Review Article

Essential pharmacologic options for acute pain management in the emergency setting

David H. Cisewski a,∗, Sergey M. Motov b

a Icahn School of Medicine at Mount Sinai Hospital, Department of Emergency Medicine, New York, NY, USA
b Maimonides Medical Center, Department of Emergency Medicine, Brooklyn, NY, USA

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ABSTRACT

Pain is the root cause for the overwhelming majority of emergency department (ED) visits worldwide. However, pain is often undertreated due to inappropriate analgesic dosing and ineffective utilization of available analgesics. It is essential for emergency providers to understand the analgesic armamentarium at their disposal and how it can be used safely and effectively to treat pain of every proportion within the emergency setting. A ‘balanced analgesia’ regimen may be used to treat pain while reducing the overall pharmacologic side effect profile of the combined analgesics. Channels-Enzymes-Receptors Targeted Analgesia (CERTA) is a multimodal analgesic strategy incorporating balanced analgesia by shifting from a system-based to a mechanistic-based approach to pain management that targets the physiologic pathways involved in pain signaling transmission. Targeting individual pain pathways allows for a variety of reduced-dose pharmacologic options – both opioid and non-opioid – to be used in a stepwise progression of analgesic strength as pain advances up the severity scale. By developing a familiarity with the various analgesic options at their disposal, emergency providers may formulate safe, effective, balanced analgesic combinations unique to each emergency pain presentation.

1. Introduction

Pain is the root cause for the overwhelming majority of emergency department (ED) visits, encompassing up to 75–80% of all presenting chief complaints.1,2 In the United States alone, pain is the chief complaint of over 100 million patients presenting to the ED each year.3 Despite this, pain management in the ED is frequently delayed due to overcrowded emergency rooms4,5 or pain is undertreated (oligoanalgesia) due to inappropriate analgesic dosing and ineffective utilization of available analgesics.6–8 While overcrowding remains a continued logistical challenge, the latter can be prevented with sufficient knowledge of available analgesic options.

The primary goal of emergency pain management is not zero pain, but a reduction in pain to an acceptable level that will allow for a bridge to inpatient care or a safe discharge with return to the patients’ daily activities.9 In the midst of the United States opioid epidemic, a discerning eye has been placed on how providers are achieving this goal and the analgesic options being used to do so. In selecting a particular analgesic regimen, emergency providers must familiarize themselves with the myriad of pharmacologic choices that will allow them to balance the intensity of the pain with the safety and efficacy of various treatment options.

The ultimate analgesic approach provides a quick onset, limited side effects, and sustained relief tailored to each pain presentation. Analgesic optimization requires a patient-centered, pain-syndrome specific regimen. A combined analgesic regimen – collectively referred to as ‘balanced analgesia’ – may be used to treat pain while reducing the overall side effect profile.10 Channels-Enzymes-Receptors Targeted Analgesia (CERTA) is a multimodal analgesic strategy that incorporates balanced analgesia11 by promoting a shift from a system-based to a mechanistic-based approach to pain management that targets the physiologic pathways involved in pain signaling transmission (see Table 1).1,2 By targeting individual pain signaling pathways, a variety of reduced-dose analgesics may be used to optimize the safety and efficacy of the analgesic regimen. CERTA emphasizes a stepwise approach of opioid and non-opioid analgesics with progression in analgesic strength as pain progresses up the severity scale (see Fig. 1).

The purpose of this review is to provide an overview of the essential pharmacologic options available to the emergency pain management armamentarium and the evidence to support their use. This review focuses on utilizing a variety of analgesics to cover the entire spectrum of pain - mild to severe - specific to the patient and pain presentation.
Pain reduction from this combination has long been considered a first line analgesic regimen for mild to moderate pain. NSAIDs are commonly used for headaches, renal colic, musculoskeletal pain, dysmenorrhea, and non-radicular back pain. Examples of multimodal CERTA pain management will be discussed and consistent with the CERTA concept of balanced analgesia.

