Ketamine for Procedural Sedation and Analgesia by Nonanesthesiologists in the Field: A Review for Military Health Care Providers

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Military health care providers located in field environments frequently face situations in which procedural sedation and analgesia are necessary, without the advantage of sophisticated monitoring equipment. Ketamine is a unique agent that can be administered either intravenously or intramuscularly to produce predictable and profound analgesia, with an exceptional safety profile. We review the issues unique to ketamine and provide a practical guide for the use of ketamine for adult and pediatric patients in a field environment.

Introduction

During conflicts, military health care providers often practice in an austere environment without sophisticated equipment or immediate specialist assistance. In this setting, providers often face casualties who require brief painful procedures such as wound exploration and closure, fracture and dislocation reduction, and abscess drainage. Although providers can accomplish some of these procedures using local anesthetics, many require procedural sedation and analgesia (PRSA). In the field environment, ketamine is an excellent choice for select procedures and patients. Ketamine has unique pharmacologic and clinical properties that make it a potent addition to the repertoire of field clinicians.[1,2] However, these same properties require some understanding of this unique medication. This article reviews the clinical use of ketamine by nonanesthesiologists in the field environment, for both adult and pediatric patients needing PRSA for short procedures. The use of ketamine combined with inhalational agents for general anesthesia, in a setting with mechanical ventilation and chemical paralysis, has been well described and is beyond the scope of this review.[3,4]

Standard PRSA

To best understand the unique clinical effects of ketamine, one must contrast them with standard agents used for PRSA. Typical medications used for PRSA include an opiate and benzodiazepine combination, a fast-acting barbiturate such as methohexital, or sedative/hypnotics such as etomidate and propofol. Inherent in the use of these agents is the concept of small titrated intravenous doses to gradually move the patient along the sedation continuum from nonsedated to mild, moderate, and then deep sedation, depending on the clinical effect needed for the procedure.[5] Clinicians attempt to use the smallest amount of agent needed to accomplish the procedure, to avoid the cardiopulmonary depression that accompanies these agents. Along with decreases in blood pressure and respiratory rate, these medications may suppress protective airway reflexes as the patient becomes more sedated. All of these agents can induce general anesthesia in larger doses, requiring assisted ventilation, with the concomitant risk of gastric distention, emesis, and (because of the loss of protective reflexes) pulmonary aspiration. Unfortunately, the effective dose of these medications for any given patient cannot always be predicted and doses vary depending on the patient and the procedure. The potential for clinically important respiratory depression and apnea for some of these agents (etomidate, propofol, and methohexital) relegates them to clinicians specifically trained and experienced in the use of these medications and their effects and operating in controlled settings.

Ketamine for PRSA

Clinical and Pharmacologic Properties

In contrast to the usual agents for PRSA, ketamine has fundamentally different clinical and pharmacologic properties. First synthesized in 1962, ketamine is structurally similar to phencyclidine. It blocks the excitatory neurotransmitter glutamate at N-methyl-D-aspartate receptors. Clinically, ketamine disconnects the thalamus from the neocortex, blocking input from the environment from reaching consciousness.[6] This induces what has been called a "dissociative" state, in which patients cannot see, hear, or feel any sensations.[7] Combined with simultaneous depression of the cortex, ketamine results in a trance-like state in which patients have profound analgesia, sedation, and amnesia.[8] For brief procedures requiring PRSA, clinicians should grade the dissociation of ketamine as either present or absent.[9] This is in contrast to the sedation continuum inherent with other agents. Once patient are dissociated, they cannot be made any more "sedated" with additional doses of ketamine (although the duration of dissociation can be prolonged). Once dissociated, a patient will not respond to pain regardless of the procedure performed. A provider can perform an arm amputation or a simple laceration repair with identical PRSA conditions. This contrasts with other agents, which typically need deeper sedation for more painful procedures. With such agents, one may never reach adequate conditions for some procedures without inducing general anesthesia (with the loss of respiratory drive and protective reflexes).

