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Prehospital Anaesthesia and Analgesia

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Learning Objectives

1. To discuss the aims of prehospital care
2. To review management of prehospital analgesia
3. To evaluate the use of sedative agents in prehospital care
4. To become familiar with monitoring and maintenance of hemodynamic stability in critically ill patients

*It's not enough that our premises should be true,
they must also be known.*

Bertrand Russell

There is no element in the continuum of critical care that is less understood than the transport of patients to hospital.¹ It includes prehospital management of severe head trauma patients as well as cardiopulmonary critically ill patients requiring emergency medical services (EMS). Prehospital emergency critical care shortens the time to both nonspecific and specific treatment. Efficient and effective prehospital EMS can improve trauma patients' in-hospital morbidity and mortality. Moreover, if correctly implemented and integrated, a sophisticated prehospital mobile critical care system can increase the efficiency of EMS. In addition, it may relieve some of the economic and logistical burdens on emergency departments and intensive care units (ICUs).

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Preparation, Training, and Clinical Background for Prehospital Medicine

Pathophysiologic changes occur in patients in emergency situations. Rapid diagnosis and treatment are essential to improve survival. Implementation of adequate therapy requires knowledge of pathophysiologic and pharmacologic principles and comprehensive clinical experience. Anesthesiology provides a strong background in basic science.^{2,3} Procedures usually used by anesthesiologists in the operating room (airway management, including tracheal intubation and manual and mechanical ventilation; intravenous administration of powerful and fast-track drugs; blood and electrolyte infusion; cardiorespiratory monitoring) are prime steps for intensive therapy and critical care medicine.^{3,4} They include, but are not limited to, positive airway pressure ventilation, end-expiratory positive pressure, cardiovascular and respiratory monitoring, cardiopulmonary resuscitation, and resuscitation of critically ill and severe head trauma patients. Prehospital settings often provide a special, difficult, and unusual context for critical care management. Highly proficient and technically competent physicians have the opportunity to play an important role in such conditions.

Prehospital Analgesia and Sedation

Out-of-hospital sedation is a very difficult and controversial area, and many solutions have been advocated. Controversial opinions exist, since most studies are small or noncontrolled and nonrandomized trials and therefore noncontributive.⁵

Pain is sometimes required for diagnosis of blunt trauma, but it carries potentially severe adverse effects such as agitation, respiratory modulation, and hemodynamic changes induced by catecholamines. No one discusses early pain management. However, analgesia, and even anesthesia, in critically ill patients frequently causes rapid changes in the patient's vital status.⁶ Consequently, specific procedures are needed to perform prehospital anesthesia and analgesia. Analgesia and anaesthesia help improve patient safety from the scene to the hospital.

Stabilization of life-threatening conditions should be the primary step. After life-threatening problems have been identified and managed and a preliminary diagnosis established, an analgesic drug can be given.

The following parameters should be monitored, as in an ICU:

- blood pressure (noninvasive or invasive evaluation)
- electrocardiographic (ECG) status (continuous monitoring)
- pulse oximetry
- temperature
- if an endotracheal tube is placed, end-tidal carbon dioxide (continuous monitoring)⁵
- if sedation is provided, anesthesia depth (continuous monitoring, with continuous electroencephalography [EEG], such as bispectral index monitoring [BIS device]),⁷
- hemodynamics (minimally invasive monitoring, such as transesophageal Doppler, can be useful to assess cardiac output and aortic flow in the critically ill and head trauma patient)

Prehospital Anesthesia Goals

Do good, but at least do not harm.

What are the indications for prehospital anesthesia and which drugs are appropriate and available? Out-of-hospital general anesthesia is used for extrication of trapped victims, for painful procedures, for multiple trauma, and for management of airway problems. A good technique is vital, and the risk-benefit ratio should be considered carefully. Most sophisticated EMS teams in Europe (e.g., France, Germany, and Norway) allow only trained anesthesiologists to perform these kinds of procedures in the field.⁵

Anesthesia is required to blunt the response to laryngoscopy and intubation. Control of pain and restlessness, prevention of memory of the traumatic event, and resuscitation may call for anesthetic techniques on the scene.^{8,9}

No anesthetic technique or agent is really safe until diligent efforts are devoted to maintain a functional airway and to provide functional respiratory and circulatory support. Anesthetic risk first depends on evaluation of safety conditions, on vital status severity score, and finally on further hospital care (ICU recommended).

