EMS systems can be traced back to the late 18th century with the pioneering work of Dominique-Jean Larrey, Napoleon's surgeon, who developed "flying ambulances" for battlefield casualty evacuation. These early systems introduced the concept of providing care at or near the point of injury and expediting transfer to definitive care facilities.

The paramedic profession as it is recognized today emerged more formally in the mid to late 20th century. In the UK and parts of the US, paramedics began as ambulance workers with additional skills but lacking a formalized scope of practice. The 1970s marked a turning point with the development of structured Emergency Medical Technician-Paramedic (EMT-P) programs featuring formal education, including classroom instruction, hospital rotations, and field internships, which expanded paramedic capabilities beyond basic life support to include advanced airway management, intravenous access, and medication administration. This progression was partly motivated by the need for advanced interventions at the scene to improve trauma outcomes and reduce mortality.

By the 1980s and 1990s, paramedics were widely accepted as essential providers of advanced prehospital care, delivering interventions such as rapid sequence intubation and drug therapies directly at the trauma scene. The expanding scope reflected growing evidence that early critical care interventions could improve survival and neurological outcomes in trauma patients. Concurrently, EMS systems increasingly emphasized paramedic-led assessment and treatment protocols tailored for trauma, blending clinical decision-making with procedural skills.

Progression from Basic Life Support to Advanced Anaesthetic Interventions

The progression of paramedic practice has paralleled advances in trauma care principles, evolving from basic life support (BLS) interventions such as airway positioning and oxygen therapy to complex prehospital emergency anaesthesia (PHEA). Initially, airway management primarily involved manual maneuvers and basic adjuncts, but as training and equipment advanced, paramedics began performing endotracheal intubation and rapid sequence induction (RSI) to secure airways in trauma patients with compromised respiratory function or decreased consciousness.

The introduction of PHEA in prehospital settings marks a significant paradigm shift. This involves the administration of anaesthetic agents and neuromuscular blockers to facilitate controlled airway management, often under severely austere conditions. Research from the United Kingdom and other advanced EMS systems shows that PHEA can be performed safely and effectively by trained paramedics, improving airway security and oxygenation before arrival at trauma centers. Modifications of induction regimes tailored to the trauma population, including the use of ketamine and avoidance of agents that cause hypotension, underscore evolving anaesthetic priorities adapted to the hemodynamic vulnerabilities of trauma patients.

Furthermore, the implementation of standardization efforts—such as checklists, equipment bundles, and training protocols—has enhanced safety during prehospital anaesthesia. The cumulative effect has been an expansion of paramedic roles in trauma care to encompass sophisticated anaesthetic management, aimed at optimizing oxygen delivery, minimizing secondary brain injury, and stabilizing critically injured patients prior to definitive hospital treatment.

Significant differences exist between civilian and military prehospital trauma anaesthesia related to environment, injury patterns, and operational constraints. Military trauma care has traditionally confronted high-velocity ballistic injuries and blast trauma with extensive tissue destruction and hemorrhage, reflecting combat injury mechanisms distinct from the blunt trauma commonly seen in

civilian settings. This difference influences anaesthetic priorities and techniques, as military providers often operate in far-forward environments with limited resources and evacuation delays.

Military prehospital anaesthetic practices emphasize damage control resuscitation and early hemorrhage control, supported by protocols integrating blood product administration and rapid induction strategies suitable for unstable patients. In contrast, civilian prehospital care typically involves quicker transport times to trauma centers with broader access to comprehensive hospital-based resources, potentially allowing different risk-benefit considerations in anaesthetic decision-making.

Despite these differences, there has been a valuable exchange of knowledge between military and civilian trauma systems, especially as military advances in prehospital trauma anaesthesia and resuscitation have informed civilian practice. This collaborative learning continues to refine anaesthetic guidelines and improve survival outcomes across both sectors.

Global guidelines on prehospital trauma care, including anaesthetic priorities, have evolved significantly over recent decades, largely driven by contributions from organizations such as the American Heart Association (AHA), European Resuscitation Council (ERC), Advanced Trauma Life Support (ATLS), and Prehospital Trauma Life Support (PHTLS).

The AHA and ERC guidelines have consistently updated resuscitation algorithms to emphasize airway management, adequate oxygenation, and circulatory support in trauma patients, adapting recommendations based on emerging evidence. For example, the 2020 AHA guidelines emphasize titrated oxygen delivery to avoid hypoxia and hyperoxia and recommend advanced airway interventions when indicated, aligning with paramedic capabilities.