Whereas higher doses of ketamine produce no additional clinical benefit once the patient is dissociated, the need to use the smallest possible effective dose (to avoid the respiratory depres-

sion and adverse effects seen with other agents) is also unnecessary. Ketamine does not cause cardiopulmonary depression or a loss of protective airway reflexes.[6] Therefore, ketamine is given as a single bolus for PRSA, rather than as repeated small doses titrated to effect.[9] Unlike many other agents, effective dosing for ketamine is well established and consistent from patient to patient. These advantages become paramount for military providers in the field environment, where there may be minimal monitoring equipment to detect hypoxia and minimal equipment, expertise, and time for airway rescue.

Although ketamine has the distinct advantages of preserving blood pressure, spontaneous respirations, and protective airway reflexes while inducing profound analgesia with well-defined dosing, it also has specific drawbacks that limit its utility in certain situations. These caveats necessitate careful patient selection, as discussed below, before the use of ketamine.

Laryngospasm and Ketamine

Although one of the advantages of ketamine is the maintenance of protective airway reflexes, this comes at the cost of an increased risk of laryngospasm, which can be thought of as a hyper-reflexive airway. The risk of laryngospasm in the two largest emergency department (ED) series of ketamine was only 0.4%[10] and 0.07%.[11] Clinically this presents as noisy respirations, stridor, and possibly desaturation. Fortunately, ketamine-associated laryngospasm is transient (lasting 1–5 minutes) and typically responds well to a few positive-pressure breaths given through a bag-and-mask apparatus. A vigorous jaw thrust may alter the airway dynamics slightly and halt the laryngospasm. Although some practitioners avoid ketamine specifically because of laryngospasm, this hesitancy seems unwarranted. In a review of 11,589 cases of ketamine PRSA, only two cases (0.02%) required intubation[12,13] and, on retrospective review, the intubation was likely unnecessary in both cases.[9] Compared with the use of other PRSA medications, with their attendant suppression of respirations and protective airway reflexes, ketamine frequently represents the safest option in a field setting.

Agitated Emergence Reactions and Ketamine

Another commonly cited drawback to ketamine for PRSA is the possibility of agitated reactions during emergence from the dissociative state. As patients begin to "reconnect" with outside stimuli, they may have hallucinations, which can be either pleasant or unpleasant. Among children receiving ketamine for PRSA, only 1.6% had reactions judged as more than mild.[10] However, adults may have higher rates of unpleasant hallucinations, ranging from 0% to 30%.[14] Very rarely, patients may have a pronounced significant reaction to ketamine, which may even include physical combativeness. Fortunately, providers can consistently alleviate these reactions, when they occur, with titrated doses of benzodiazepines, such that they rarely affect normal operations.

Although research has shown that the risk of these hallucinatory emergence reactions is quite low (particularly for children), many providers anecdotally associate ketamine with frequent recovery agitation among pediatric patients. However, agitation after sedation occurs with most medications used for PRSA, and providers should understand that hallucinatory emergence reactions differ from simple nonhallucinatory recovery agitation. The rates of nonhallucinatory recovery agitation are identical for children sedated with ketamine and those sedated with midazolam alone.[15–17] Agitation occurs more frequently among patients <5 years of age (22.5%), compared with those >5 years of age (12.5%).[18] Therefore, the concern that ketamine produces frequent pronounced agitation during recovery is not substantiated, based on review of the available literature. It is likely that providers who observe nonhallucinatory recovery agitation associate this with ketamine, despite equal rates with midazolam alone.

Use of Ketamine for Pediatric Patients

Choice of Ketamine for PRSA

In the developed world, physicians use ketamine predominantly for pediatric procedures. Guidelines for using ketamine for PRSA among children were recently published by the American College of Emergency Physicians.[9] Although these guidelines pertain to ketamine use in the ED and not the field, they are an excellent reference (Table I).