2. COX-1, COX-2 inhibitors: ibuprofen, diclofenac, naproxen, ketorolac

Cyclooxygenase (COX-1 and COX-2) inhibitors (NSAIDs) reduce pain by inhibiting prostaglandin synthesis involved in both acute and chronic pain conditions. Though classically used for mild to moderate pain, NSAIDs are a complement to the entire spectrum of pain severity. Ibuprofen may be administered via PO, IV, IM, PR routes, and typically. 400 mg PO ibuprofen every 8 h (1200 mg/per day) is the dosing regimen consistent with analgesic ceiling – the dose of drug above which no further analgesic efficacy is achieved. Alternatively, 50 mg PO diclofenac every 8 h or 250–500 mg PO naproxen every 8–12 h can be used with similar analgesic effect. NSAIDs are commonly used for headaches, renal colic, musculoskeletal pain, dysmenorrhea, and non-radicular back pain. The synergistic combination of 400 mg ibuprofen with 1000 mg paracetamol (acetaminophen) is a classic example of balanced analgesia and has long been considered a first line regimen for mild to moderate acute pain presentations. Pain reduction from this combination has analgesic efficacy comparable to oral opioid combinations (oxycodone/hydrocode-acetaminophen) in treating acute musculoskeletal pain in the emergency setting. Ketorolac is the most commonly used parenteral NSAID in the emergency setting in the United States (diclofenac is the most commonly used parenteral NSAID worldwide). Due to an unpredictable absorption rate, delayed onset of analgesia, and injection pain associated with intramuscular (IM) administration, IV ketorolac is preferred. Research has shown 10 mg IV ketorolac to be the analgesic ceiling for acute pain in the emergency setting. Administration of 10–15 mg IV ketorolac every 6 h (based on the analgesic ceiling dose) is the recommended dosing regimen for moderate to severe pain presentations.

Similar to other NSAIDs, ketorolac is effectively used for management of pain associated with headaches, renal colic, biliary colic, and acute musculoskeletal pain. The combination of 15 mg IV ketorolac-5mg IV morphine (administered twice at 0 and 20 min) has shown to more effectively reduce acute renal colic pain than either ketorolac or morphine alone and required less rescue analgesia. Topical NSAIDs – diclofenac (gel, patch), ketoprofen, ibuprofen (5%) - offer the advantage of preferential localization to cartilage, meniscus, and tendons at concentrations up to 100-fold parenteral administration. Each agent may be used to effectively treat acute musculoskeletal injuries, neuropathies, soft-tissue strains and sprains, contusions, burns, skin ulcers, acute herpetic zoster, low back pain, osteoarthritis, cancer-related pain, and visceral pain. Topical agents should be administered with gloves to avoid mucous membrane irritation and used without heating pads to prevent excessive absorption.

Adverse effects of NSAIDs include gastric ulcers, platelet function inhibition, helicobacter pylori infection, and nephrotoxicity. Patients with gastrointestinal ulcers, active hemorrhage, hepatic or renal disease, heart failure, and elderly patients with multiple comorbidities should consider alternative analgesics. Although data suggests the short-term use of NSAIDs for mild/moderate acute pain may be used without a profound reduction in renal perfusion, the recommendation remains to avoid NSAIDs in patients with renal disease. Further, NSAIDs should be avoided in cirrhotic patients where renal perfusion is reliant on prostaglandin synthesis to prevent hepatorenal syndrome. NSAIDs during the second and third trimester of pregnancy should be avoided due to adverse effects on fetal development and risk of peri-partum hemorrhage.

3. TRPV1 receptor agonist: capsaicin, acetaminophen

Transient Receptor Potential (TRP) channels play a dual role in pain signaling. Whereas immediate activation of TRP channels stimulates pain signaling, repeated stimulation desensitizes the pain-conducting neurons, silencing the pain signal. Capsaicin and acetaminophen both function as TRPV1 receptor agonists.

Capsaicin comes in both patch (8%) and cream (0.025–0.075%) formulations. Capsaicin is used to treat osteoarthritis, postherpetic neuralgias, diabetic neuropathy, and cannabinoid hyperemesis syndrome (CHS) when applied to the abdomen during acute pain presentations.