An important advantage for patients receiving anesthesia in the field is that they have a total loss of memory of the event. It has been observed in disasters (e.g., train crashes) that having no recall was of great psychological benefit for the patient. This was formally illustrated in the study by Bogetz,¹⁰ in which the recall in patients receiving emergency anesthesia immediately on arrival at the hospital was analyzed. Some patients received no anesthesia whereas others received balanced anesthesia. Those without anesthesia had more than 40% to 50% recall of the event, which was predominantly a negative experience.⁵ BIS index monitoring should help control the depth of anesthesia and protect patients from event recall.^{7,11,12}

Medical Team and Equipment

A three-member critical care medical team is a valid approach. Essential training for emergency physicians and

other members of the medical team consists of a preliminary training period, day-to-day experience, and regular training in an operating room and on a critical care unit.

All appropriate equipment should be immediately available for treatment. This includes supplemental oxygen; suction; advanced airway equipment to establish a patent airway, such as face mask and endotracheal tube; ventilation; means of vascular access; infusion solutions; and resuscitation medications. A functional defibrillator is also required. Vital signs should be monitored at regular intervals or continuously to detect changes in the patient's cardiovascular and ventilatory status: heart rate, blood pressure (invasive or at least noninvasive monitoring), pulse oximetry, and end-tidal carbon dioxide).

Specific Treatment: High Therapeutic Index Solutions for Sedation and Analgesia

Sedation and analgesia allow a conscious patient to obtain an anxiety-free and a pain-free state. Monitoring of a patient's response to verbal commands should be routine during moderate sedation. During deep sedation, patient responsiveness to a more profound stimulus should be sought to ensure that patient has not drifted into a state of general anesthesia.^{13,14}

Sedation and analgesia are an integral part of the management of critically ill patients. It can be added to specific treatment, for example, immobilization of a broken limb, thrombolytic therapy in acute myocardial infarction, psychological care, or noninvasive ventilatory support (Table 1).

Table 1. Methods of Providing Prehospital Analgesia⁵

- Nonspecific (e.g., rewarming, splinting fractures)
- Nitrous oxide (i.e., Entonox[®] or Kalinox[®])
- Minor drugs (e.g., aspirin, paracetamol)
- Opiates
- Mixed opioid agonist/antagonists
- Regional analgesia

Minor drugs can be administered safely outside the hospital by a parenteral or enteral route. Nonsteroidal, anti-inflammatory agents and analgesic drugs such as paracetamol are effective for minor pain and peripheral injuries, but there may be an additive effect if used in combination and with an anxiolytic agent. Many studies of the anxiolytic effects of drugs such as midazolam confirm their efficacy while maintaining neurologic, pulmonary, and hemodynamic status.^{5,13}

For many years, nitrous oxide (Entonox[®] or Kalinox[®]) administered by mask in a 50-50 mixture with oxygen has been used for emergency analgesia. It is simple to use, has a rapid onset with a short duration of action, and is effective for minor to moderate injuries. However, it has many limitations in prehospital settings: the patient has to be cooperative, and suspected pneumothorax represents a contraindication. It may be difficult to use in patients with facial injury. Additionally, everyone in the ambulance will breathe the same mixture. Furthermore, the gas mixture is greatly influenced by the outside temperature of the bottle; in a cold environment (<0°C), the inhaled mixture may consist of more than 50% nitrous oxide, which may be deleterious if the patient is in poor condition.