When contemplating the use of any sedation medication for children, providers must review specific known contraindications. Absolute contraindications, as stated in the guidelines, include only age of <3 months and previous psychiatric conditions.[9] Although ketamine can rarely induce laryngospasm in any given patient, this tendency is likely heightened among children <3 months of age, and other agents should be used in this group. Previous psychiatric conditions greatly increase the likelihood of agitated emergence reactions and contraindicate the use of ketamine.[19] Relative contraindications to ketamine use include several conditions that, based on inconclusive data, suggest an increased risk of complications. Laryngospasm may occur more frequently among children 3 to 12 months of age[8] and children with active upper respiratory tract infections or active asthma.[20] However, the magnitude of this risk appears minimal, and many clinicians use ketamine despite these characteristics.[9] Ketamine may increase intracranial pressure[21] and traditionally has been avoided for patients with possible head injuries or other conditions with increased intracranial pressure.[22] Similarly, intraocular pressure is transiently increased with ketamine, and clinicians must weigh this risk when considering its use among patients with serious eye injuries.[23] Finally, the sympathomimetic effect of ketamine, although well tolerated by most children, may be aggravated among patients with hyperthyroidism[24] and poorly tolerated by patients with certain cardiac conditions.[6]

The procedure required also may necessitate the use of agents other than ketamine. Clinicians should consider an increased risk of laryngospasm when performing procedures that may stimulate the upper airway (such as peritonsillar abscess drainage or intraoral laceration repair).[25] Procedures requiring muscle relaxation may require an agent other than ketamine (although fracture and dislocation reductions can be easily accomplished). Some random motions during ketamine sedation may limit its use if the patient must remain completely still for procedural reasons or for imaging studies. Delicate ocular procedures require the use of agents other than ketamine because of nystagmus and random eye movements that may occur during the sedation.

TABLE I

SUMMARY OF KETAMINE FOR PEDIATRIC PRSA

Indications	Short, painful, or emotionally disturbing procedures that require PRSA
Contraindications	Absolute: age of <3 months, history of psychosis; relative: age of <12 months, active asthma, upper respiratory infections, thyroid dysfunction, cardiac conditions, risk of increased intracranial pressure, eye injury, glaucoma, procedures that stimulate the hypopharynx
Preparation	When available, monitors (oxygen saturation, ECG, and blood pressure), suction, oxygen source, airway rescue equipment, and physical restraints; council those present on unique effects of ketamine; prepare patient for "dreaming"
Dosing	Intramuscular: 4–5 mg/kg; intravenous: 1.5–2 mg/kg over 60 seconds
Coadministered medications	Atropine: 0.01 mg/kg (minimum, 0.1 mg; maximum 0.5 mg), not mandatory; benzodiazepines: not recommended routinely for children
Onset and duration	Intramuscular: 5–10-minute onset, 20–30-minute duration; intravenous: 60-second onset, 5–10-minute duration; use same doses for redosing if necessary
Monitoring	Apnea in first 1–2 minutes after rapid intravenous dosing; stridor could be misaligned airway (0.7%), laryngospasm (0.4%), or hypersecretions; reposition airway, positive-pressure breaths if needed for 1–5 minutes, suction
Postprocedural observations	Emesis (3.5–12%), dysconjugate gaze, ataxia, emergence reactions (treat with titrated doses of benzodiazepine)
Discharge criteria	Returned to preprocedural verbal skills and obeys commands (ataxia does not need to resolve before discharge)

Preparation for Ketamine PRSA

The use of ketamine requires the standard precautions used for all PRSA. When available, monitoring equipment (for oxygen saturation monitoring, blood pressure monitoring, and electrocardiography [ECG]) should be used for all PRSA. The maintenance of independent respirations and hemodynamics inherent with ketamine argues strongly for its preferential use in field conditions where limited monitoring equipment is available. Suction equipment should be available in case of emesis, ideally with equipment needed for airway rescue (e.g., bag-valve-mask devices, Combitubes (Tyco Healthcare Nellcor), endotracheal tubes, and laryngeal mask airways). Practitioners using any agent for PRSA should develop familiarity with this equipment and with rescue techniques for establishing an airway and providing assisted respirations. Fortunately, ketamine has a remarkable safety profile in terms of unanticipated airway complications, partly because of its lack of respiratory depression.