Acetaminophen (APAP, Paracetamol) administered PO, PR, and IV may be used as a first-line agent for acute pain presentations of mild intensity.
(maximum 4 g per day) is a recommended dosing regimen.\textsuperscript{12} 1000 mg PO acetaminophen is considered the analgesic ceiling dose for acute pain.\textsuperscript{39}

The combination of 1000 mg acetaminophen-400 mg ibuprofen has long been considered the base standard for mild to moderate acute pain management.\textsuperscript{29} As mentioned, this combination has been shown to be as effective as oral opioid combinations (oxycodeone/hydrocodone-acetaminophen) and may be used as the baseline regimen for mild to moderate musculoskeletal injuries.\textsuperscript{18}

Intravenous acetaminophen is an effective analgesic in patients who cannot tolerate oral or rectal delivery and may reduce overall opioid consumption when used as an analgesic adjunct.\textsuperscript{45} In the emergency setting, however, the use of IV paracetamol as an adjunct for pain management offered no superiority over oral paracetamol.\textsuperscript{41}

Acetaminophen is considered safe for a developing fetus and is the first-line analgesic agent in pregnant and lactating women with mild to moderate pain.\textsuperscript{32}

4. Sodium channel blockers: lidocaine, mepivacaine, bupivacaine, chloroprocaine, procaine

Sodium channel blockers such as lidocaine, mepivacaine, bupivacaine, chloroprocaine, and procaine function as analgesics through the noncompetitive inhibition of nerve signal propagation.\textsuperscript{42,43} Nerve blocks (regional anesthesia) refer to the infiltration of peripheral nerves with sodium channel-blocking agents creating localized analgesic relief (see Table 2 for a list of commonly used anesthetics in the emergency setting).\textsuperscript{42,44} Nerve blocks prevent systemic loading of anesthetic medications, improve door-to-anaesthesia timing,\textsuperscript{45,46} and are optimally used when combined as part of a multimodal analgesic regimen. Epinephrine may be added to anesthetic injection to provide local vasoconstriction that prolongs analgesic duration by delaying anesthetic clearance.\textsuperscript{42,44,45}

Pain syndromes that benefit from either nerve blocks or local anesthetic infiltration include laceration repair,\textsuperscript{46} headaches and migraines,\textsuperscript{47} extremity and hip fractures,\textsuperscript{48,49} abscess drainage,\textsuperscript{50} shoulder reductions,\textsuperscript{51} chest tube placements,\textsuperscript{52} and paraphimosis reductions.\textsuperscript{53}

Intravenous lidocaine can also be used to treat chronic regional pain syndrome,\textsuperscript{54} post-herpetic neuralgia, and post-spinal cord injury radiculopathy.\textsuperscript{55} Several clinical trials have also shown 1.5 mg/kg IV lidocaine administered over 10 min was successful in reducing renal colic refractory to traditional NSAID and opioid regimen\textsuperscript{56,57} with efficacy comparable to 0.1 mg/kg IV morphine.\textsuperscript{58}

Local anesthetic systemic toxicity (LAST) may occur when excessive quantities accumulate intravascularly. Adverse effects include confusion, anxiety, headaches, drowsiness, lightheadedness, tremors, seizures, cardiac dysrhythmias, and hemodynamic instability.\textsuperscript{46,57} Patients receiving systemic anesthetic should be placed on cardiac monitoring to assess for systemic toxicity.\textsuperscript{46} Ultrasound guidance with nerve blocks may prevent direct injection of anesthetic into vasculature causing similar toxicity.\textsuperscript{46}

5. Dopamine Receptor (D1-R, D2-R) Antagonists: metoclopramide, prochlorperazaine, chlorpromazine, haloperidol, droperidol

Beyond its role in motivational behavior, dopamine plays an active role in the pain signaling pathway where inhibition may prevent signal propagation.\textsuperscript{59} Common dopamine antagonists used in the emergency setting include metoclopramide, prochlorperazaine, chlorpromazine, haloperidol, and droperidol.

