M. Michael[1] · B. Hossfeld[2] · D. Häske[3] · A. Bohn[4] · M. Bernhard[1]

Analgesia, sedation and anaesthesia in emergency care

1 Zentrale Notaufnahme, Universitäts-
   klinikum Düsseldorf
   (Ärztlicher Leiter: Priv.-Doz. Dr.
   M. Bernhard)

2 Klinik für Anästhesiologie, Intensiv-
   medizin, Notfallmedizin und Schmerz-
   therapie, Bundeswehrkrankenhaus Ulm
   (Direktor: Prof. Dr. M. Helm)

3 Eberhard Karls Universität Tübingen /
   DRK Rettungsdienst Reutlingen, Medizi-
   nische Fakultät
   (Direktor: Prof. Dr. P. Rosenberger)

4 Stadt Münster, Feuerwehr, Ärztlicher
   Leiter Rettungsdienst / Klinik für Anäs-
   siologie, operative Intensivmedizin und
   Schmerztherapie, Universitätsklinikum
   Münster
   (Direktor: Prof. Dr. A. Zarbock)

Summary

Sedation, analgesia and emergency anaesthesia are key elements of pre-hospital emergency medical care. These measures pose a significant challenge to the whole emergency team. Pain may be eased through supportive measures (e.g. reduction of fractures, immobilisation) and verbal emotional support. In many cases however, patients will only be pain free once potent analgesics have been administered. Numerous emergency medical services in Germany permit trained and certified paramedics ("Notfallsani-täter") to administer analgesics and analgosedation in accordance with standard operating procedures within the scope of job delegation. Whilst this can shorten the time to treatment especially for severe pain, it does not make the emergency physician redundant. Basic monitoring should be established as a matter of principle whenever analgose-dation is administered. Provision of emergency anaesthesia is reserved for emergency physicians and includes a critical evaluation of the indication for anaesthesia, taking into account patient, scenario and provider-related factors. As a rule, rapid sequence induction (RSI; aka "crash" induction) should be used for emergency anaesthesia and should include the following points: standard monitoring, preoxygenation, standardised provisions for emergency anaesthesia (anaesthetic and emergency drugs, airway and breathing equipment), drug administration, temporary manual in-line stabilisation of the cervical spine during intubation (if required), airway management and securing of the endotracheal tube following verification of correct placement. Standard preparation for general anaesthesia includes prior accord, secure labelling of anaesthetic and emergency drugs, checking required equipment and making available alternative airway management devices. Standard monitoring for prehospital analgesia, sedation and emergency anaesthesia should include an electrocardiogram, automatic or manual measurement of blood pressure and pulse oximetry. Continuous capnography is required without exception for verification of correct endotracheal tube placement, for detection of disconnection or dislocation and for indirect haemodynamic monitoring.

Introduction

Analgesia, sedation and emergency anaesthesia are the cornerstones of prehospital emergency care.

Standards employed in a hospital environment cannot unreservedly be assigned to emergency medical services (EMS). Numerous scenario and patient-specific features need to be taken into account, as do regional guidelines and the personal experience of the provider, all of which play significant roles in the provision of emergency medical care. The following digest summarises the principles of prehospital analgesia, sedation and emergency anaesthesia.

Analgesia

Preliminary remarks

Following initial emergency care (ABCDE-algorithm) to avert threats to life, pain should be ascertained and treated [1]. Pain is a common reason for activation of the EMS and brings with it an inherent requirement for an emergency physician [2]. Trauma is the most common cause of prehospital pain, followed by chest and abdominal pain (Table 1) [3]. The degree to which pain is alleviated is a significant factor in patients' perception of quality of care received. However, research shows that <60% of patients with cardiopulmonary disease, <50% of trauma patients and only approximately 30% of patients with abdominal pain receive sufficient analgesia in the prehospital setting [4-11]. Providers argue the following causal factors:

- age or origin of the patient;
- limited ability to communicate;
- willingness to endure pain.

In some cases, however, provider insecurity leads to omission of analgesic therapy (e.g. concern surrounding respiratory depression as a side effect of treatment [with opioids]) [11].

That **sufficient treatment for pain** be provided as a basic measure by EMS and emergency physicians should be demanded in this day and age. Progressive professionalisation of the EMS (e.g. the institution of "Notfallsanitäter" – the German equivalent of a trained and licensed paramedic) has led to the introduction of standard operating procedures and treatment pathways for analgesia and analgosedation which must, however, be subject to the same level of standards with regard to patient safety as treatment by an emergency physician would be.

> **Sufficient analgesia is an important component of qualified emergency medical care and a necessity if further threats to life and complications are to be averted.**

Prehospital analgesia not only increases patient comfort, but is actually physiologically valuable:

- pain causes a sympathoadrenal response (e.g. sweating, tachycardia, hypertension, hyperventilation) and increases myocardial oxygen requirements.
- Local inflammation with release of cytokines and nociceptor sensitization can promote development of hyperalgesia and chronification of pain.
- Increased muscle tone and avoidance behaviour caused by pain can lead to relevant hypoventilation and thus cause hypoxaemia [12].

Qualitative and quantitative assessment of pain

Various systems are available for detection and quantification of pain, for interpretation of the character of pain and for confirmation of the diagnosis. Pain should be asked after and documented whenever emergency care is provided. A complete registration of vital signs provides important information regarding physiological reactions (e.g. tachypnoea as an expression of pain) [13].

Pain and its possible causes can be classified using the so-called **OPQRST mnemonic** (documentation of onset, provocation and palliation, quality, region and radiation, severity, time [duration and course]; Table 2) [14].

The **numeric rating scale (NRS)** has established itself as a prehospital tool for quantitative assessment of pain and response to analgesic management. The patient is asked to rate the intensity of their pain on a scale of $0-10$ (0 = no pain ranging to 10 = most severe pain imaginable). A requirement for prehospital analgesia is assumed from a value of 4 upwards, heightening from there with the reported intensity. The aim of treatment is to provide sufficient analgesia by reducing the NRS to <4 or by 3 points whilst avoiding complications and side effects [5]. Analgesic management in a prehospital setting can employ pharmacological and non-pharmacological means as well as supportive measures (such as repositioning the fracture, positioning the casualty, and verbal emotional support).

> **Pain can be assessed using the numeric rating scale (NRS). The aim of analgesic management should be to reduce to the NRS to under 4.**

Checklist for use of analgesics

Use of analgesics is subject to the following prerequisites:

- **Assess** and **document intensity of pain** (using the NRS).
- **Elicit** a thorough **history** (e.g. standardised "SAMPLER" history

Table 1
Incidence of pain in relation to prehospital diagnosis groups (modified from [3]).

Primary diagnosis group	Prehospital incidence
Trauma	50–55%
Chest pain	27–34%
Abdominal pain	7–21%

Table 2
"OPQRST" mnemonic (modified from [14]).

O (Onset)	onset/time/situation/trigger
P (Palliation/Provocation)	palliating/provoking factors (e.g. movement)
Q (Quality)	character of pain: colicky, spasmodic, sharp, dull
R (Radiation)	localisation and radiation of pain
S (Severity)	intensity of pain scored on NRS
T (Time)	duration and course of pain since onset

NRS: Numeric Rating Scale

[symptoms, allergies, medication, past pertinent medical history, last oral intake, events leading up to current situation, risk factors] in accordance with various emergency medicine course concepts), paying attention to allergies.