Ketamine's dissociative state produces sedation conditions that differ from those of other agents. Those assisting with or observing ketamine sedation should anticipate that the patient's eyes will remain open and may show dysconjugate gaze and nystagmus; random movements unrelated to painful stimuli may be observed. Rarely, patients develop some lacrimation, and parents should be assured that this is not related to pain. Blood pressure and heart rate increase as a result of the sympathomimetic effects. During recovery, the patient may reach out into space to grasp at nonexistent objects. Despite these unusual observations, the patient does not perceive any pain or discomfort and will not recall the procedure. Because of rare agitated emergence reactions, clinicians should warn parents or other observers of this possibility and physical restraints, if available, should be at hand.

Many patients who experience ketamine sedation recall vivid dreaming after the procedure.[26] This has led some clinicians to "program" older children and adults before ketamine administration by having them pick the dreams they would like to have and imagine what they want to see, hear, feel, and smell. Although not studied, this may reduce the chance of unpleasant emergence reactions.

Dosing and Administration of Ketamine

Ketamine is poorly absorbed orally and typically must be administered through either intramuscular or intravenous routes. Fortunately, effective dosing for either route is well established and consistent from patient to patient. The choice of route depends on the procedure, the setting, and the patient. The advantages of intramuscular administration lie in its convenience and minimal equipment needs (preserving intravenous catheters if supplies are limited). Intramuscular injection of ketamine is given as a 5 mg/kg dose.[10] Onset occurs within 5 to 10 minutes, and sedation lasts 20 to 30 minutes. For the unusual child who is not dissociated within 10 minutes after the first intramuscular dose, a second dose of 2.5 to 5 mg/kg should be given.[10] This dissociates essentially all children within an additional 5 to 10 minutes. The disadvantages of intramuscular administration include the lack of intravenous access if a complication necessitates rescue medications, the slightly longer effective duration, compared with intravenous administration, and the rare need for a second injection.

Ketamine is administered intravenously as a bolus of 1.5 to 2 mg/kg.[8] Although ketamine does not normally suppress respirations, the notable exception occurs when higher doses are given through rapid intravenous injection.[27] Therefore, intravenous ketamine injections should be administered over at least 60 seconds.[9] Onset after intravenous dosing occurs within 60 seconds, and sedation lasts between 5 and 10 minutes. To prolong sedation, an additional 1.5 mg/kg can be administered over 60 seconds. Intravenous dosing obviously requires the placement of an intravenous catheter, which can be difficult for some children if the clinician is not experienced with pediatric intravenous access. If the intramuscular route is chosen, then it may be prudent to initiate the first dose of ketamine through

intramuscular injection and then place an intravenous catheter once the child is dissociated, in case additional doses are required.

Because of the unique effects of ketamine, smaller doses provide no advantage over larger doses across the usual therapeutic range. Therefore, clinicians should avoid the temptation to "titrate" ketamine in doses that are smaller than recommended.

Ketamine is available in vials with three different concentrations that vary by as much as tenfold, requiring providers to carefully assess the vial at hand before measuring and administering doses. Intravenous dosing is typically accomplished with the 10 mg/mL concentration (some physicians dilute this to a 1 mg/mL concentration). Intramuscular administration ideally requires the 100 mg/mL concentration, to minimize the injected volume. A 50 mg/mL concentration also exists.

When patients emerge from dissociation before the completion of a procedure (usually noted with motion in response to pain), ketamine should be redosed with the administration of an additional full dose, 5 mg/kg, if the intramuscular route is used or 0.5 to 1 mg/kg for the intravenous route.[9]

Coadministered Medications

Many physicians experienced with ketamine PRSA have traditionally administered ketamine along with atropine, a benzodiazepine, or both. The tendency for ketamine to increase oral secretions led many providers to give either atropine or glycopyrrolate simultaneously with ketamine.[6] More recent research suggests that anticholinergics are not routinely needed and should not be considered mandatory.[9] If used, the dose of atropine is 0.01 mg/kg administered intravenously or intramuscularly (minimum, 0.1 mg; maximum, 0.5 mg).