Metoclopramide, prochlorperazine, and chlorpromazine are commonly used to treat migraine headaches.\textsuperscript{40} 10 mg IV metoclopramide may be used as a first-line agent in the treatment of acute migraine attacks.\textsuperscript{60} 10 mg IV prochlorperazaine has also demonstrated significant headache relief\textsuperscript{61} and superiority over opioids in the treatment of migraines.\textsuperscript{62} 10 mg IV chlorpromazine has also been shown to be as effective as metoclopramide for headache relief.\textsuperscript{63}

Droperidol and haloperidol - classically known for their function as high-potency, first generation antipsychotics\textsuperscript{64} - have also shown efficacy in treating headaches in the emergency setting.\textsuperscript{60,65,66} 2.5 mg IV (or IM) droperidol has been shown to be the minimum effective dose for migraine relief\textsuperscript{66} with efficacy comparable to 10 mg IV prochlorperazaine.\textsuperscript{65} Alternatively, 5 mg IV haloperidol has been shown to be as efficacious as 10 mg IV metoclopramide.\textsuperscript{60,64} Further off-label utilization of haloperidol has also been studied for its antiemetic and analgesic efficacy in treating gastroparesis, cannabinoid-induced hyperemesis, and cycling vomiting syndrome.\textsuperscript{67,68}

Side effects of dopamine-receptor antagonists include QT prolongation, extrapyramidal side effects (akathisia, dystonia), anti-muscarinic effects (drowsiness, dry mouth, constipation, hypotension), and neuroleptic malignancy syndrome (hyperpyrexia, muscle rigidity, rhabdomyolysis).\textsuperscript{12,69} Metoclopramide, prochlorperazine, and chlorpromazine can be administered over a 15–30 min infusion to reduce extrapyramidal effects.\textsuperscript{63,65} 25 mg IV or PO diphenhydramine may also be used with prochlorperazine to offset the associated akathisia.\textsuperscript{65,70}

6. Glutamate/NMDA receptor antagonists: ketamine, nitrour oxide

Glutamate serves as an excitatory neurotransmitter in the central nervous system.\textsuperscript{71} Pharmacologic agents focused on reducing central pain sensitization and hyperalgesia by blocking the N-methyl-D-aspartate (NMDA) glutamate receptor are key analgesic targets.\textsuperscript{72} Examples used in the emergency setting include ketamine and nitrour oxide.

Ketamine is used for analgesia in subdissociative doses (SDK) - 0.1–0.3 mg/kg IV or subcutaneous (SQ) - that provide analgesic relief while preserving respiratory and cardiopulmonary stability in the emergency setting.\textsuperscript{72,73} SDK has shown to be effective in treating acute pain.\textsuperscript{74} Table 2

Table 2

| Anesthetic | Class | Onset | Common Concentration | Dose | Max Dose | Duration |
|------------|-------|-------|----------------------|------|---------|----------|
| Chloroprocaine (w/epi) | Ester | Rapid | 2%/20 mg/ml | 14 mg/kg | 1000 mg | 0.5–1 h |
| Chloroprocaine (w/o epi) | Ester | Rapid | 2%/20 mg/ml | 11 mg/kg | 800 mg | 0.5–1 h |
| Lidocaine | Amide | Rapid | 1% (10 mg/ml) | 7 mg/kg | 500 mg | 1.5–3 h |
| Lidocaine (w/o epi) | Amide | Rapid | 1% (10 mg/ml) | 4.5 mg/kg | 300 mg | 1–2 h |
| Bupivacaine (w/epi) | Amide | Slow | 0.5% (5 mg/ml) | 3 mg/kg | 225 mg | 1–3 h |
| Bupivacaine (w/o epi) | Amide | Slow | 0.5% (5 mg/ml) | 2.5 mg/kg | 175 mg | 3–6 h |
| Ropivacaine (w/o epi) | Amide | Slow | 0.5% (5 mg/ml) | 3 mg/kg | 225 mg | 3–6 h |