Intravenous narcotics are the most efficient and powerful analgesics used in anesthesiology. There are two types—pure agonists and morphine agonist-antagonists (e.g., buprenorphine, nalbuphine)—and both require monitoring. Agonist-antagonists could interfere with in-hospital anesthesia management.^{5,14}

Morphine sulfate has been used for centuries for pain control and is still an up-to-date analgesic drug. Intravenous morphine is simple to administer and can be readily titrated to provide adequate analgesia. Pain should be assessed via a numeric scale. Small and incremental doses should be titrated to the desired analgesic end point (e.g., 3 to 5 mg [or 0.1 to 0.15 mcg/kg]). The pain should be assessed again 5 minutes later, before additional administration. Thus, morphine remains one of the safest and most familiar drugs available.^{14,15}

Many other products, such as fentanyl, alfentanil, sufentanil, and remifentanyl, are much more potent and generally preferred by anesthesiologists, critical care specialists, and emergency physicians. Respiratory depression secondary to administration of these agents is well known. They may also lead to emergency intubation and ventilation, since the patient is no longer able to breathe independently. Fentanyl has been widely used in the field; it has a rapid onset and short duration, does not cause histamine release, and provides relative hemodynamic stability. These features make fentanyl one of the standard drugs for prehospital or emergency department analgesia, but its pharmacokinetics do not allow repeated incremental doses for pain titration. In France, fentanyl has been used consistently by many EMS teams for 20 years, and adverse effects are uncommon though recognized and reported.^{5,14} It is no longer used as a simple analgesic agent but as part of a balanced anesthesia with sedative and neuromuscular blockade agents.

Agonist-antagonist analgesics are useful for pain control, although, unfortunately, analgesia is limited by the ceiling effect. They also can cause adverse respiratory effects and dose-related sedation, particularly when used in combination with sedatives. Nevertheless, these drugs can interfere with enhanced general anesthesia management. It is therefore important to coordinate prehospital and in-hospital techniques, especially for trauma patients requiring emergency surgery. In case of life-threatening conditions, or after failure or in addition to high therapeutic index medications or specific measures, lower therapeutic index procedures, including induction of general anesthesia to facilitate tracheal intubation, should be considered.

General Anaesthesia

Anesthesia-associated risks on the dynamics of oxygen delivery and consumption are largely extrapolated from experimental data and studies of anesthetized healthy patient clinical observations. The following hypothesis, based on anecdotal clinical observations and physiologic considerations, has to be formally tested: early anesthetic induction may yield a holistic therapeutic effect on the trauma patient due to

- a) lowered basal metabolic rate (reduced oxygen consumption, restoring oxygen consumption/demand balance, and thereby reducing oxygen debt),
- b) improved oxygenation, ventilation, and pulmonary washout as a result of endotracheal intubation, and
- c) improved hemodynamic monitoring and support as a result of early intervention by the one-on-one critical care provided by an appropriately trained prehospital anesthesiologist.

Airway/Ventilation. The respiratory and circulatory consequences of general anesthesia depend on situation-induced stress on the ventilatory and cardiovascular systems¹⁶ and on the individual patient's ability to tolerate various anesthetic agents. Newer anesthetic agents (e.g., fentanyl, midazolam, vecuronium) provide hemodynamic stability. Providing a patent airway and appropriate ventilation is fundamental to anesthesia management and to all situations in which respiratory failure may develop. Physicians should be familiar with airway evaluation when deep sedation or general anesthesia is required.^{7,15} Before and during airway management, pulmonary aspiration of gastric contents is the most important risk shared by patients in emergency situations. Rapid-sequence induction is required for general anesthesia. If any doubt exists regarding the ability to proceed with endotracheal intubation, conscious intubation with preoxygenation, mild or moderate sedation, and topicalisation should be discussed.^{7,17} Therefore, in these situations, alternative strategies should be planned, with the necessary equipment (e.g., MacIntosh guide, laryngeal mask airway control [Fastrach device], surgical airway devices, and fiberoptic) readily available.¹⁸

Cardiovascular/Hemodynamic Stability. Cardiovascular depression is the main determinant for the appropriate choice of anesthetic management, of anesthetic agents, and for the dose to achieve anesthesia. Therapeutic ranges are often narrow.^{6,19,20,21} Central nervous and bronchomotor tone effects, allergy status, and potential side effects influence the choice of drugs. The goal of anesthesia induction is no response to laryngoscopy and intubation and, at the same time, a minimal amount of cardiovascular depression. Selection, incremental doses, slow rate of administration, and weight- and age-adjusted doses of intravenous anesthetic agents serve to mitigate most adverse circulatory side effects. Monitoring of sedation depth should allow adjustment of doses and limit postinduction hemodynamic adverse events, especially for head trauma patients.¹¹ It must also be remembered that positive airway pressure ventilation could add detrimental hemodynamic effects (i.e., decreased venous return) to adverse pharmacologic anesthetic consequences (i.e., decreased mean blood pressure).^{6,19,21} Catecholamine support could be useful to prevent blood pressure pitfalls.