Theoretically, benzodiazepines coadministered with ketamine should reduce the risk of unpleasant emergence reactions.[6] Although this seems reasonable, blinded controlled studies have not shown any advantage of coadministered benzodiazepines for pediatric PRSA.[28,29] The potential respiratory depression associated with benzodiazepines, coupled with the lack of demonstrated efficacy, have led to a recommendation that benzodiazepines not be routinely coadministered for pediatric PRSA.[9]

Monitoring during PRSA

After ketamine administration, when the patient shows a lack of responses to stimuli, providers can begin their procedures. Ideally, two providers assist with PRSA, one who performs the procedure and one who monitors the patient.[9] In some field environments, this may not be possible and the sole provider must exercise extreme vigilance to monitor the patient and to execute the procedure simultaneously. When available, an oxygen saturation monitor should be attached. Blood pressure monitoring and ECG are ideal, although not typically necessary in the field environment, given the hemodynamic stability afforded by ketamine.

Providers should anticipate an increase in blood pressure as great as 25% of the baseline mean arterial pressure, along with an increase in heart rate.[30] Nystagmus and random limb movements are not uncommon.

Along with anticipated reactions to ketamine, providers must understand and prepare for uncommon events. As noted earlier,

rapid intravenous administration of ketamine may produce apnea or respiratory depression 1 or 2 minutes after dosing.[27] Although transient, this may require assisted respirations. Noisy respirations, including stridor, may occur during sedation. Providers should immediately consider three conditions, i.e., airway misalignment, laryngospasm, and excessive airway secretions. Airway misalignment occurs for 0.7% of pediatric patients.[10] Although this misalignment is not directly caused by ketamine, any unintended obstructive positioning of the airway is not noted or corrected by the patient in a dissociative state. Children have a proportionately much larger occiput than adults and a much narrower airway. Laying a child supine may result in flexion of the neck and kinking of the airway. Placement of a small roll under the shoulders (not under the head) allows the head to extend slightly to a more neutral position, better aligning the airway. Other attempts at aligning the airway (jaw thrust and chin lift) may be required.

If the airway appears appropriately aligned for a patient with noisy or stridorous respirations, then laryngospasm may be to blame. Providers should immediately stop any procedures that stimulate the hypopharynx. A few gentle, positive-pressure breaths typically resolve the laryngospasm; in many cases, even this is unnecessary if oxygen saturation monitoring is available and demonstrates normal levels.[9] Providers should avoid the temptation to immediately intubate these patients, because virtually all laryngospasm resolves without the need for aggressive airway management.[8] Patients with noisy respirations may simply need suctioning, because of the tendency of ketamine to increase oral secretions.

Monitoring after Sedation

As patients emerge from dissociation, they may demonstrate unusual phenomena not noted with other agents. Nystagmus and dysconjugate gaze are common, and older patients may comment on the double vision or find it disturbing. Reaching into the air to grasp at nonexistent objects occurs frequently as patients continue to hallucinate. Patients often exhibit tongue thrusting, giggle, or make odd statements.

Less common reactions noted during emergence include hallucinatory and nonhallucinatory agitation (as discussed above), which should be treated with small doses of benzodiazepines titrated to effect.[9] Ideally these drugs are administered intravenously, although intramuscular injection is acceptable if the intravenous route is not available. Physical restraints may be needed in very rare situations. Anecdotally, many clinicians avoid excessive stimulation during emergence by keeping noise, light, and physical contact to a minimum.

Toward the end of dissociation, and for a few hours thereafter, patients have a risk of emesis. Fortunately, when this occurs most patients are already awake and responsive and can clear their airway themselves.[10] Because ketamine maintains airway reflexes, the few patients who vomit while dissociated should simply require assistance with suctioning or otherwise clearing their airway.