* Odashima K, Strasberg S, Dickman E. Ultrasound-Guided Regional Nerve Blocks in Emergency Medicine Brooklyn, NY2017 [June 27, 2018]. Available from: http://painandpsa.org/rnb/.
abdominal pain, renal colic, back pain, headaches, and extremity pain. 0.3 mg/kg IV ketamine has been shown to be as efficacious as 0.1 mg/kg IV morphine for acute pain while doses as low as 0.15 mg/kg IV ketamine have been shown to reduce overall morphine consumption up to 26% when used as an adjunct analgesic. The side effects of ketamine include a feeling of unreality, gastric irritation, sedation, dizziness, and nystagmus (seen shortly after onset). These side effects are increasingly prominent among geriatric patients where S/D should be used cautiously. Administering ketamine as a slow infusion over 15 min (versus IV push) can reduce these adverse side effects. Co-administration of prophylactic ondansetron and midazolam can be used to treat post-ketamine nausea and emergence reaction respectively. 

Nitrous oxide (N2O) is an odorless gas with a fast-onset and a short half-life. N2O effects range from analgesia at low doses to neurologic depression and medullary paralysis at high doses. Low-dose N2O administration allows for conscious, rational thought with a decreased pain perception. Analgesic N2O is administered as a combined equimolar mixture of 50% oxygen – 50% nitrous oxide. Average onset is 3–5 min with recovery occurring within 5 min of discontinuation.

N2O research in the pediatric population has demonstrated efficacy for bone and joint procedures, laceration repairs, abscess drainage, foreign body removal, and urinary catheterization placement. N2O has increased utility when IV access is undesired or difficult to attain. Side effects of N2O include gastrointestinal disturbance, dizziness, headaches, increased intracranial pressure, oral distaste (delivery system tubing), and respiratory depression. N2O should be administered under continuous pulse oximetry and cardiac monitoring in a setting where airway management is available.

7. GABA receptor agonists: propofol

The gamma-aminobutyric acid (GABA) receptor agonist propofol has traditionally been used for anesthesia induction, procedural sedation, and in the treatment of status epilepticus. Propofol may be used to treat acute headaches in the emergency setting. 30–40 mg IV propofol (sub-anesthetic doses) has been shown to decrease pain perception and its use as an adjunct analgesic has been promoted to support balanced analgesia. Propofol may be used to treat acute headaches in the emergency setting. 30–40 mg IV propofol (sub-anesthetic doses) with repeat boluses of 10 mg every 3–5 min (maximum 120 mg) has shown efficacy in the treatment of migraines refractory to a traditional migraine regimen and as effective as 6 mg subcutaneous sumatriptan with less gastrointestinal disturbance. Adverse effects of propofol include respiratory depression, hypotension, sedation, pain at the injection pain, and propofol infusion syndrome (PRIS). Concomitant use of opioids may potentiate the risk of respiratory failure and should be avoided. Propofol should be administered under continuous pulse oximetry and cardiac monitoring in a setting of airway management accessibility.

8. Serotonin (5HT-1) receptor agonists: sumatriptan

Serotonin receptor agonists such as sumatriptan (triptans) are hypothesized to prevent pain signal propagation by inhibiting calcitonin gene-related peptide (CGRP) release. Triptans are effective in treating migraines and cluster headaches. Administration of 6 mg subcutaneous sumatriptan may be used to treat acute migraines in the emergency setting with repeat delivery of 6 mg after 1 h if symptoms persist (max 12 mg per day). Additionally, 100 mg PO sumatriptan has been shown to reduce 24-h migraine recurrence. Sumatriptan is most effective in treating migraines when used as part of a balanced analgesic regimen including acetaminophen, NSAIDs, metoclopramide (or prochlorperazine), and IV fluids. Adverse effects of triptans include paresthesias, flushing, palpitations, fatigue/drowsiness, transient neck tightness, chest pressure, and dysrhythmias. The American Headache Society concluded that the incidence of serious cardiovascular events was extremely low and that the chest pain generally not serious or explained by ischemia, thus favoring triptan use in the absence of contraindications.