General Anaesthetic Agents. Ketamine is often recommended for prehospital or emergency settings, since it has a good reputation for hemodynamic stability with a positive effect on blood pressure and vascular resistance. Ketamine increases cerebral metabolism, blood flow, and intracranial pressure. Ischemic heart disease, increased intracranial pressure, vascular aneurysms, psychiatric disorders, and an expected short intubation period in the ICU are contraindications. However, in some situations (e.g., hypovolemic shock), it may be beneficial to use ketamine specifically because of its hemodynamic effects.²²⁻²⁴ Animal and human studies using ketamine have shown increased survival and improved regional circulation. Many claim the use of ketamine to be very simple and straightforward for out-of-hospital settings. Ketamine possesses both indirect sympathomimetic stimulation and direct depressant myocardial effects. Thus, it is important to bear in mind a study of acute hemorrhage with animals anaesthetized by either ketamine or thiopentone.²⁵ There was no difference in terms of hypotension or cardiac output, but the ketamine increased plasma lactate and epinephrine levels. This study

Table 2. Effects of Anesthetic Agents on Hemodynamics in Normovolemic Patients

	MAP	HR	CO	SVR	Venous Capacitance	Cereb. VD	CMRO ₂
Induction							
Thiopental	↓	↑	↓	0/↑	↑	0	↓
Propofol	↓	↓/↑	↓	↓	↑	0	↓
Midazolam	0/↓	↓/↑	0/↓	0/↓	↑	0	↓
Etomidate	0	0	0	0	0	0	↓
Ketamine	↑	↑	↑	↑	0	↑	↑
Maintenance							
Midazolam	0/↓	↓/↑	0/↓	0/↓	↑	0	↓
Gamma-OH	0/↓	↓	0	↓	0/↑	0	↓
Fentanyl	0/↓	↓	0/↓	↓	↑	0	↓
Droperidol	↓	0/+	↓	↓	↑	0	↓
Vecuronium	0	0/↓	0	0	0	0	0
Etomidate	0	0	0	0	0	0	↓

MAP, mean arterial pressure; HR, heart rate; CO, cardiac output; SVR, systemic vascular resistance; Cereb. VD, cerebral vasodilatation; CMRO₂, cerebral O₂ consumption; ↓, decreased; ↑, increased; 0, unchanged.

therefore implies that ketamine may promote tissue ischemia and increase myocardial oxygen demand with no effect on global oxygen delivery. It is contraindicated in patients with coronary artery disease.

The main advantage of *etomidate* is its minimal effect on cardiovascular parameters (Table 2), which may justify its extensive prehospital use. Barbiturates, propofol, and high doses of benzodiazepines may induce hypotension, particularly when administered in doses not sufficiently reduced and adjusted for a critically ill patient.²⁶

Barbiturates are commonly associated with hypotension due to myocardial depression and ganglionic blockade, which elevate heart rate and oxygen consumption. Eclampsia and epileptic status remain indications for barbiturate induction.

Propofol causes more hemodynamic depression than barbiturates. Even in healthy patients, a 15% to 30% drop in blood pressure could be observed. This hypotension is related to a negative inotropic effect and a decrease in systemic vascular resistance.²⁷

Benzodiazepines such as midazolam are used for emergency sedation or hypnosis. Their effects are mild in healthy patients and safe in patients with coronary artery disease if used alone. This relative hemodynamic stability depends on compensatory mechanisms. A single dose of opioids or benzodiazepines may cause a drop in cerebral perfusion pressure, which can be deleterious in cases of suspected intracerebral hypertension.