ATLS, originally developed by the American College of Surgeons, established a standardized approach to trauma assessment and initial management, promoting the ABCs (Airway, Breathing, Circulation) with early airway control as a cornerstone. Over time, ATLS integrated considerations for prehospital anaesthesia and rapid sequence intubation as adjuncts in advanced trauma life support.

PHTLS has played an influential role in prehospital education, focusing on practical, evidence-based approaches for EMS providers, including paramedics. Its protocols have evolved to endorse anaesthetic priorities like airway protection, pain management, and hemodynamic stabilization, reflecting a balance between timely transport and appropriate on-scene interventions.

Together, these international guidelines have shaped paramedic training and protocols worldwide, encouraging an integrated, patient-centered approach to prehospital trauma anaesthesia that adapts dynamically to patient condition, provider skill, and system resources.

Paramedic Roles in Prehospital Trauma Anaesthesia

Paramedics play a critical role in delivering anaesthesia-related care in the prehospital trauma setting, where rapid airway management, analgesia, sedation, and resuscitation can be lifesaving. Their responsibilities include advanced airway interventions such as endotracheal intubation, administration of anaesthetic agents, and management of anaesthetic complications—all within often unpredictable and austere environments. This scope of practice varies worldwide based on regional regulations, healthcare system models, and available training.

Scope of Practice Variations Worldwide

Paramedic roles in prehospital anaesthesia differ globally, reflecting diverse emergency medical service (EMS) models and regulatory frameworks. In the United Kingdom, Critical Care Paramedics (CCPs) or Advanced Paramedics trained in advanced airway management frequently perform rapid sequence induction (RSI) of anaesthesia under physician oversight or locally agreed protocols. Studies from UK trauma networks show CCPs successfully intubate most patients requiring prehospital anaesthesia,

sometimes independently, with success rates comparable to physicians in controlled teams (McQueen et al., 2015).

In the United States, paramedic training includes advanced airway management, but the authority to perform RSI and administer anaesthetic agents varies by state and local EMS protocols. Generally, RSI is reserved for flight paramedics or those part of physician-led teams, reflecting the Anglo-American "scoop and run" model prioritizing rapid transport over definitive on-scene treatment (Eaton, 2023).

In much of mainland Europe, the Franco-German model dominates, where prehospital anaesthesia is primarily administered by physicians or anesthesiologists. Paramedics generally have more limited roles focused on airway adjuncts and basic ventilation support. However, some European systems have begun expanding paramedic training and competency frameworks to include limited anaesthetic interventions.

In Australia, paramedic roles are evolving rapidly with the emergence of Paramedic Practitioners and Critical Care Paramedics who possess extended scopes, including limited prescribing and delivery of anaesthetic drugs under strict governance. These developments seek to bridge gaps in rural and remote trauma care where physician presence is limited.

In low- and middle-income countries (LMICs), paramedic roles in prehospital anaesthesia are often constrained due to limited training, equipment shortages, and insufficient legal frameworks. Where prehospital critical care exists, a focus remains on basic airway management and rapid transfer rather than complex anaesthetic procedures (Wilkinson-Stokes et al., 2025).

Legal and Ethical Boundaries

Paramedics operate under strict legal and ethical frameworks delineating their scope in administering anaesthesia. They must work within regulated competencies and established protocols to maintain patient safety, avoiding unauthorized procedures. Legal boundaries restrict paramedics from independently prescribing or administering anaesthetic agents beyond approved lists or operating outside physician directives (Carver et al., 2020).

Ethical principles guiding paramedic anaesthesia include beneficence, non-maleficence, and respect for patient autonomy. Ethical challenges arise in emergency settings when consent is limited or when balancing risks of procedures such as intubation in unstable trauma patients, highlighting the need for clear clinical governance and continual professional development.

Interprofessional Collaboration

Effective prehospital anaesthesia requires seamless collaboration between paramedics, physicians, anaesthetists, flight medical teams, and other emergency responders. Interprofessional teamwork supports decision-making for complex interventions like RSI, ensuring role clarity and task delegation amidst dynamic scenes. Joint training and simulation exercises improve cohesion, communication, and patient outcomes by fostering mutual understanding of roles and skills (Eisenmann et al., 2018).

Physician-led teams often provide oversight, with paramedics performing anaesthetic tasks under delegated authority, especially in air medical retrievals. Such collaboration reduces cognitive overload during critical procedures and maintains high standards of care.