- **Assess risk:** Fasted? Allergies? Past medical history? Time to hospital?
- **Choose drugs** based on indication, experience of the emergency physician and regional protocols (e.g. standard operating procedures/ treatment pathways specific to the particular emergency medical service, availability).
- Obtain **informed consent** when required, including and especially when analgesia is provided by paramedics.
- Establish **secure intravenous access** (test for backward flow, free flowing IV fluids), using alternatives if required when peripheral venous access is unavailable:
  - Intranasal administration (e.g. fentanyl, ketamine/esketamine, midazolam) [15]
  - Intraosseous administration (dose as for intravenous administration) [16]
  - Intramuscular administration (as a measure of last resort for selected drugs, e.g. ketamine/esketamine or for burns)
- **Establish standard monitoring for analgosedation:** respiratory rate, pulse oximetry, ECG and blood pressure, capnography even for spontaneously breathing patients.
- **Avoid overdosing by titrating to effect** ("as much as necessary, as little as possible"). Take the age and condition of the patient (e.g. haemodynamics) into account, reducing the dose when necessary and waiting an appropriate length of time before administering further doses.
- **Administer oxygen** (via nasal cannula or non-rebreather mask) whenever **opioids** and **ketamine/esketamine in combination with midazolam** are used, as these drugs can cause respiratory depression. **Options**

for securing the airway should be immediately available [17,18].

- The provider (regardless of whether emergency physician or paramedic) must be in a position to treat **side effects** attributable to the employed drugs safely and competently.

Close monitoring is a requirement for any analgosedation: depending on the drugs used there is a fine line between sufficient analgesia and relative overdose impeding on vital functions (causing e.g. loss of consciousness, respiratory depression and circulatory collapse). As such, in addition to standard monitoring and prophylactic oxygen insufflation, titrating drugs to effect is expedient. Furthermore, any equipment necessary for securing the airway should be immediately available.

Supportive non-pharmacological measures

Non-pharmacological measures include repositioning, in-line stabilisation and local cooling for trauma of the limbs, but also comfortable patient positioning (e.g. knees drawn up and supported for abdominal or lower back pain) [19]. Verbal emotional support provided by emergency medical professionals and the emergency physician play an equally decisive role and can positively influence the individual experience of pain. For children especially, involving an attachment figure is of importance.

Availability and selection of analgesics

According to the WHO pain ladder, analgesic management should be started with non-opioid analgesics. For acute pain (an intensity of NRS 4 or above), however, the initial treatment should be with potent analgesics administered at a sufficient dose to achieve rapid remission. Especially when short-acting analgesics (e.g. ketamine) are used, a combination with longer-acting analgesics providing an overlapping or extended effect, and

therefore relief beyond the prehospital setting, should be considered. All in all, only a small selection of low-potency analgesics is available to German EMS and emergency physicians [20].

Prehospital pain management should be multilevel if required and include a combination of different analgesics.

Non-opioid analgesics

Paracetamol

Intravenous administration of paracetamol has a relatively small analgesic effect [21–25]. When administered for fractures of the limbs, paracetamol does not provide adequate analgesia. It does, however, exhibit very good antipyretic effects and can be indicated in appropriate prehospital settings (e.g. fever) [26]. As setron-type antiemetics [5-HT$_3$ antagonists (e.g. ondansetron)] can influence the effect of paracetamol, this combination should be avoided in the prehospital setting [27].

Metamizole

Metamizole exhibits a spasmolytic component (Table 3). Its delayed onset of action is a disadvantage. Major side effects include

- a possible drop in blood pressure (particularly following rapid intravenous injection) and
- allergic reactions.

Metamizole is used commonly in hospital and prehospital emergency situations [28]. Whilst often-cited, **agranulocytosis** is a very rare side effect which does, however, have to be included in an informed consent conversation [29]. Equally, pancytopenia and its typical symptoms should be included. Whether or not informed consent can be obtained from a patient suffering pain should be judged on an individual basis. There is discussion surrounding an attenuating effect of metamizole on the effect of long-term ASA on platelet inhibition [30–32].

Table 3
Peripheral analgesics (modified from [67]).

Drug	Indication	Dose	Mode of action	Contraindications	Notes
Paracetamol	Mild to moderate pain Fever	15 mg/kg BW IV 4 g maximum daily dose for adults	Cyclooxygenase inhibition in CNS Metabolised via cytochrome P450 Possible 5-HT3 receptor mediated spinal inhibition	Risk of intoxication in small children, the elderly, liver disease, alcohol abuse, concomitant use of other drugs causing enzyme induction	Antidote in case of intoxication: N-acetylcysteine Drug effect possibly impaired by concomitant administration of 5-HT$_3$ antagonists (e.g. ondansetron)
Metamizole	Colic Acute severe pain Fever	15 mg/kg BW IV 1 g IV single dose 5 g maximum daily dose	Pyrazolone derivative Active metabolite: 4-N-methyl-aminoantipyrin Peripheral und central COX II inhibition Mild antiphlogistic Spasmolytic Mild antipyretic Bioavailability 90%	In emergencies no dose adjustment required for renal or hepatic impairment. For long-term use reduce dose. Contraindications: analgesic asthma syndrome impaired bone marrow function glucose-6-phosphatase dehydrogenase deficiency acute intermittent hepatic porphyria pregnancy (final trimester)	Slow IV push (caution: hypotension) Anaphylaxis Rare: Agranulocytosis → informed consent required Metabolites found in breast milk

Agranulocyto-sis is a very rare side effect of metamizole which does, however, have to be included in an informed consent conversation. Informed consent should be obtained in a fashion adapted to the situation, although the patient should be informed of possible symptoms even in an emergency situation.

Table 4 sets out an overview of onset and duration of action of various analgesics.

Table 4
Onset and duration of action of analgesics (modified from [51]).

Agent	Onset of action (min)	Duration of action (min)
Metamizole IV	15–30	240
Ketamine/ esketamine IV	0.5	5–10
Ketamine/ esketamine IN	5–10	12–25
Morphine IV	5–10	30–120
Fentanyl IV	1	20–40
Fentanyl IN	5–10	30–60
Piritramide IV	5–20	40–60

Ketamine/esketamine

In analgesic doses, ketamine, an NMDA antagonist, exhibits a rapid and potent onset of action without impacting on spontaneous breathing or airway protective reflexes ("dissociative analgesia"). Side effects include

- hallucinations,
- hypersalivation,
- hyperacusis and
- nystagmus.

Central stimulation of the sympathetic nervous system leads to an increase in heart rate and blood pressure with a consecutive increase in myocardial oxygen requirements. Whilst this effect is desired especially in hypovolaemic trauma patients or those with haemodynamic instability, it represents a relative contraindication in patients at risk of cardiac complications or exhibiting hypertension [33]. Use of ketamine for patients with **head injuries** whilst monitoring with capnography is deemed established current practice and is not contraindicated [34,35].

As ketamine can cause nightmare-like conditions, it is typically combined with a sedative (e.g. midazolam) for analgosedation (caution: respiratory depression).

Hypersalivation caused by ketamine can be treated particularly in children by weight-adjusted administration of atropine. Due to hyperacusis, patients should be provided with hearing protection during technical rescue and transfer to hospital.

The enantiomer esketamine (S-ketamine) is a more potent analgesic and anaesthetic (observe altered dosing regimen). Because ketamine is not a controlled substance under German law, it is recommended for use by emergency medical professionals as a potent analgesic for predefined conditions (e.g. trauma pain following injuries to the limbs). Numerous EMS stipulate analgosedation provided by paramedics for trauma pain using ketamine and midazolam in accordance with fixed algorithms. This reduces the time to treatment prior to arrival of an emergency physician; convincing data demonstrate the safety of this approach [36-38]. Guidelines, training and certification of each individual employee rest with the respective medical director of EMS within the principles of delegation. Ketamine can also

be administered nasally, orally, rectally and intramuscularly. Intranasal use in particular is suitable for analgesia in children, although this mode of delivery constitutes off-label use [39,40].