Etomidate has been used by anesthesiologists in both North America and Europe for many years and has recently been used in out-of-hospital settings. It has a rapid action and is highly suitable for emergency anaesthesia. It has no significant effect on myocardial contractility and improves the myocardial oxygen supply-to-demand ratio. A 0.3-mg/kg induction dose increases coronary blood flow by 19% with no increase in myocardial oxygen consumption.²⁸⁻³¹

However, etomidate infusion could cause discomfort: nausea and vomiting may occur, and it interferes with the adrenocorticoid axis when infusion is continued for several days in an ICU.⁵

Succinylcholine is still the only neuromuscular blocking agent that produces excellent intubation conditions in less

than 1 minute. Studies comparing rapacuronium with succinylcholine concluded that succinylcholine is better because fewer intubation responses such as coughing were observed, especially when used with fentanyl or any other opioid.³²⁻³⁵ An equally great advantage is its rapid offset of action by ester hydrolysis, especially in the scenario of a potentially difficult airway. Contraindications in prehospital settings are rare and most often offset by a safe induction and rapid intubation sequence.⁸ Some case reports have described cardiac arrest in relation to hyperkalemia.²¹

In the classic form, when performing rapid-sequence induction, the patient is preoxygenated using spontaneous ventilation with a face mask and reservoir bag. Diseased lungs need a longer period of preoxygenation to ensure adequate nitrogen washout. After preoxygenation, intravenous short-acting anesthetics and neuromuscular blocking drugs are administered. As the patient becomes unconscious, proper "cricoid pressure" (Sellick's maneuver) is applied to occlude the esophagus between the anterior portion of the C6 vertebra and the posterior wall of the cricoid cartilage. Laryngoscopy and orotracheal intubation are performed after the onset of myorelaxation without any preceding manual ventilation (circulation, SpO₂). Cricoid pressure is released after checking tube placement (PEtCO₂, auscultation) and cuff inflation. If intubation is not possible, mask ventilation can be provided while cricoid pressure continues.⁸ The achieved tracheal intubation should be controlled by end tidal expired CO₂. Sellick's maneuver is no longer recommended in cases of suspected spinal trauma.

Maintenance of anesthesia progresses from intravenous anesthesia induction to tracheal intubation and adequate ventilation. Modes and doses are adjusted to weight, age, and hemodynamic effect (Table 2). Continuous infusion is always necessary because most patients who are intubated and sedated in an emergency department or a prehospital setting will remain intubated and sedated for many hours and days. Continuous sedation maintenance avoids awakening nausea; this is especially important during patient transfer.

Monitoring of sedation (bispectral index), oxygenation (SpO₂), hemodynamics (PEtCO₂, heart rate, mean arterial pressure), and esophageal temperature should replace

reduced patient spontaneous warnings. Prehospital indications for continued infusion of myorelaxants are reduced and limited to severe hypercapnia due to refractory asthma or respiratory failure and intracranial hypertension. Anaesthetized patients should be mobilized and transported with care.

Regional Analgesia and Anesthesia

Regional blocks may also be useful in the prehospital setting. Epidural and spinal analgesia are not used, since there are few situations in which they are warranted and they are difficult to perform, especially in terms of the need for aseptic technique and for careful monitoring of hemodynamics.

Isolated peripheral troncular nerve blocks may prove useful in some situations. This technique can provide very effective analgesia to a part of the body with very few complications and no effect on patient consciousness and hemodynamic. This type of block has been used in various circumstances in a number of small studies.⁵ For example, peripheral troncular neural blockade, such as a femoral nerve block or an infraclavicular block (with carbocaine, 1.5%, or ropivacaine, 0.475%, 0.3 ml.kg⁻¹) may be proposed for femoral shaft fracture and arm trauma, following usual anaesthesia patient safety guidelines.^{15,14} A take-away nerve stimulator helps locate the nerve. This technique is associated with high success rates, fewer side effects, and reduced doses.³⁶

Transition Period: Prehospital to In-hospital

The receiving hospital staff should be trained to receive anesthetized patients from the prehospital setting. This is not a problem in several European countries because anesthesiologists are trained for both situations and work in both environments on alternate days.

Radiologic evaluations and computed tomographic scans should be obtained on all patients. Mobile fast-track ultrasonography has become a routine procedure for emergency physicians in emergency departments and prehospital settings to detect intraabdominal hemorrhage that could require an urgent surgical procedure.