Common Limitations Faced by Paramedics in Field Anaesthetic Management

Paramedics encounter several operational and clinical limitations when managing anaesthesia in the prehospital setting. Skill fade is significant due to low procedure frequency; paramedics may perform only 1-2 intubations per year on average, risking deterioration in technical proficiency. Training opportunities are limited compared to in-hospital anesthesia providers, and ongoing competency maintenance remains a challenge.

Environmental constraints including poor lighting, difficult patient positioning, limited equipment, and the chaotic scene add complexity to airway management and anaesthesia delivery. Medicolegal concerns and varying protocols restrict paramedic autonomy, potentially delaying critical interventions. Moreover, patient factors such as trauma severity, airway contamination, and physiological instability increase procedural difficulty and complication risks (Beecham & Kohn, 2025).

Physiological Priorities in Trauma Anaesthesia from a Paramedic Perspective

Trauma anaesthesia in the prehospital setting prioritizes physiological stability by securing the airway, ensuring adequate breathing and ventilation, maintaining circulation and hemodynamics, and addressing neurological considerations. These priorities are crucial for preventing secondary injury and optimizing survival chances for trauma patients.

Airway Protection

Advanced airway management is indicated in trauma patients with apnea, Glasgow Coma Scale (GCS) <8, inability to protect the airway from aspiration of vomitus or blood, severe maxillofacial fractures, neck hematoma, or airway obstruction from laryngeal or tracheal injury. Definitive airway management is needed to prevent hypoxia and aspiration, which are leading contributors to prehospital trauma mortality. Airway obstruction can result from anatomical disruption in maxillofacial trauma—such as posterior displacement of fractured maxilla blocking nasopharynx, fractured mandible displacing the tongue posteriorly, or obstructing debris including bone fragments and blood—as well as from soft tissue swelling and edema that may cause delayed compromise. Prompt airway control and cervical spine protection are essential during airway manipulation to avoid neurological injury and ensure patency (Khan et al., 2011).

Risks of hypoxia and hypoventilation include increased mortality, particularly in traumatic brain injury (TBI). Hypoxia leads to cerebral ischemia, worsening outcomes. Hyperventilation, especially unintentional, causing hypocapnia can induce cerebral vasoconstriction and brain tissue hypoxia. Maintaining appropriate oxygenation and ventilation is critical during prehospital emergency anaesthesia to avoid secondary brain injury.

Breathing and Ventilation

Oxygenation is a primary goal in trauma, with prehospital oxygen delivery vital to tissue survival. Capnography serves as a key monitoring tool to confirm endotracheal tube placement and assess ventilation efficacy, correlating with cardiac output and tissue perfusion. It provides early detection of tube dislodgement or respiratory compromise faster than pulse oximetry, making it a standard of care in advanced airway management.

Positive pressure ventilation (PPV) is often necessary during anaesthesia to maintain oxygenation and ventilation, especially in patients unable to breathe spontaneously. However, spontaneous breathing is preferable if patient condition permits, to avoid potential complications of PPV. PPV must be cautiously applied in pulmonary trauma, such as tension pneumothorax, where it can exacerbate hemodynamic compromise. Immediate needle decompression followed by chest tube thoracostomy is the treatment of choice to relieve tension pneumothorax and stabilize ventilation and circulation (Potchileev et al., 2023).

Circulation and Haemodynamics

Hemodynamic instability from hemorrhage or shock is common in trauma. Anaesthetic agents can depress myocardial function and blood pressure, exacerbating hypotension and impaired cardiac output. Intravenous induction agents should be chosen carefully considering the patient's circulatory status; shock states require agents with minimal cardiovascular depression effects. Rapid recognition and control of

hemorrhage, volume resuscitation with caution to avoid dilutional coagulopathy, and maintaining perfusion pressure are essential to prevent irreversible shock (Scallan et al., 2023).

Neurological Considerations

Traumatic brain injury (TBI) demands special anaesthetic attention. Maintaining cerebral perfusion pressure (CPP) by avoiding hypotension and hypoxia is critical to minimizing secondary brain injury. Prevention of secondary insults includes careful oxygenation, avoidance of hypotension, and maintenance of normocapnia to prevent cerebral vasoconstriction or edema. Both hypoxia and hypotension are associated with increased mortality in TBI, hence the paramedic's role is pivotal in managing airway and circulation while preventing these adverse events until definitive care (Árnason et al., 2021).