Opioids

In prehospital settings, morphine and fentanyl, and less commonly sufentanil and piritramide are provisioned. Both sufentanil and fentanyl are not approved for use as analgesics outside general anaesthesia, however. Opioids exhibit differing analgesic, sedative and antitussive properties. Side effects include

- respiratory depression,
- sedation,
- bradycardia,
- hypotension,
- pruritus,
- bronchospasm,
- sweating and
- miosis.

In emergencies, there are no contraindications to opioid use. This remains true even during pregnancy and breast-feeding, when risks and benefits would otherwise have to be considered carefully. Antiemetic co-medication (e.g. ondansetron, dimenhydrinate) can be used if required. Doses should be titrated when treating geriatric patients, particularly to avoid respiratory depression [41].

Morphine is significantly less potent than fentanyl (1:100) and has a delayed onset of action at 5 to 10 minutes. As such, repeat doses should not be administered too quickly. Morphine offers advantages especially when used for myocardial infarction, where its sedative and parasympathomimetic properties (e.g. bradycardia) are desirable. In addition, the reduction of pulmonary vascular resistance is an advantage over other analgesics. Despite providing sufficient analgesia, morphine is at a disadvantage when treating trauma patients because of its delayed onset of action – positioning the patient or repositioning a fracture in particular call for rapid onset of analgesia [42]. Newer research shows that morphine may exhibit an unfavourable effect on thrombocyte function and size of infarction in patients with ST-elevation myocardial infarction [43], although this is not yet relevant to treatment.

Intravenous **fentanyl** exhibits a rapid analgesic effect but also a high potential for respiratory depression; it can, however, be used – carefully titrated – for analgesia in spontaneously breathing patients (caution: observe breathing closely). Ideally, **capnography** should be used even in spontaneously breathing patients. In addition to intravenous and intranasal routes, fentanyl is suitable for buccal or mucosal administration [44].

Sufentanil is especially suited to induction of general anaesthesia. When used for analgesia in spontaneously breathing patients, the risk of respiratory depression must be observed. Piritramide, which is made available by some EMS, exhibits a delayed onset of action similar to that seen in morphine [22]. However, many emergency physicians have experience with this drug by the use in a hospital setting. Current research shows no advantage in use of a specific analgesic (fentanyl vs. morphine, opioids vs. ketamine) [19].

Increasingly, paramedics are using opiates and opioids in accordance with fixed algorithms within the scope of delegation and without the presence of a physician [45,46]. In some cases, a system of telephoned orders (so-called "call-back" procedure) has been established [47].

When comparing analgesic regimens using morphine, fentanyl and ketamine, available research shows no clear superiority of any one substance over the other.

Further substances with analgesic effects

In some countries (e.g. the United Kingdom), nitrous oxide has been used for decades by emergency medical professionals to treat pain in prehospital settings. Nitrous oxide is used by inhalation as a fixed combination with oxygen (e.g. Entonox®, 50% nitrous oxide, 50% oxygen) [48]. Studies show an effect especially for trauma pain [49]. Individual EMS in Germany provide nitrous oxide/oxygen mixtures for pain relief for administration by emergency medical personnel; this is currently not standard practice, however.

Sedation

When treating aroused, anxious or panicking patients, or those suffering psychiatric emergencies, and as a supportive measure in various other emergency situations such as for technical rescue, sedation may be required when verbal interventions (e.g. talk down, calming the patient, creating a calm atmosphere) are insufficient. **Benzodiazepines** not only exhibit an anxiolytic effect, but also have additional somatic effects (e.g. reduction of myocardial oxygen requirements). With regard to the indication for and monitoring of sedation the same requirements should be met as for analgesia.

In addition to use of benzodiazepines (e.g. midazolam, lorazepam) in emergency care, **morphine** is used for analgosedation in patients undergoing non-invasive ventilation (NIV). **Neuroleptics** (e.g. haloperidol) are no longer widely made available by EMS and are reserved for specific indications [50].

Benzodiazepines can be administered intravenously but also via the nasal or buccal routes, offering an advantage in those patients who are so agitated that venous access cannot initially be established. (Side) effects are

- anxiolysis,
- amnesia and
- dose-dependent respiratory depression.

Low dose **propofol** can also be used for sedation, especially when use of benzodiazepines is contraindicated or shows insufficient effect. That propofol is easily controlled is of advantage in these situations.

Patients undergoing sedation with propofol must – as with any other drug – be observed closely for airway obstruction through regurgitation/ aspiration and for respiratory depression at all times. In addition to obligatory monitoring, equipment for airway management must be held available.

Prehospital emergency anaesthesia

Preliminary remarks

Induction of prehospital emergency anaesthesia is a task reserved for the emergency physician and represents a central therapeutic measure in emergency care [51–54]. The S1 guideline on "prehospital emergency anaesthesia in adults" [54] observes that emergency physicians – regardless of their speciality – must be competent to autonomously and safely induce emergency anaesthesia in the context of a variety of injuries, diseases and risks, even when complicated by the prehospital setting. Induction itself poses a challenge to the whole team, especially as the prehospital setting is not comparable with elective routine anaesthesia. Assistance offered by emergency medical personnel – including prior consultation with the whole team – is an important requisite for safe execution, avoiding complications [55].

The following elaborations are based on recommendations made by the German Society of Anaesthesiology and Intensive Care Medicine (DGAI) and the S1 guideline on "prehospital emergency anaesthesia in adults" [54].

Critical considerations

In general, the requirement for prehospital emergency anaesthesia is influenced by a number of factors and it is the duty of the emergency physician – following careful appraisal of the situation as a whole – to review the indication and determine a suitable procedure [54].

First and foremost, reversible causes impeding vital functions (such as hypoglycaemia causing unconsciousness) should be excluded. The following constellations are typical situations requiring prehospital emergency anaesthesia, securing the airway:

- sustained impaired consciousness with risk of aspiration (e.g. suspected intoxication, intracranial haemorrhage),
- acute respiratory distress,

- traumatised patients suffering severe thoracic injuries, respiratory or cardiovascular instability or head injuries (Glasgow Come Scale GCS <9) and
- patients suffering life-threatening neurological emergencies (e.g. status epilepticus).

> In summary, emergency anaesthesia is indicated in those patients with acute or impending disruption of oxygenation or ventilation in whom conservative management (incl. NIV) is insufficient and in those with impaired consciousness with a consecutive risk of aspiration [54].

The aims of anaesthesia and airway management are to secure the airway, uphold oxygenation and ventilation (normocapnia), provide sufficient analgesia, reduce oxygen requirements and ultimately avoid secondary myocardial and cerebral damage [54]. The indication for and planning and execution of emergency anaesthesia are influenced by various factors [54]:

- training, practical experience and capabilities of the emergency physician and emergency medical personnel,
- environmental factors on scene (e.g. light, available space and weather conditions),
- transfer time and type (ground or air transport),
- circumstances surrounding airway management with specific regard to the patient and signs of difficult intubation (e.g. expected difficult airway in an emergency patient with sufficient spontaneous breathing).

Emergency anaesthesia encroaches on bodily integrity and is associated with a relevant mortality risk. It is as such that the emergency physician must as part of a risk/benefit analysis consider the possible disadvantages and risks (e.g. vomiting, aspiration, airway obstruction, cardiovascular depression, allergic reactions) associated with emergency anaesthesia. These risks make it essential that every emergency physician should

have good command of concepts for induction and maintenance of emergency anaesthesia and be able to anticipate possible complications [54].

> The emergency physician is called upon to critically evaluate the indication for emergency anaesthesia, taking risks and benefits into account and ultimately – together with the whole team – deciding on a clear concept for anaesthesia including alternatives.