Finally, specific analgesia and anesthesia techniques used outside the hospital should be closely related to those used subsequently in the hospital to optimize benefits and avoid interference and side effects.

Conclusion

Prehospital anaesthesia procedures are closely linked to safer intensive therapy. In the field, anaesthesia requires proficient and day-to-day critical care physicians. Because of their background and inherent competencies, anesthesiologists might be, de facto, most logically involved in induction of anesthesia outside the hospital and operating room when such procedures are required. However, the reality of limited staffing in anaesthesia departments implies the importance of imparting their sophisticated knowledge and techniques to non-anesthesiologist traumatology colleagues through medical education statements and appropriate follow-up via quality assurance mechanisms.

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Etomidate for Prehospital Emergency Anesthesia

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Learning Objectives

1. To identify the indications for use of etomidate in the prehospital setting
2. To understand the prehospital conditions that constitute contraindications for the use of etomidate
3. To appreciate the advantages of etomidate administration for some patients during the prehospital phase of care

Induction of general anesthesia and tracheal intubation in emergency situations is hazardous. Compared with patients undergoing elective surgery, patients requiring prehospital emergency interventions are at high risk for aspiration of gastric contents into the lungs and hemodynamic instability, and many have unknown or undiagnosed diseases as well as unrecognized injuries. Moreover, on the front line we occasionally find less experienced anesthetists (or paramedics) with a higher risk of failed or false endotracheal intubation. The risk of an unrecognized esophageal intubation following administration of neuromuscular blocking agents has led some clinicians to suggest avoiding neuromuscular relaxants altogether for emergency tracheal intubation. Only a few pharmacologic or technical suggestions have been presented to ease this dilemma.¹

Omission of anesthetic agents and/or neuromuscular relaxants can make tracheal intubation even more difficult, but complete avoidance of anesthetics for intubation cannot be recommended. Intubation is a potent noxious stimulus that can itself provoke vomiting, increase intracranial pressure (ICP),

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cause unfavorable hemodynamic responses, and cause utter discomfort to responsive patients. Moreover, strict avoidance of anesthetic drugs can make the intubation procedure technically impossible; therefore, anesthetic agents are invaluable in the prehospital setting. This discussion focuses on the author's use of hypnotic agents for prehospital emergency medicine (PHEM).

Choice of Anesthetic Agent for PHEM

The choice of anesthetic agent depends on its pharmacologic profile; physicochemical characteristics; and effects on the cardiovascular, respiratory, central nervous, and other systems. Several serious adverse effects may be associated with the use of intravenous anesthetics, such as histamine release (barbiturates), negative inotropic effects (barbiturates, propofol), laryngospasm (ketamine, barbiturates), and respiratory depression (barbiturates, propofol). Etomidate, on the other hand, has many desirable properties for use in the prehospital setting: rapid onset of profound hypnosis of short duration, hemodynamic stability, minimal respiratory depression, and favorable cerebral effects. Unlike thiopental, which must first be dissolved in a liquid, etomidate is ready to use, a very important advantage in the field. For these reasons, etomidate has become the author's preferred anesthetic induction agent in PHEM, although ketamine is still used in certain circumstances.

Another important advantage of using etomidate as the preferred hypnotic in PHEM is the salutary effect of etomidate on upper airway reflexes in the absence of neuromuscular blockade (Table 1). However, it is extremely difficult to report on the effects of etomidate on the muscles of the pharynx, larynx, and trachea because these reflexes are extremely difficult to measure accurately. In addition, such measurements would not reflect the effect of the concomitant administration of other anesthetic agents and paralytics. Thus, the data listed in Table 1 must be interpreted with caution.²

Table 1. Impact of IV Induction Agents on Upper Airway Reflexes

	Pharynx	Larynx	Trachea	Respiration
Barbiturates, low-dose	Increased	Spasm	Increased	Depressed
Barbiturates, high-dose	Depressed	Depressed	Depressed	Apnea
Ketamine	Increased	Spasm	Depressed	None
Propofol	Depressed	Depressed	Depressed	Depressed
Etomidate	Depressed	Depressed	None	None

Spasm = tendency to laryngospasm.