In summary, the prehospital paramedic's anaesthetic priorities in trauma care encompass securing the airway, optimizing breathing and ventilation with advanced monitoring, supporting circulation with tailored anaesthetic choices, and protecting neurological function through vigilant management of oxygenation and hemodynamics. These physiological goals form the cornerstone of emergency trauma anaesthesia to improve patient outcomes.

Airway Management in Prehospital Trauma

Airway management remains an essential and often challenging priority in prehospital trauma care. Effective airway control is critical to ensure adequate oxygenation and ventilation, prevent aspiration, and optimize outcomes by minimizing secondary brain injury and hypoxia in trauma patients. From basic airway adjuncts to advanced techniques such as rapid sequence induction (RSI) with endotracheal intubation, paramedics operate under complex and often austere conditions to secure the airway in critically injured patients (Braithwaite et al., 2022).

Techniques

Basic Airway Adjuncts

For many trauma patients, basic airway maneuvers are first-line interventions and include head tilt-chin lift, jaw thrust, and the use of adjuncts such as oropharyngeal (OPA) and nasopharyngeal airways (NPA). These devices serve to maintain airway patency by displacing the tongue and soft tissues, especially in unconscious patients without protective airway reflexes. Basic airway adjuncts are typically employed by paramedics and EMTs given their simplicity and rapid applicability, representing crucial initial steps before advancing to more invasive measures (Braithwaite et al., 2022).

Supraglottic Devices

Supraglottic airway devices (SGAs) such as laryngeal mask airways (LMA) and laryngeal tube devices offer an intermediary option between basic adjuncts and endotracheal intubation. SGAs are designed to sit above the vocal cords and provide a secure airway rapidly with less technical difficulty and training than intubation. Their utility in trauma patients lies in facilitating ventilation when endotracheal intubation attempts are unsuccessful or in the absence of advanced airway skills. Outcomes data suggest SGAs may provide efficient oxygenation, but tracheal intubation remains the gold-standard for definitive airway management in severely injured patients.

Endotracheal Intubation in Trauma Patients

Endotracheal intubation (ETI) is considered the definitive airway method and allows for controlled ventilation and airway protection, especially in patients with traumatic brain injury (TBI) or compromised airway reflexes. Prehospital ETI success rates vary and are operator-dependent but achieving first-pass success is critical to minimize hypoxia and trauma to airway structures. Advanced airway management

with ETI often involves the use of RSI to facilitate intubation in combative or unconscious trauma patients (Lauriks et al., 2025).

Surgical Airway Approaches (Cricothyrotomy)

When non-surgical airway techniques fail or are contraindicated, emergency surgical airways such as cricothyrotomy become necessary. Cricothyrotomy provides direct access to the trachea via an incision through the cricothyroid membrane, bypassing upper airway obstruction. This is a rare but lifesaving procedure in cases of severe maxillofacial trauma, airway obstruction, or failed intubation attempts in the field. Proper training and timely decision-making are crucial for successful surgical airway management.

Rapid Sequence Induction (RSI)

RSI is a controlled approach combining rapid administration of an induction agent and neuromuscular blocker to facilitate swift, atraumatic endotracheal intubation. In prehospital trauma care, RSI is indicated for patients with compromised airway reflexes, inability to maintain oxygenation, altered mental status, or significant facial or neck trauma requiring definitive airway control. RSI reduces the risk of aspiration and improves intubating conditions but necessitates careful patient assessment and preparation (Lyon et al., 2015).

Preoxygenation is vital prior to RSI to extend the safe apnea time by maximizing oxygen reserves. However, in the prehospital setting, challenges include environmental constraints, patient agitation, uncontrolled bleeding, and limited equipment, all complicating effective preoxygenation. Hypoxemia before and during intubation is common and associated with increased morbidity. Strategies include high-flow oxygen, face mask or bag-valve-mask ventilation, and continual oxygen delivery up to and during the apneic phase (Barbosa & Mosier, 2024).

Choice of Induction Agents

Popular induction agents for trauma RSI include ketamine, etomidate, and midazolam, each with unique pharmacologic profiles:

- **Ketamine**: Preferred for its hemodynamic stability due to sympathetic stimulation, ketamine increases heart rate and blood pressure, advantageous in shock patients. It also provides analgesia and bronchodilation, making it widely suited for trauma.
- **Etomidate**: Valued for minimal cardiovascular effects and rapid onset, etomidate is useful in patients at risk of hypotension but may transiently suppress adrenal function.
- **Midazolam**: Used less frequently as a sole induction agent due to slower onset; typically supplemented with other agents.