Special considerations

Preliminary remarks

Emergency anaesthesia is associated with an increased risk of complications [56,57]. In accordance with the DGAI recommendations regarding prehospital airway management, multifactorial risk-inducing conditions can be characterised by provider-specific, patient or scenario-related factors [53].

Patient-related factors

Emergency patients must be considered non-fasted with a high risk of aspiration: RSI with rapid induction of anaesthesia should be employed and the airway secured without intermediate mask ventilation. Anatomic features and airway injuries (e.g. intraoral haemorrhage, midfacial fractures) must be evaluated prior to induction for their potential to cause difficult intubation. Reduced mobility of the cervical spine (pre-existing, traumatic or through immobilisation) is a patient-related risk factor, as are cardiopulmonary and other impairments caused by pre-existing disease and/or injuries (e.g. haemorrhagic shock when blood loss is often underestimated, the number of oxygen carrying erythrocytes is critically reduced and there is a risk of serious decrease in blood pressure). The patient's medication should be taken into consideration (standardised "SAMPLER" history). It is recommended that peripheral venous access should be gained at two sites and that intraosseous access be considered when venous access is difficult.

Scenario-related factors

The **position of the patient** can be relevant with regard to anaesthesia: patients trapped or partially inaccessible can be rescued following analgosedation with preserved spontaneous breathing, later undergoing induction of anaesthesia in a more favourable location (e.g. in the paramedic unit) under optimised conditions. The **limited range of emergency equipment** and a limited selection of drugs for induction of anaesthesia should be taken into consideration. In addition, as a rule, induction of emergency anaesthesia is **time critical** such that depending on the specific situation it usually occurs under pressure.

> **Organising prehospital emergency anaesthesia comprises the following points:**
> - **thorough evaluation and examination of the patient,**
> - **critical evaluation of the indication for prehospital emergency anaesthesia,**
> - **optimisation of the patient's condition through preoxygenation, haemostasis and fluid therapy (if required),**
> - **standardised preparation for and execution of prehospital emergency anaesthesia,**
> - **managing complications.**

Preparing for and carrying out emergency anaesthesia

The decision to undertake emergency anaesthesia is communicated to the whole medical team. Together, a decision is taken where anaesthesia should be induced (e.g. in the patient's home vs in the paramedic unit), tasks are allocated, and the choice of anaesthetic drugs and necessary doses are discussed together with any important details and instructions. This way, the team determines the approach to emergency anaesthesia, which should ideally be oriented toward a standardised process [54]. In addition, alternatives should be agreed upon and prepared [54].

Induction of emergency anaesthesia is as a modified RSI, administering a hypnotic and a neuromuscular blocking agent in rapid succession. An analgesic can be administered prior to or immediately after these two drugs, or after the airway has been secured. Any necessary equipment must be prepared and emergency resources (e.g. alternative means of securing the airway) ready to hand [53]. The following points are important:

- Begin preoxygenation as early as possible at the same time as preparing anaesthetic and emergency drugs; whenever justifiable extend over at least 3–4 minutes using 100% oxygen via a non-rebreather mask or a tight sitting bag valve mask using an oxygen reservoir (minimum 12–15 l O_2/min). Use of a demand valve or non-invasive ventilation (NIV) is both more effective and saves oxygen [54,58–60].
- Establish optimum monitoring of vital signs using pulse oximetry (SpO_2) with heart rate and oxygen saturations (pulse tone as an acoustic signal), 3-lead ECG (heart rate and rhythm), automatic blood pressure monitoring at close intervals (minimum 3 minutes, every minute if possible) and capnography.
- Prepare anaesthetic and emergency drugs. Use sticky syringe labels in accordance with the DIVI recommendations if possible – if not, it is indispensable syringes be labelled in writing [61].
- In so far as not impermissible (e.g. spinal immobilisation in trauma patients, haemodynamically unstable patients) elevate the upper body (e.g. in-line).

Check venous access (test for backward flow, connect IV fluids):
- Begin induction of anaesthesia following team briefing and allocation of tasks.
- Drugs and doses (in ml and mg) should be called out by the emergency physician and confirmed by emergency personnel ("closed-loop" communication).
- In patients with an immobilised cervical spine, have an additional helper perform manual in-line stabilisation (MILS) [59].
- Secure the airway following loss of consciousness and onset of neuro-muscular block (in adults typically without intermediate ventilation).
- In individual cases, intermediate ventilation may be required to maintain oxygenation irrespective of the risk of aspiration [60].
- Change to an alternative (e.g. supraglottic airway) following a maximum of 2 intubation attempts. Perform intermediate ventilation if necessary.
- Inflate the cuff on the endotracheal tube or supraglottic airway (SGA, e.g. laryngeal mask, laryngeal tube) immediately after insertion.
- Check the correct position (e.g. capnography, video laryngoscopy, auscultation) and securely fix in place.
- Maintain anaesthesia, use catecholamines if required, adjust and re-evaluate the respirator settings (define and check target values, capnography).

> **During anaesthesia, aim for normoxia, normocapnia, a sufficient depth of anaesthesia and haemodynamic stability.**

Standard monitoring must be used throughout anaesthesia so as to provide professional care and to recognise and respond to changes in vital functions in a timely fashion. In case of changes or abrupt complications (e.g. a drop in SpO_2) a re-evaluation along the lines of the ABCDE-algorithm is a must. When airway complications are suspected, the mnemonic "DOPES" (dislocation, obstruction, pneumothorax, equipment, stomach [hyperinflation]) can be helpful in systematically detecting the cause, particularly in emergency situations (Table 5) [62].

> **Acute changes to vital signs (e.g. a drop in SpO_2, an increase in inspiratory pressure) following induction or during maintenance of anaesthesia must trigger immediate re-evaluation in accordance with the ABCDE-algorithm, so as to rapidly detect and rectify the cause.**

Table 5
"DOPES" mnemonic for acute airway problems in intubated patients (modified from [62]).

D	Dislocation (endotracheal tube disconnected? → Check breathing system!)
O	Obstruction (bronchospasm following induction of anaesthesia → auscultation, capnography)
P	Pneumothorax (auscultation? Inspiratory pressure? Trauma?)
E	Equipment (ventilator and monitoring intact? Breathing system set up correctly? Leaks? → Examine the whole system)
S	Stomach (paediatric patients especially may have suffered gastric insufflation during mask ventilation → insert a gastric tube or suction air once-off)

Managing complications and problems

Complications must be recognised rapidly and rectified in a structured and consequent fashion. A **difficult airway** must be anticipated in the prehospital setting. Generally speaking, video laryngoscopy is an option which can optimise intubation conditions even when the patient cannot be ideally positioned, or neck extension is limited. For trauma patients in particular, video laryngoscopy should be used from the outset [59]. A return to spontaneous breathing can hardly be put into effect when an unexpected difficult airway is encountered in a prehospital setting. Instead, thinking forwards, a sufficient airway management strategy must be enacted. Following a maximum of two intubation attempts (intermediate ventilation!) a switch should be made to an alternative approach, initially using a supraglottic airway but moving on to establish a surgical airway (cricothyrotomy) as a measure of last resort if required [53].

An **insufficient depth of anaesthesia** can lead to movement, laryngo- and bronchospasm and awareness. Manipulation of the patient should be suspended, and the depth of anaesthesia increased.

The incidence of **hypotension** following prehospital induction of anaesthesia is 7–18% [63,64]. Use of standard monitoring including oscillometric blood pressure measurements at close intervals is essential. Depending on the patient's situation, fluids should be administered and vasopressors be utilised early (e.g. cafedrine/theodrenaline, noradrenaline e.g. 10 µg boli IV or possibly adrenaline).