Children should be closely observed at all times during and after ketamine PRSA, until they return to their presedation baseline levels in terms of verbalization and obeying commands. Children who are still under the dissociative effects of ketamine and are not appropriately supervised by a health care provider may develop airway misalignment and subsequent hypoxia.

Post-PRSA Effects

After patients recover from the dissociative effects of ketamine, they may demonstrate some mild ataxia and transient dysconjugate gaze for several hours. Guardians should supervise children to avoid trauma related to falls. Vomiting may also occur, and providers should alert parents.

Ketamine for PRSA among Adults

Risks and Benefits

In the developed world, ketamine has been used almost exclusively for pediatric PRSA. However, in the third world and in disaster and military field environments, ketamine has been used extensively for adult patients.[1,2,12,13,31–33] The advantages of preserved spontaneous respirations, hemodynamics, and protective reflexes often outweigh the rare complications of ketamine seen in this population (Table II). There are two important differences between adult and pediatric patients that providers must understand when considering ketamine for adult PRSA. First, agitated emergence reactions, although rare, may create an unmanageable situation with a combative hallucinating adult. Children can be readily restrained, which is not necessarily the case with adults. Second, the sympathomimetic effect of ketamine, which is well tolerated by children, could theoretically cause cardiac ischemia among susceptible adults.[14] The risk of inducing cardiac ischemia with ketamine is unclear. In the largest series of adult patients undergoing ketamine PRSA in an ED setting, there were no reported cases of ischemia.[26] However, an editorial accompanying that research suggested that, at some age limit, the risk of ketamine likely outweighs its benefits.[14] In an ED setting, many clinicians who use ketamine for adults have a somewhat arbitrary age cutoff of 40 years.[14] In the field setting, where other agents may not be available, the risk of ischemia must be weighed against other considerations.

Selection of Ketamine for Adult PRSA

Many of the contraindications associated with pediatric use of ketamine also hold true for adults. Patients with previous psychiatric conditions typically should not receive ketamine because of the risk of producing hallucinations or psychosis. Similarly, patients with underlying conditions that would predispose them to hallucinations, such as heavy alcohol use or amphetamine abuse, should not receive ketamine if other agents are available.[14]

Patients with conditions with increased risks of complications attributable to sympathomimetic stimulation (e.g., patients with underlying heart disease, cardiac arrhythmias, cerebrovascular disease, or hyperthyroidism) may be poor candidates for ketamine use. In addition, ketamine should be avoided for older patients at increased risk of undiagnosed ischemic heart disease.

Although they are uncommon, providers must anticipate agitated emergence reactions when contemplating ketamine PRSA for adults. If a combative patient cannot be rapidly controlled, because of the lack of intravenous access, the lack of available benzodiazepines, or the absence of available assistants to physically restrain the individual, then the risks of ketamine likely outweigh its advantages.

As with pediatric patients, procedures that stimulate the hypopharynx may increase the risk of laryngospasm. However, the absolute risk of laryngospasm among adults appears greatly reduced, compared with that among children.[14]

Dosing and Administration

When used for adults, ketamine generally should be administered intravenously whenever possible. Emergence reactions among adults may require rapid titration of benzodiazepines. The dosing for intravenously administered ketamine for adults is 1.5 to 2 mg/kg. Again, intravenous ketamine injections must be administered over at least 60 seconds to avoid respiratory depression. Onset is within 60 seconds, and sedation lasts 5 to 10 minutes. If intravenous access is not available, then intramuscular administration with a dose of 5 to 10 mg/kg should suffice. A second dose of 5 mg/kg may be needed if dissociation has not resulted within 10 minutes. The onset and duration of intramuscularly administered ketamine for adults are similar to