Paralytic Options: Succinylcholine vs Rocuronium

Neuromuscular blockers are essential for RSI to achieve muscle relaxation. Traditionally, succinylcholine was the agent of choice given its rapid onset and short duration. However, rocuronium, at higher doses, has shown similar intubation quality with a longer duration of action, which may enhance safety by preventing premature patient movement. Rocuronium also has fewer contraindications and less impact on potassium levels but requires adequate sedation for prolonged paralysis.

Monitoring Airway Success

Capnography

Capnography is the most reliable non-invasive method to confirm endotracheal tube placement by detecting exhaled CO2. Continuous waveform capnography aids early detection of tube dislodgement,

esophageal intubation, or ventilatory compromise. It has significantly reduced unrecognized failed intubations in prehospital care and is considered a standard of care (Richardson et al., 2016).

Oxygen Saturation

Pulse oximetry monitoring provides real-time feedback on oxygenation status, essential during airway management to identify hypoxia promptly and guide oxygen delivery and ventilation strategies.

Clinical Assessment of Tube Placement

Physical examination techniques remain supplementary and include auscultation of breath sounds, observation of chest rise, and tube length markings. Despite their use, traditional clinical signs alone are insufficient to confirm tube placement without capnography corroboration.

Analgesia in Prehospital Trauma

Effective analgesia is a critical component of prehospital trauma care, with a paramount role in improving patient outcomes from a paramedic perspective. The management of pain in trauma patients in the prehospital setting is essential not only for comfort but also for mitigating harmful physiological and psychological consequences associated with untreated pain.

Importance of Optimal Analgesia

Optimal analgesia in trauma care serves to prevent pain-induced physiological stress, which can exacerbate patient instability. Severe pain triggers a neurohumoral stress response with increased sympathetic activity, resulting in tachycardia, hypertension, elevated oxygen demand, and compromised tissue perfusion. These factors can worsen hemorrhage and contribute to morbidity and mortality if unaddressed. Furthermore, untreated pain has been associated with increased risk of adverse outcomes, including prolonged hospital stays, impaired immune response, and development of chronic pain syndromes. The relief of acute pain has also been linked to improved physiological parameters and psychological well-being, which are critical for trauma patient stabilization and recovery (Häske et al., 2017a).

Commonly Used Analgesics

Prehospital analgesia employs a range of pharmacologic agents targeted to balance efficacy, safety, and practicality in emergency settings.

Opioids: Fentanyl and Morphine

Opioids, particularly fentanyl and morphine, are the mainstay analgesics in prehospital trauma care. Fentanyl offers rapid onset and short duration advantageous for titration by paramedics. Morphine, with its established efficacy, remains widely used though associated with a higher incidence of nausea and vomiting. Both agents are administered intravenously as first-line options, with comparable analgesic effects demonstrated in multiple studies. Intranasal fentanyl is increasingly favored in pediatric populations and situations where IV access is delayed (Lindbeck et al., 2023).

Ketamine as Analgesic and Sedative

Ketamine serves a dual role in prehospital trauma care as both an analgesic and sedative. It provides effective pain control via NMDA receptor antagonism and sympathomimetic effects, which can preserve respiratory drive and hemodynamic stability, an advantage over opioids. Meta-analyses confirm ketamine's effectiveness as comparable to opioids, with fewer respiratory depressant effects but a higher incidence of minor adverse events such as emergence reactions. Ketamine is particularly useful in severe trauma pain, hemodynamically unstable patients, or when opioids are contraindicated (Yousefifard et al., 2019).

Nitrous Oxide

Nitrous oxide (N2O) is a rapidly acting inhaled analgesic with practical usage constraints. It requires intact patient cooperation and mental status due to self-administration, limiting its use in severe trauma, altered consciousness, or facial injuries. N2O is effective for moderate pain and has a favorable safety profile but is less utilized due to logistical challenges, including storage and administration in the field. It is contraindicated in conditions with potential air entrapment like pneumothorax (Hyldmo et al., 2024).

Non-Opioid Adjuncts

Adjunct non-opioid analgesics such as nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, and low dose methoxyflurane have roles as supplementary or alternative options to opioids. Methoxyflurane inhalation, in particular, has gained traction for moderate trauma pain due to ease of use, non-invasive administration, and rapid onset. NSAIDs and acetaminophen are used with caution considering bleeding risks and hemodynamics. These agents expand the analgesic options available to prehospital providers, allowing tailored patient-centered care and minimizing opioid exposure (Sobieraj et al., 2019).