Anaphylactic reactions can potentially be caused by any anaesthetic agent, especially by neuromuscular blocking agents. In such cases, standardised management (e.g. glucocorticoids, H_1/H_2 receptor blockers and adrenaline IV) must be instigated immediately. **Aspiration and oral, nasal and pharyngeal haemorrhage** have been reported with an incidence of 14–20% [65] – as such it is crucial suction should be available immediately. **As hypoxia** can arise with an incidence of 5–18% [66], effective preoxygenation is essential, reducing the risk of hypoxia due to failed or delayed airway management [60].

Concepts in anaesthesia for miscellaneous emergencies

The following concepts for anaesthesia are based on suggestions in the S1 guideline on "prehospital emergency anaesthesia in adults" [54]:

Trauma/multiple trauma: Table 6 lays out a suggestion for standardised prehospital emergency anaesthesia in the context of major (multiple) trauma using a selection of suitable drugs. In that context, haemodynamic instability due to hypovolaemia must be taken into consideration. Ketamine with midazolam is especially suitable for induction of anaesthesia and adequate fluid administration during induction is essential.

Isolated neurotrauma, apoplexy, intracranial haemorrhage: Drugs which lower intracranial pressure such as propofol or thiopental are particularly suitable for induction of anaesthesia and can help avoid blood pressure spikes (with consecutive increased intracranial pressure) associated with inadequate depth of anaesthesia.

High cardiac risk patients: Anaesthetics drugs such as midazolam, etomidate, fentanyl or sufentanil which exert only minor effects on the cardiovascular system (shifts in inotropy, preload and afterload) should be preferred.

Patients in respiratory failure: rapid-acting drugs should be used for induction of anaesthesia. Ketamine may be indicated specifically for its bronchodilatory effect.

Table 6
Emergency anaesthesia in patients with severe trauma (modified from [54]).

Example: motor vehicle accident, 25-year-old male, SBP 110 mmHg, HR 96 bpm, SpO₂ 88%, body weight approx. 70 kg, head injury, chest injury, open right femur fractur, left upper ankle joint fracture, currently still trapped in his vehicle.	
Analgosedation maintaining spontaneous breathing during the extrication phase:	midazolam 3 mg IV + esketamine 25 mg IV (bolus 10 mg approx. every 20 min if required) + fluid resuscitation using suitable fluids IV
Prepare for anaesthesia and **preoxygenate**	
Induction of anaesthesia*	thiopental 200 mg or midazolam 7 mg or propofol 100 mg IV + esketamine 100 mg or fentanyl 0.2 mg or sufentanil 20 µg IV + rocuronium 70–100 mg or succinylcholine 100 mg IV
Secure airway* increase depth of anaesthesia with midazolam 3–5 mg IV if required	
Maintenance of anaesthesia*	midazolam 3–5 mg IV (repeat approx. every 20 min) + esketamine 20 mg (repeat approx. every 20 min) or fentanyl 0.15 mg IV (repeat approx. every 20 min) + rocuronium 20 mg IV (repeat approx. every 20 min)

* Haemodynamic support using noradrenaline 10 µg boli as required to attain SBP goal or via syringe driver.

Drug Overview

Preliminary remarks

This section provides an overview of the most commonly used drugs in the context of induction and maintenance of anaesthesia in an emergency medical setting. Generally speaking, to avoid critical hypotension or complications ranging from cardiac failure to cardiac arrest, drugs used for analgesia and emergency anaesthesia should be dose adapted or titrated to effect especially in critically ill patients and those in cardiorespiratory failure.

Hypnotics

Propofol: as the arguably most commonly used induction-agent in the in-hospital setting, propofol is also made available in many EMS (Table 7). It causes respiratory depression and a decrease in blood pressure by moderating sympathoadrenal stimulation and reducing peripheral vascular resistance. These side effects are exacerbated in patients with cardiovascular failure and hypo-volaemia especially. As such, propofol should be used for RSI only in haemo-dynamically stable patients and the dose should be adapted appropriately. With regard to anaesthesia, propofol exhibits only hypnotic effects and a short duration of action – maintenance of anaesthesia requires alternative drugs (e.g. midazolam) or – for haemodynamically stable patients – continuous administration of propofol 2% via syringe driver. Its ability to reduce intracranial pressure and its anticonvulsive effect can be put to use when it is used for induction of anaesthesia in head injuries, intracranial haemorrhage and status epilepticus.

Etomidate: this purely hypnotic induction agent is still made available in numerous EMS for its propensity to provide haemodynamic stability during induction of anaesthesia (Table 7). It can cause myoclonus (caution: this may lead to difficult mask ventilation) and administration should therefore be preceded by a benzodiazepine. Irreversible inhibition of cortisol synthesis in the adrenal gland has been reported, which has led to increasing use of alternatives or even substitution of etomidate. With regard to intubation success and haemodynamic stability, ketamine is seen as equivalent to etomidate and should as such be favoured when treating trauma patients [59].

Midazolam: this rapid but short acting benzodiazepine has a broad therapeutic index (Table 7). Midazolam has a plasma half-life of 1.5 to 2.5 hours – notably longer than that of etomidate – and can be used in various combinations for induction of anaesthesia, although not as monotherapy. A combination with opioids (e.g. midazolam/fentanyl) is common, as is the combination with ketamine. Midazolam is especially suited to main-

Table 7
Hypnotics (modified from [54]).

Drug	Dose	Mode of Action	Side effects	Notes
Propofol	Induction of anaesthesia: (1–) 1.5–2.5 mg/kg BW IV Maintenance of anaesthesia: 3 (4) – 6 (–12) mg/kg BW/h IV or bolused as required 0.25–0.5 mg/kg BW IV Onset of action: 15–45 s Duration of action: 5–10 min	GABA receptor agonist	Respiratory depression or apnoea, decreased blood pressure (negative inotropic effect, reduced peripheral vascular resistance) especially in the presence of hypovolaemia, excitation phenomena, injection pain, histamine liberation	Mild bronchodilatory effect, favourable effects in head injuries and increased ICP
Etomidate	Induction of anaesthesia: 0.15–0.3 mg/kg BW IV Onset of action: 15–45 s Duration of action (half-life): 3–12 min	Not conclusively established, hypnotic effect partially exerted via a GABAergic mechanism	Nausea and vomiting, mild respiratory depression, injection pain, myoclonus	Impairs cortisol synthesis (11β-hydroxylase) even following single use, increasing the risk to patients suffering trauma or sepsis of complications such as ARDS, multiorgan failure, increased hospital and/or intensive care length of stay, increased duration of mechanical ventilation, increased mortality
Midazolam	Induction of anaesthesia: 0.15–0.2 mg/kg BW IV Maintenance of anaesthesia: 0.03–0.2 mg/kg BW IV Onset of action: 60–90 s Duration of action (half-life): 1–4 h	Binds to the α-subunit on the GABA receptor effecting prolonged opening of chloride channels and with that an increased effect of the inhibitory CNS transmitter GABA.	Paradoxical excitation Caution: combination with alcohol (alcohol effects increased), respiratory depression when combined with opioids	Caution: Dosing errors due to mix-up when multiple different concentrations are provisioned [5 mg/5 ml (=1 mg/ml) ampoules and 15 mg /3 ml (= 5 mg/ml) ampoules]
Thiopental	Induction of anaesthesia: 3–5 mg/kg BW IV Onset of action: 10–20 s Duration of action: 6–8 min	GABA receptor agonist	Respiratory depression, hypotension, histamine liberation	Powder for solution, requires reconstitution prior to use Caution: paravascular administration causes necrosis

Table 8
Analgesics (modified from (67)].