TABLE II

SUMMARY OF KETAMINE FOR ADULT PRSA

Indications	Brief painful procedures requiring PRSA
Contraindications	Absolute: prior psychosis; relative: coronary artery disease, cerebrovascular disease, uncontrolled hypertension (blood pressure of >140/90 mm Hg), risk factors for coronary artery disease, age of >40 years, procedures that stimulate the hypopharynx, inability to control an emergence reaction (no intravenous access, no benzodiazepines, or no assistance), need for injured party to actively engage enemy or maneuver immediately after procedure (impaired because of ataxia and diplopia)
Preparation	When available, monitors (oxygen saturation, ECG, and blood pressure), suction, oxygen source, airway rescue equipment, and physical restraints; council those present on unique effects of ketamine; prepare patient for "dreaming"
Dosing	Intravenous (preferred): 1.5–2 mg/kg over 60 seconds; intramuscular: 4–5 mg/kg
Coadministered medications	When available, give a small dose of benzodiazepine (2–3 mg of midazolam for normal-sized adult) before or concurrent with ketamine; no need for atropine
Onset and duration	Intramuscular: 5–10-minute onset, 20–30-minute duration; intravenous: 60-second onset, 5–10-minute duration; use same doses for redosing if necessary
Monitoring	Apnea in first 1–2 minutes after rapid intravenous dosing; stridor may reflect misaligned airway (rare) or laryngospasm (rare); reposition airway, positive-pressure breaths if needed for 1–5 minutes
Postprocedural observations	Emergence reactions rare, treat with intravenous benzodiazepines; emesis (3%), dysconjugate gaze, ataxia
Discharge criteria	Returned to baseline verbal and motor skills (ataxia and diplopia may persist); carefully assess abilities before returning weapons

those for children (onset, 5–10 minutes; duration, 20–30 minutes). When prolongation of the dissociative state is needed, additional doses of 0.5 to 1 mg/kg administered intravenously or 5 to 10 mg/kg administered intramuscularly should be used.

Presedation and Coadministered Medication

The guidelines for ketamine use in pediatric PRSA specifically note that clinicians should not routinely coadminister benzodiazepines because of the possibility of respiratory suppression.[9] Emergence reactions among children, when they do occur, can rapidly be treated with titrated benzodiazepines. However, two characteristics of adults make administration of benzodiazepines beneficial. First, the prevention of emergence reactions in adults is of greater importance, given the difficulty of controlling an agitated adult patient. Second, benzodiazepines help attenuate the sympathomimetic effects of ketamine[34] and presumably lower the risk of ischemia- or hypertension-related adverse events. Typical adjunctive doses of a benzodiazepine for a normal-sized adult would be 2 to 3 mg of midazolam or equivalent doses of lorazepam or diazepam.[14] The timing of benzodiazepine administration for adults has not been well studied. Some prefer administration before ketamine administration, with the thought that adults may have fewer emergence reactions if they dissociate in a more relaxed state. High doses of a benzodiazepine, as used in standard opiate and benzodiazepine PRSA, should be avoided when used with ketamine. There is no advantage to higher doses and the risk of respiratory depression increases.[26] It should be noted that, if diazepam is chosen as the benzodiazepine, it should not be mixed in the same syringe as ketamine, because precipitation may occur.

For children, many clinicians coadminister atropine to reduce the slight increase in oral secretions. Among adults, however, the risk of clinically important hypersecretion is trivial and the increase in heart rate resulting from atropine exacerbates the sympathomimetic effects of ketamine. Therefore, routine atropine administration should be avoided among adults.

Preparation and Monitoring

Preparation and monitoring for adult ketamine PRSA parallel those for pediatric PRSA, with the exception that physical restraints play an even greater role for adults. When adults sedated with ketamine are being monitored, reactions similar to those noted among children should be anticipated, including nystagmus, purposeless motions, and elevated heart rate and blood pressure. Laryngospasm, which is rare among children, is likely more uncommon among adults and, when it occurs, lasts only a few minutes.[26] When needed, bag-valve-mask ventilation should be instituted. With larger and stiffer airways, adults rarely develop misalignment, although occasionally those prone to sleep apnea may require a nasopharyngeal airway or jaw thrust.