Safety and Monitoring

Prehospital analgesia requires vigilant monitoring and balancing of analgesic effects against risks, particularly respiratory depression, hypotension, and altered mental status.

Risks of Hypoventilation and Hypotension

Opioids are associated with respiratory depression and hypotension risk, especially if overdosed or in vulnerable populations. Ketamine maintains respiratory function but can increase blood pressure and heart rate, which may be detrimental in patients with cardiac pathology. Nitrous oxide mild hypotension and dizziness may occur but are transient. Non-opioid adjuncts tend to have more favorable safety profiles but require appropriate patient selection (Häske et al., 2017b).

Balancing Analgesia with Hemodynamic Status

Paramedics must balance adequate pain relief with maintaining hemodynamic stability. Intravenous route preferred for precise titration, but alternative routes including intranasal administration improve accessibility. Continuous monitoring of respiratory rate, oxygen saturation, blood pressure, heart rate, and level of consciousness is essential. Emergency equipment for airway management and resuscitation should always be immediately available during analgesic administration in the prehospital trauma setting.

Sedation in Prehospital Trauma: A Paramedic Perspective

Sedation in prehospital trauma care primarily serves to facilitate critical procedures and enhance patient management. Key indications include procedural facilitation such as splinting fractures, airway management, and invasive interventions where patient movement or resistance could compromise care or worsen injury. Another important indication is anxiety reduction in conscious trauma patients who may be distressed by pain, environmental factors, or the trauma itself. Effective sedation helps to improve cooperation, minimize physiological stress responses, and potentially reduce secondary injury (Reede et al., 2023).

Agents

Ketamine is widely favored for procedural sedation in the trauma prehospital setting due to its unique pharmacological profile. It provides sedation, analgesia, and amnesia while preserving airway reflexes and respiratory drive, making it safer in patients with compromised airways or hemodynamic instability. Ketamine's sympathomimetic effects also help maintain cardiovascular stability in hypovolemic trauma patients, supporting its use in emergencies requiring rapid sedation and analgesia.

Benzodiazepines, notably midazolam, are used for sedation, anxiolysis, and seizure control in prehospital trauma care. Midazolam has a rapid onset and short duration, useful for managing agitation and anxiety. Studies indicate that midazolam is safe for prehospital sedation in head injury and combative patients, though closely monitored due to potential respiratory depression risks.

Propofol use in prehospital trauma sedation is limited to advanced teams due to its potent hypotensive effects and respiratory depression potential. It requires precise dosing, monitoring, and airway management capabilities, typically reserved for physician-led responses. Because trauma patients are often hemodynamically unstable, ketamine or etomidate is preferred over propofol to maintain blood pressure stability.

Risks

Sedation in prehospital trauma care carries significant risks primarily related to respiratory depression and airway compromise. Sedatives such as benzodiazepines and propofol can depress respiratory drive, leading to hypoxia or apnea. The uncontrolled and resource-limited prehospital environment poses challenges in monitoring and managing these complications. Continuous monitoring of oxygen saturation, respiratory rate, and level of consciousness is critical but often limited by equipment constraints and environmental factors.

Additional risks include hemodynamic instability, particularly hypotension induced by agents like propofol, which can exacerbate trauma-related shock. Hence, sedative choice must consider patient-specific factors such as injury severity, cardiovascular status, and airway risk. Paramedics must be trained in advanced airway management and prepared to rapidly intervene in case of sedation-related adverse events.

Special Trauma Populations

Paediatric Patients

Paediatric trauma patients have distinct anatomical and physiological differences that influence anaesthetic management. Their airway anatomy features a relatively large occiput causing natural head flexion, a small oral cavity with a large tongue, a short, high, anterior larynx with a U-shaped floppy epiglottis, and a narrowest point at the cricoid cartilage. These differences predispose children to airway obstruction and complicate intubation. Physiologically, children have a higher oxygen consumption and lower functional residual capacity, making them vulnerable to rapid hypoxia and bradycardic response on apnea, necessitating swift and careful airway management. Maintaining adequate preoxygenation and minimizing apneic times are key priorities. The risk of aspiration is higher due to typically full stomach status in emergency trauma settings. Drug choices and doses must be carefully adjusted based on age and weight, with appropriate dilution and labelling to ensure safe administration. Fluid and temperature management also require attention due to children's vulnerability to hypothermia and fluid imbalances in trauma care.