Drug	Dose	Mode of action	Side effects	Notes
Morphine 10 mg/1 ml	Titrate to response, e.g. 2.5 mg boli IV	Pure opioid receptor agonist with high affinity to μ receptor and low affinity to κ receptor Reduces pulmonary vascular resistance Hydrophilic, and as such delayed onset of action (5–15 min) Duration of action 3–5 h	Respiratory depression, muscle rigidity, hypotension especially in the context of hypovolaemia, emesis, nausea, bradycardia, pruritus, bronchospasm, sedation	Antidote: naloxone Histamine liberation Active metabolites morphine-6-glucuronide and morphine-3-glucuronide which can cumulate in the presence of renal failure
Piritramide 7.5 mg/1 ml 15 mg/2 ml	Analgesia: 0.1 mg/kg	Potency 0.7 (morphine equivalency) Onset of action after 5–15 min Duration of action 3–4 hours	Respiratory depression muscle rigidity hypotension especially in the context of hypovolaemia bradycardia	
Fentanyl 0.1 mg/2 ml 0.5 mg/10 ml	Analgesia: titrate to response, 0.05–0.1 mg IV boli Induction of anaesthesia: start with 2 μg/kg BW IV Maintenance of anaesthesia: 1–3 μg/kg IV Onset of action: <30 s Duration of action (median): 0.3–0.5 h	Pure opioid receptor agonist with high affinity to μ receptor and low affinity to κ receptor	Respiratory depression muscle rigidity hypotension especially in the context of hypovolaemia bradycardia	Antidote: naloxone Store protected from light May cause chest wall rigidity
Sufentanil	Start with 0.15–0.7 μg/kg IV + 0,15 μg/kg IV repeat doses Onset of action: <2–3 min Duration of action (median): 0.2–0.3 h	Pure opioid receptor agonist with high affinity to μ receptor and low affinity to κ receptor	Respiratory depression muscle rigidity hypotension especially in the context of hypovolaemia bradycardia	Antidote: naloxone Store protected from light
Esketamine	0.25–0.5 mg/kg BW IV for analgesia preserving protective reflexes. Induction of anaesthesia: 0.5–1 mg/kg BW IV or 1.5–5 mg/kg IM Onset of action (IV): 30 s Duration of action (IV): 5–15 min	Non-competitive NMDA receptor antagonist Agonist effect on opioid receptors Inhibits peripheral catecholamine reuptake Influences central and peripheral monoaminergic and cholinergic neurotransmission, produces dissociative anaesthesia	Sympathomimetic; increases heart rate and blood pressure, respiratory depression ranging to apnoea, increased defensive reflexes in the pharyngeal and laryngeal regions (caution: laryngospasm when suctioning or intubating), anxiety, hallucinations	Esketamine does not increase ICP and can be used in the presence of head injuries. Use with caution in the context of severe heart failure. Do not store under 0° C as vial may shatter.
Ketamine	0.5–1 mg/kg BW IV for analgesia preserving protective reflexes. Induction of anaesthesia: 1–2 mg/kg BW IV or 4–10 mg/kg IM Onset of action (IV): 30 s Duration of action (IV): 5–15 min	Non-competitive NMDA receptor antagonist Agonist effect on opioid receptors Inhibits peripheral catecholamine reuptake Influences central and peripheral monoaminergic and cholinergic neurotransmission, produces dissociative anaesthesia	Sympathomimetic; increases heart rate and blood pressure respiratory depression ranging to apnoea increased defensive reflexes in the pharyngeal and laryngeal regions (caution: laryngospasm when suctioning or intubating), anxiety, hallucinations	Ketamine does not increase ICP and can be used in the presence of head injuries. Use with caution in the context of severe heart failure. Bronchodilatory effect in asthma. Do not store under 0° C as vial may shatter.

Table 9

Neuromuscular blocking agents (modified from (54)].

Drug	Dose	Mode of action	Side effects	Notes
Succinyl-choline	Single, on-off dose: in all age groups 1.0–1.5 mg/kg BW IV Onset of action: 60 - 90 s Duration of action: 3–6 min	Only depolarising neuro-muscular blocking agent; exerts its effect on the nicotinic acetylcholine (ACH) receptor at the motor end plate	Arrhythmias, tachycardia, brady-cardia, potassium liberation ranging to asystole, blood pressure changes muscle pain following fasciculations allergic reactions increased intraocular pressure (caution: penetrating injuries) increased gastric pressure increased salivation increased jaw pressure (up to 60 s), malignant hyperthermia	Increased sensitivity in the context of neuromuscular disease (reduce dose in necessary), pre-treatment with non-depolarising agent mitigates side effects, noteworthy rigor of the masseter muscle is deemed to be a warning sign for rhabdomyolysis or malignant hyperthermia, duration of action increased in the context of reduced cholinesterase activity
Rocuro-nium	For RSI: 1.0–1.2 mg/kg BW IV For geriatric patients use 0.6 mg/kg BW IV (Duration of action can be prolonged) Onset of action: 60–120 s Duration of action: 30–67 min	Non-depolarising neuromuscular blocking agent with an intermediate duration of action Competitive effect on the nicotinic acetylcholine (ACH) receptor at the motor end plate	Tachycardia, injection pain, allergic reactions	Reversible using sugammadex physically incompatible with dexamethasone, diazepam, furosemide, hydrocortisone sodium succinate, insulin, intralipid, methylprednisolone, prednisolone sodium succinate, thiopental

tenance of anaesthesia via repeat bolus administration during transfer to hospital. It exhibits amnestic and anticonvulsive effects.

Thiopental: this drug is made available as a powder for solution by some EMS (Table 7). As a barbiturate it exhibits a rapid onset of action, good suppression of reflexes and depth of anaesthesia, and anticonvulsive effects in addition to reducing intracranial pressure. As such it is particularly suited to induction of anaesthesia in head injuries, intracranial haemorrhage and status epilepticus. Its side effects are hypotension (so provide fluid management and possibly vasopressors), liberation of histamine potentially causing bronchospasm, and widespread necrosis following paravascular administration.

Analgesics

Fentanyl: well-established in most EMS, fentanyl can be carefully titrated as monotherapy at low doses to provide analgesia whilst maintaining spontaneous breathing or in combination with a hypnotic for induction and maintenance of anaesthesia (Table 8). It is also effective when administered via the nasal or buccal routes. Its major side effect is respiratory depression, something which

should be taken into account especially when treating geriatric patients.

Sufentanil: with regard to opioids commonly used in emergency medicine sufentanil exhibits the greatest affinity to µ receptors but – like fentanyl – is not approved for use as an analgesic outside the setting of general anaesthesia (Table 8). It can be bolused or administered continuously via syringe driver.

Ketamine/esketamine: depending on dose administered, ketamine and esketamine can be used as analgesics or for induction and maintenance of anaesthesia. Low doses lead to dissociative analgesia (a cataleptic state entailing amnesia and analgesia) whilst protective reflexes and spontaneous breathing are sustained depending on dose. Medium doses cause hypnosis whilst high doses also lead to bronchodilation, making ketamine especially suited to induction of anaesthesia for status asthmaticus. The opioid and NMDA (N-methyl-D-aspartate) receptor mediated analgesic effect is desirable. Conversely, undesirable states of arousal and nightmares have been described (such that benzodiazepines are co-administered), as have hyperacusis and hypersalivation (requiring suction). Ketamine can be used in patients with

head injuries on the condition that normoventilation is monitored using capnography.

Neuromuscular blocking agents

For RSI neuromuscular blocking agents with a rapid onset of action are essential (Table 9) – it is for this reason that rocuronium and succinylcholine are suitable for use in emergency medicine. Succinylcholine distinguishes itself from rocuronium through its more rapid onset and significantly shorter duration of action. Its side effect profile and contraindications (hyperkalaemia, contraindications: prolonged immobilisation, possible trigger for malignant hyperthermia) have, however, led to more frequent use of rocuronium in the prehospital setting. Ultimately only neuromuscular block can provide optimum conditions for intubation in an emergency setting. Potential reversal of neuromuscular block following a correct decision to induce anaesthesia is the subject of ongoing debate. The authors are of the opinion, however, that prehospital airway management should instead employ a strategy of going forwards, providing and using alternative means of airway management.