Postprocedural Monitoring

Adults, like children, may vomit with ketamine (3% in one series).[26] Usually this occurs during recovery, when patients can clear their own airways. The most serious concern during the recovery phase is the potential for agitation. The largest series of adult patients in an ED setting found no cases of combativeness among 77 patients.[26] Of those 77 patients, 25% recalled dreaming during the sedation. Most of those dreams (17% of the overall sample) were described as pleasant dreams, 3% as unpleasant, 4% as both pleasant and unpleasant, and 1% as neither. However, the literature reveals several case reports of combative adults, and providers should prepare for this contingency.

After ketamine sedation, adults frequently report diplopia and ataxia. In a field environment, these adverse effects may substantially limit the postprocedural capabilities of adult patients. In particular, the ability to locate targets and to effectively engage the enemy may be severely impaired. Depth perception may be unreliable because of dysconjugate gaze, and soldiers may lose the ability to run without falling because of ataxia. Military providers should carefully assess the capabilities of soldiers after ketamine sedation, before releasing them back to combat duties or returning their weapons.

Operational Issues Related to Ketamine

Ketamine has many unique characteristics that contribute to its popularity in the field environment (Table III). The preservation of spontaneous respirations with complete analgesia is unparalleled. However, military providers must understand several characteristics of ketamine that may affect operational success. Patients undergoing PRSA with ketamine may make spontaneous utterances and purposeless motions. If operational security demands strict noise discipline, then agents

TABLE III

SUMMARY OF OPERATIONAL ISSUES INVOLVING KETAMINE

Minimal equipment needs	In settings without monitors, ketamine has an excellent relative safety profile, given the preservation of spontaneous respirations, blood pressure, and protective airway reflexes
Limited expertise needed	Ketamine virtually never requires advanced airway techniques such as intubation
Intramuscular dosing in select cases	Preserves intravenous catheters for other uses
Effective for adults and children	Expands scope of care available in the field
Motion and vocalization during sedation	May draw attention to provider's position
Emergence reactions	Rarely may require management of a combative patient; may draw attention to provider's position
Diplopia and ataxia	May impair patient's ability to engage the enemy following PRSA
Storage and transport	Appears to tolerate field conditions without impairing effectiveness (but not well researched); requires only small volume of effective dose (1.5 mL of 100 mg/mL concentration for an adult); one provider can carry doses for multiple patients
Abuse potential	Providers must secure and control the medication

other than ketamine may be preferred. Similarly, emergence agitation rarely may be pronounced and, until the patient is sedated with benzodiazepines, he or she may draw unwanted attention to the provider's position.

As noted above, after PRSA with ketamine, a soldier's ability to engage the enemy may be impaired because of dysconjugate gaze and ataxia. The duration of these effects has not been well researched, but they generally last <1 hour after ketamine administration.

Field use of any medication requires that the agent tolerate conditions different from those found in a hospital setting. Ideally, ketamine should be stored at room temperature (between 59°F and 86°F) and should not be frozen. The stability and effectiveness of ketamine after exposure to temperature extremes have yet to be researched, although third world use suggests little change in its capabilities when it is kept in environments that are warmer than usual. When exposed to light, ketamine, which is normally a clear liquid, may develop a slightly yellow tinge. This usually does not degrade effectiveness, although providers should avoid excessive exposure to light. Ketamine is a cost-effective agent as well, selling for as little as 16¢ for a 500-mg vial.[35] Providers should understand that ketamine has the potential for abuse, and those responsible for its procurement, storage, and transport must secure the vials and prevent unauthorized use.

Conclusions

Those familiar with ketamine in a field environment have repeatedly found it to be an exceptional medication with unparalleled safety and efficacy.[1,2] Military providers who may be called on to perform PRSA in austere conditions should understand the unique issues related to ketamine and, ideally, should develop experience with ketamine in a controlled setting. Because of the popularity of agents such as propofol among anesthesiologists, most ketamine sedations are now performed by emergency medicine physicians. Therefore, providers may find that the ED provides the most accessible venue for developing expertise with ketamine.

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