Geriatric Patients

Geriatric trauma patients present additional challenges due to frailty, comorbidities, polypharmacy, and altered responses to anaesthetic agents. Age-related physiological changes affect cardiovascular, respiratory, and neurologic systems, increasing the risk of haemodynamic instability during anaesthesia. These patients often have diminished respiratory reserve, weaker airway muscles, and impaired clearance of secretions, raising the risk of postoperative pulmonary complications such as pneumonia. Dose adjustments for volatile and intravenous anaesthetic agents are necessary due to changes in pharmacodynamics and pharmacokinetics, often requiring reduced dosages. The presence of medications such as anticoagulants and cardiac drugs can complicate haemostasis and increase bleeding risks, especially in head trauma. Airway management can be difficult due to dental and cervical spine changes

affecting mask ventilation and laryngoscopy. Monitoring and intervention to maintain cardiovascular stability are critical, with vasopressors and antihypertensive agents prepared for induction responses. Neuraxial anaesthesia may be preferable for certain surgeries to reduce pulmonary complications and postoperative delirium.

Pregnant Trauma Patients

Pregnancy adds complexity to prehospital trauma anaesthesia due to physiological changes and dual patient (maternal and fetal) considerations. Airway management is critical, as pregnant women have increased risk of airway edema, aspiration, and difficult intubation. Hypoxia prevention is essential to protect both mother and fetus, with supplemental oxygen administration prioritized. Rapid sequence induction with cricoid pressure is commonly employed due to increased aspiration risk from decreased lower esophageal sphincter tone and delayed gastric emptying. Maternal stabilization takes precedence; however, fetal monitoring and trauma center transport with obstetric capabilities are important. In cases of maternal cardiac arrest beyond 20 weeks gestation, resuscitative hysterotomy (perimortem cesarean) may be indicated within 4-5 minutes to optimize outcomes. This invasive procedure requires prompt decision-making and coordination if prehospital resources include qualified personnel.

Patients with Polytrauma

Polytrauma patients pose significant anaesthetic challenges due to multiple competing injuries affecting various organ systems. Prehospital anaesthesia must balance airway management, haemodynamic resuscitation, and pain control while accounting for trauma-induced coagulopathy, shock, and potential brain injury. Rapid assessment and prioritization of life-threatening injuries guide anaesthetic choice, with regional techniques favored when feasible to minimize systemic effects. Fluid resuscitation and permissive hypotension strategies must be carefully titrated to avoid worsening bleeding while maintaining organ perfusion. Anaesthesiologists and paramedics involved in prehospital care must be prepared for difficult airways, cardiovascular instability, and the need for ongoing monitoring amidst logistical constraints. Multidisciplinary coordination is essential for optimal outcomes in these complex patients.

Patient Outcomes and Evidence Base

Prehospital anaesthesia (PHA), particularly in trauma patients, is a critical intervention aimed at securing the airway and optimizing ventilation, with significant impact on survival and neurological outcomes. Evidence from studies demonstrates survival benefits, especially when anaesthesia is delivered rapidly on-scene by skilled providers such as Helicopter Emergency Medical Service (HEMS) crews. For example, a study in Southeast England showed that prehospital emergency anaesthesia (PHEA) by HEMS resulted in faster intervention (average 64 minutes from call) compared to awaiting hospital-based anaesthesia (84 minutes), potentially translating into improved outcomes for major trauma patients, including those with traumatic brain injury (TBI).

Neurological outcomes in severe TBI patients are positively influenced by the presence of on-scene anaesthetists who provide advanced airway management and prevent secondary brain injury through appropriate ventilation and resuscitation. A retrospective analysis found lower mortality and better Glasgow Outcome Scores when an anaesthetist performed prehospital care. Early definitive airway control is central to this benefit, preventing hypoxia and hypercapnia that could worsen brain injury.

The quality of anaesthesia, including adherence to guidelines and monitoring for adverse events, is essential to maximize benefits and limit harm. Adverse events such as hypoxia, hypotension, and bradycardia occur but can be minimized with skilled providers and appropriate drug selection. Data from German EMS showed high guideline adherence in prehospital emergency anaesthesia, with incidences of adverse events correlating with patient severity and medication choices. Commonly used induction agents

(ketamine, fentanyl, rocuronium) are tailored to patient physiology to reduce risks of cardiovascular instability.