Maintenance of anaesthesia

In a prehospital setting, maintenance of anaesthesia can only be by intravenous means. Because of its controllability and ubiquitous availability, midazolam is the agent of choice and can be bolused as required both during prehospital care and transfer to hospital. Analgesia may also require continuation when transfer times are prolonged. Where available, anaesthesia can also be maintained using propofol via syringe driver whilst paying attention to haemodynamic stability. To avoid complications (e.g. awareness, endotracheal tube dislocation, increased intracranial pressure caused by spontaneous breathing or pain) sufficient depth of anaesthesia must be upheld, especially when the patient is positioned or otherwise manipulated.

Literatur

1. Hossfeld B, Holsträter S, Bernhard M, Lampl L, Helm M, Kulla M: Prähospitale Analgesie bei Erwachsenen – Schmerzerfassung und Therapieoptionen. Anästhesiol Intensivmed Notfallmed Schmerzthr 2016;51:84–95

2. Indikationskatalog für den Notarzteinsatz. Handreichung für Telefondisponenten in Notdienstzentralen und Rettungsleitstellen, Stand: 22.02.2013. Deutsches Ärzteblatt 2013;110(11):A-521

3. Hofmann-Kiefer K, Praeger K, Fiedermutz M et al: Qualität schmerztherapeutischer Maßnahmen bei der präklinischen Versorgung akut kranker Patienten. Anaesthesist 1998;47:93–101

4. Hofmann-Kiefer K, Praeger K, Buchfelder A et al: Präklinische Schmerztherapie an einem innerstädtischen Notarztstandort. Anästh Intensivmed 1998;8:362–368

5. Guéant S, Taleb A, Borel-Kühner J, et al: Quality of pain management in the emergency department: results of a multicenter prospective study. Eur J Anaesthesiol 2011;28:97–105

6. Todd KH, Ducharme J, Choiniere M et al: Pain in the emergency department: results of the pain and emergency medicine initiative (PEMI) multicenter study. J Pain 2007;6:460–466

7. Abbuhl FB, Reed DB: Time to analgesia for patients with painful extremity injuries transported to the emergency department by ambulance. Prehosp Emerg Care 2003;7:445–447

8. McEachin CC, McDermott JT, Swor R: Few emergency medical services patients with lower-extremity fractures receive prehospital analgesia. Prehosp Emerg Care 2002;6:406–410

9. Oberholzer N, et al: Factors Influencing Quality of Pain Management in a Physician Staffed Helicopter Emergency Medical Service. Anesth Analg 2017; 125:200–209

10. Albrecht E, Taffe P, Yersin B, Schoettker P, Decosterd I, Hugli O: Undertreatment of acute pain (oligoanalgesia) and medical practice variation in prehospital analgesia of adult trauma patients: a 10 yr retrospective study. Br J Anaesth 2013; 110:96–106

11. Galinski M, Ruscev M, Gonzalez G, et al: Prevalence and Management of Acute Pain in Prehospital Emergency Medicine. Prehosp Emerg Care 2010;14:334–339

12. Stork B, Hofmann-Kiefer K: Analgesia as an important component of emergency care. Notfall Rettungsmed 2008; 11:427–438

13. Bendall JC, Simpson PM, Middleton PM: Prehospital vital signs can predict pain severity. Europ J Emerg Med 2011;18: 334–339

14. Shade BR, Collins TE, Wertz EM, et al: Mosby's EMT Intermediate textbook for the 1999 National Standard Curriculum, 3. Auflage. St. Louis: Mosby 2007

15. Girrbach FF, Bernhard M, Hammer N, Bercker S: Intranasale Medikamentenapplikation im Rettungsdienst. Technik und Indikationen. Notfall Rettungsmed 2018;21:120–128

16. Helm M, Gräsner JT, Gries A, Fischer M, Böttiger BW, Eich C et al: Die intraossäre Infusion in der Notfallmedizin. Anästh Intensivmed 2018;59:667–677

17. Green SM, Roback MG, Kennedy RM, et al: Clinical practice guideline for emergency department ketamine dissociative sedation: 2011 update. Ann Emerg Med 2011;57:449–461

18. Taeger K: Leitlinie zur Sedierung und Analgesie (Analgosedierung) von Patienten durch Nicht-Anästhesisten. Anästh Intensivmed 2002;43:639–641

19. Häske D, Böttiger BW, Bouillon B, Fischer M, Gaier G, Gliwitzky B et al: Analgesie bei Traumapatienten in der Notfallmedizin: Eine systematische Übersichtsarbeit und Metaanalyse. Dtsch Arztebl Int 2017;114:785–792

20. Rörtgen D, Schaumberg A, Skorning M, et al: Stocked medications in emergency physician-based medical services in Germany. Reality and requirements according to guidelines. Anaesthesist 2011;60:312–324

21. Craig M, Jeavons R, Probert J, Benger J: Randomised comparison of intravenous paracetamol and intravenous morphine for acute traumatic limb pain in the emergency department. Emerg Med J 2012;29:37–39

22. Hoogewijs J, Diltoer MW, Hubloue I, et al: A prospective, open, single blind, random- ized study comparing four analgesics in the treatment of peripheral injury in the emergency department. Eur J Emerg Med 2000;7:119–123

23. Viallon A, Marjollet O, Guyomarch P, et al: Analgesic efficacy of orodispersible paracetamol in patients admitted to the emergency department with an osteoarticular injury. Eur J Emerg Med 2000;14:337–342

24. Woo WW, Man SY, Lam PK, Rainer TH: Randomized double-blind trial comparing oral paracetamol and oral nonsteroidal antiinflammatory drugs for treating pain after musculoskeletal injury. Ann Emerg Med 2005;46:352–361

25. Furyk J, Levas D, Close B, et al: Intravenous versus oral paracetamol for acute pain in adults in the emergency department setting: a prospective, double-blind, double-dummy, randomised controlled trial. Emerg Med J 2018;35: 179–184

26. Angster R, Hainsch-Müller I: Postoperatives Schmerzmanagement. Anaesthesist 2005;54:505–533

27. Roger L, Cros J, Boulogne P, et al: Inhibition of acetaminophen analgesic action by ondansetron after amygdalectomy in children: the Paratron randomized trial: 10AP5-4. Eur Journal Anaesthesiol 2014;31:174

28. Kötter T, daCosta BR, Fässler M, Blozik E, Linde K, Jüngi P, et al: Metamizole-Associated Adverse Events: A Systematic Review and Meta-Analysis. PLoS One 2015;10:e0122918

29. Metamizol (Novalgin, Berlosin, Novaminsulfon, etc.): BfArM weist auf richtige Indikationsstellung und Beachtung von Vorsichtsmaßnahmen und Warnhinweisen hin. https://www.bfarm.de/ SharedDocs/Risikoinformationen/ Pharmakovigilanz/DE/RI/2009/RI-metamizol.html (Zugriffsdatum: 13.01.2020)

30. Polzin A, Zeus T, Schror K, et al: Dipyrone (metamizole) can nullify the antiplatelet effect of aspirin in patients with coronary artery disease. J Am Coll Cardiol 2013;62:1725–1726

31. Polzin A, Richter S, Schror K, et al: Prevention of dipyrone (metamizole) induced inhibition of aspirin antiplatelet effects. Thromb Haemost 2015;114:87–95

32. Achilles A, Mohring A, Dannenberg L, et al: Analgesic medication with dipyrone in patients with coronary artery disease: Relation to MACCE. Int J Cardiol 2017;236:76–81