Comparative studies of physician- versus paramedic-delivered anaesthesia reveal similar intubation success rates and complication profiles when paramedics operate under structured training and protocols, particularly within physician-paramedic teams. Research from Southwest England reported first-pass success rates of 85% for physicians and 78% for paramedics, with manageable complication rates, underscoring paramedics' capability in delivering safe RSI. However, controversies remain about the optimal provider model—European systems favor physician-led prehospital critical care, whereas Anglo-American models rely heavily on advanced paramedics—with varying evidence on mortality impact.

Ongoing controversies focus on patient selection criteria (e.g., hypotensive patients), optimal drug regimens, timing of anaesthesia vs rapid transport, and the potential risks integrated with prehospital interventions. Some studies highlight increased mortality in hypotensive, awake trauma patients receiving PHEA, cautioning the need for balanced resuscitation before induction. The balance between "stay and play" versus "scoop and run" approaches continues to be debated relative to patient outcomes.

Innovations and Future Directions

Emerging Monitoring Techniques

Portable ultrasound has emerged as a valuable tool in prehospital trauma care, enabling real-time assessment of airway structures, lung pathology, cardiac function, and hemodynamics. Studies have demonstrated its utility in identifying cardiac wall motion during resuscitation, differentiating types of pulseless electrical activity, and guiding clinical decision-making, potentially improving survival to hospital admission. Advances in portable capnography allow continuous and quantitative monitoring of end-tidal CO2, which informs ventilation adequacy and resuscitation effectiveness during PHEA, thereby improving patient safety in the prehospital setting.

New Drug Developments

Safer induction agents with more favorable hemodynamic profiles are under evaluation. Protocols have shifted towards tailored dosing regimens that consider clinical frailty, hemodynamic stability, and consciousness level to minimize adverse events such as hypotension post-induction. For instance, a recent adult induction regime recommends fentanyl followed by ketamine and rocuronium, with dose modifications for frail or hypotensive patients, reflecting increased sophistication in pharmacological approaches in prehospital anesthesia.

Telemedicine and Remote Support

Telemedical links facilitating physician oversight during prehospital anaesthesia are increasingly incorporated into EMS. Remote decision support via telemedicine allows paramedics to access real-time expert consultation, enhancing safety and adherence to protocols while expanding paramedic autonomy. This evolving model may optimize resource use and patient outcomes by combining advanced paramedic skills with specialist input remotely.

Expanding Paramedic Practice

Critical care paramedicine roles are broadening to include advanced airway and anaesthesia interventions, supported by dedicated education and clinical governance. Integration of paramedic teams with Helicopter Emergency Medical Services (HEMS) extends critical care capabilities for rapid on-scene interventions and complex trauma management, ensuring timely anaesthesia delivery in challenging environments.

Knowledge Gaps and Research Needs

Despite progress, significant gaps remain in the evidence base for prehospital anaesthesia. A lack of randomized controlled trials limits strong conclusions on mortality and neurological benefits, and most data derive from observational or retrospective studies. Variability in EMS models and training contributes to heterogeneous outcomes, complicating generalizability.

Data collection challenges in the prehospital environment, including incomplete records and difficulties in follow-up, hinder robust research. Further studies are needed specifically focused on pediatric and geriatric populations, where evidence for PHA protocols and outcomes is limited. Additionally, the integration of anaesthetic protocols into mass casualty and disaster planning requires expansion to ensure protocol applicability in high-demand scenarios.

CONCLUSION

Anaesthetic management in prehospital trauma care represents a cornerstone of modern paramedic practice, significantly influencing patient outcomes by addressing airway, breathing, circulation, and neurological priorities before hospital arrival. This review highlights the evolution of paramedic roles from basic life support to advanced anaesthetic interventions, emphasizing both their growing competencies and the operational challenges they face. Evidence supports the effectiveness of paramedics in delivering safe and timely anaesthesia, particularly when guided by standardized protocols, multidisciplinary collaboration, and ongoing professional development. Despite these advances, substantial variability persists across international EMS systems, reflecting differences in training, legislation, and available resources. Addressing these disparities, improving access to advanced education, and leveraging emerging technologies such as telemedicine and portable monitoring will be crucial in enhancing the consistency and quality of prehospital anaesthesia. Future research should prioritize outcome-focused studies, particularly in vulnerable trauma populations, to establish stronger evidence bases for protocols and interventions. Ultimately, strengthening paramedic capabilities in anaesthetic care has the potential to reduce trauma-related mortality and morbidity, ensuring that patients benefit from expert-level care at the earliest stages of their journey.

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