33. Chudnofsky CR, Weber JE, Stoyanoff PJ, et al: A combination of midazolam and ketamine for procedural sedation and

analgesia in adult emergency department patients. AcadEmergMed 2000;7:228–235

34. Bourgoin A, Albanese J, Leone M, et al: Effects of sufentanil or ketamine administered in target-controlled infusion on the cerebral hemodynamics of severely brain-injured patients. Crit Care Med 2005;33:1109–1113

35. Bredmose PP, Lockey DJ, Grier G, Watts B, Davies G: Pre-hospital use of ketamine for analgesia and procedural sedation. Emerg Med J 2009;26:62–64

36. Häske D, Schempf B, Gaier G et al: Prähospitale Analgosedierung durch Rettungsassistenten. Anaesthesist 2014; 63:209–216

37. Höll M: Präklinische Analgosedierung mit Ketamin-S und Midazolam durch Notfallsanitäter. Anästh Intensivmed 2017;58:S108

38. Schempf B, Casu S, Häske D: Prähospitale Analgosedierung durch Notärzte und Rettungsassistenten. Anaesthesist 2017;66:325–332

39. Johansson J, Sjöberg J, Nordgren M, Sandström E, Sjöberg F, Zetterström H: Prehospital analgesia using nasal administration of S-ketamine – a case series. Scand J Trauma Resusc Emerg Med 2013;21:38

40. Yeaman F, Oakley E, Meek R, Graudins A: Sub-dissociative dose intranasal ketamine for limb injury pain in children in the emergency department: a pilot study. Emerg Med Australas 2013;25:161–167

41. Keita H, Tubach F, Maalouli J, et al: Age-adapted morphine titration produces equivalent analgesia and adverse effects in younger and older patients. Eur J Anaesthesiol 2008;25:352–356

42. Galinski M, Dolveck F, Combes X, et al: Management of severe acute pain in emergency settings: ketamine reduces morphine consumption. Am J Emerg Med 2007;25:385–390

43. Farag M, Spinthakis N, Srinivasan M, et al: Morphine analgesia pre-PPCI is associated with prothrombotic state, reduced spontaneous reperfusion and greater infarct size. Thromb Haemost 2018;118:601–612

44. Kotwal RS, O'Connor KC, Johnson TR, et al: A novel pain management strategy for combat casualty care. Ann Emerg Med 2004;44:121–127

45. Scharonow M, Alberding T, Oltmanns W, Weilbach C: Project for the introduction of prehospital analgesia with fentanyl and morphine administered by specially trained paramedics in a rural service area in Germany. J Pain Res 2017;10: 2595–2599

46. Greb I, Wranze E, Hartmann H, Wulf H, Kill C: Analgesie beim Extremitäten-trauma durch Rettungsfachpersonal. Notfall Rettungsmed 2011;14:135–142

47. Brokmann JC, Rossaint R, Hirsch F, Beckers SK, Czaplik M, Chowanetz M, et al: Analgesia by telemedically supported paramedics compared with physician-administered analgesia: A prospective, interventional, multicentre trial. Eur J Pain 2016; 20:1176–1184

48. Kariman H, Majidi A, Amini A, et al: Nitrous oxide/oxygen compared with fentanyl in reducing pain among adults with isolated extremity trauma: A randomized trial. Emerg Med Australas 2011;23(6):761–768. DOI: 10.1111/j.1742-6723.2011.01447.x

49. Hengefeld N, Lukas RP, Klaus S et al: Lachgas-Sauerstoff-Gemisch (Livopan®) bei Extremitätentrauma – die LAbET Studie. Anästh Intensivmed 2014;55:S13

50. Rote-Hand-Brief zu Haldol® und Haldol Decanoat Depot® (Haloperidol): Änderungen der Indikationen und Dosierung. https://www.bfarm.de/SharedDocs/Risikoinformationen/Pharmakovigilanz/DE/RHB/2017/rhb-haldol.html (Zugriffsdatum: 13.01.2020)

51. Stollings JL, Diedrich DA, Oyen LJ, et al: Rapid-sequence intubation: a review of the process and considerations when choosing medications. Ann Pharmacother 2014;48:62–76

52. Adams HA, Flemming A: Analgesie, Sedierung und Anästhesie in der Notfallmedizin. Anästh Intensivmed 2015;56:75–90

53. Timmermann A, Böttiger BW, Byhahn C, Dörges V, Eich C, Gräsner JT et al: S1-Leitlinie: Prähospitales Atemwegsmanagement (Kurzfassung). Anästh Intensivmed 2019;60:316–336. DOI: 10.19224/ai2019.316

54. Bernhard M, Bein B, Böttiger BW, Bohn A et al: Handlungsempfehlung: Prähospitale Notfallnarkose beim Erwachsenen. Anästh Intensivmed 2015; 56:S477–S491

55. Sefrin P, Kuhnigk H, Wurmb T: Narkose im Rettungsdienst. Notarzt 2014;30:73–84

56. Cook T, Behringer EC, Benger J: Airway Management outside the operating room: hazardous and incompletely studied. Curr Opin Anestesiol 2012;25:461–469

57. Heuer JF, Barwing TA, Barwing J, et al: Incidence of difficult intubation in intensive care patients: Analysis of contributing factors. Anaest Intensive Care 2012;40:120–127

58. Paal P, Herff H, Mitterlechner T, et al: Anesthesia in prehospital emergencies and in the emergency room. Resuscitation 2010;81:148–154

59. S3-Leitlinie Polytrauma/Schwerverletzten-behandlung, AWMF-Register Nr.: 012/019

60. Weingart SD, Levitan RM: Preoxygenation and prevention of desaturation during emergency airway management. Ann Emerg Med 2012;59(3):165–175

61. DIVI-Empfehlung zur Kennzeichnung von Spritzen in der Intensiv- und Notfallmedizin 2012. https://www.divi.de/empfehlungen/publikationen/empfehlung-spritzenetiket-ten/349-20120702-publikationen-di-vi-spritzenetiketten-empfehlung (Zugriffsdatum: 13.01.2020)

62. Maconochie IK, Bingham R, Eich C et al: Lebensrettende Maßnahmen bei Kindern („paediatric life support"). Notfall + Rettungsmedizin 2015;18:932

63. Newton A, Ratchford A, Khan I: Incidence of adverse events during prehospital rapid sequence intubation: A review of one year on the London helicopter emergency medical service. J Trauma 2008;64:487–492

64. Rognås L, Hansen TM, Kirkegaard H, Tønnesen E: Pre-hospital advanced airway management by experienced anaesthesiologists: a prospective descriptive study. Scand J Trauma Resusc Emerg Med 2013;21:58

65. Helm M, Hossfeld B, Schäfer S, Hoitz J, Lampl L: Factors influencing emergency intubation in the prehospital setting – a multicentre study in the German Helicopter Emergency Medical Service. Br J Anaesth 2006;96:67–71

66. Helm M, Kremers G, Lampl L, Hossfeld B: Incidence of transient hypoxia during pre-hospital rapid sequence intubation by anaesthesiologists. Acta Anaesthesiol Scand 2013;57:199–205

67. Hossfeld B, Holsträter S, Bernhard M, Lampl L, Helm M, Kulla M: Prähospitale Analgesie beim Erwachsenen. Notfall-med up2date 2015;10:269–284.

Correspondence-adresse

Priv.-Doz. Dr. med. Michael Bernhard, MHBA

Zentrale Notaufnahme
Universitätsklinik Düsseldorf
Moorenstr. 5
40225 Düsseldorf, Germany

Phone: 0211 81-07749
Fax: 0211 81-015-07749

Mail: Michael.Bernhard@med.uni-duesseldorf.de

ORCID-ID: 0000-0003-1179-7943