9. Calcium channel blockers: gabapentin, pregabalin

The calcium channel blocker anticonvulsants pregabalin and gabapentin reduce central pain sensitization by preventing voltage-gated postsynaptic neurotransmitter release. Pregabalin functions similar to gabapentin but with increased potency and binding affinity.

Both pregabalin and gabapentin are effective in treating neuropathic pain, where other analgesics offer little relief. Pregabalin was the first FDA-approved drug for the management of post-herpetic and diabetic neuropathic pain. Administration of 150 mg daily PO pregabalin divided into 3 daily doses with titration up to 300–600 mg daily as tolerated is the recommended approach. Research has shown that 600 mg pregabalin daily was effective for postherpetic neuralgia, diabetic neuropathy, and fibromyalgia though medication compliance was hindered by an unfavorable side effect profile.

Gabapentin is also recommended for postherpetic neuralgia and diabetic neuropathy. A gabapentin titration of 300 mg on day 1, 300 mg twice a day on day 2, 300 mg three times a day on day 3, and further titration up to 1800 to 3600 mg per day divided into 3 doses as tolerated is the recommended approach. Similar to pregabalin, multiple studies have shown its use hindered by a high percentage of intolerable side effects.

Adverse effects of both gabapentin and pregabalin include dizziness, fatigue, ataxia, peripheral edema, nystagmus, tremor, rhabdomyolysis, angioedema, and weight gain. Pregabalin/gabapentin should be used cautiously among elderly populations to avoid precipitating cognitive impairments. Both gabapentin and pregabalin are excreted un-metabolized in the urine and are contraindicated in patients with impaired renal function. Neither gabapentin nor pregabalin should be administered with opioids as both may potentiate the euphoric effects of opioids when taken concomitantly, increasing susceptibility to abuse and a worsening respiratory and CNS depression.

A detailed summary of commonly used non-opioid analgesic options in the emergency setting can be found in Table 3.
Table 3

Non-opioid analgesic options used in the emergency setting. The medications, doses, and durations listed are estimates based on average responses in the general population; a full consideration of the individual patient's presentation and comorbidities should be given prior to initiating an analgesic regimen.

| Medication        | Average Dose       | Duration | Max Dose               | Side effects                                                                                     |
|-------------------|--------------------|----------|------------------------|--------------------------------------------------------------------------------------------------|
| Ibuprofen         | 400 mg PO          | 8 h      | 1200 mg per day        | GI irritation, bleeding, renal dysfunction, bronchospasm, delayed wound healing                  |
| Diclofenac        | 50 mg PO           | 8 h      | 150 mg per day         | GI irritation, bleeding, renal dysfunction, bronchospasm, delayed wound healing                  |
| Naproxen          | 250 mg PO (every 8 h) | 8-12 h  | 1000 mg per day        | GI irritation, bleeding, renal dysfunction, bronchospasm, delayed wound healing                  |
|                   | 500 mg PO (every 12 h) |         |                        |                                                                                                 |
| Ketorolac         | 10–15 mg IV        | 6 h      | 60 mg per day          | GI irritation, bleeding, renal dysfunction, bronchospasm, delayed wound healing                  |
| Capsaicin         | thin film to effected area | 6–8 h    | Varies                | Localized pain, erythema (rare - transient hypertension, pruritus, swelling, papules)          |
| Acetaminophen     | 325-1000 mg PO     | 4–6 h    | 4 g per day            | Nausea, vomiting, liver toxicity                                                                |
| Lidocaine         | 1.5 mg/kg (admin over 10 min) | Varies | 200 mg per administration | Confusion, anxiety, sense of impending doom, headache, drowsiness, cardiac dysrhythmias           |
| Metoclopramide    | 10 mg IV           | 1–2 h    | 40 mg per day          | Akathisia, dystonia, drowsiness, QT prolongation, torsade de pointes                              |
| Prochlorperazine  | 10 mg IV, PO       | 3–4 h    | 40 mg per day          | Akathisia, dystonia, drowsiness, QT prolongation, torsade de pointes                              |
| Chlorpromazine    | 10 mg IV, PO       | 4–6 h    | 25 mg per day          | Akathisia, dystonia, drowsiness, QT prolongation, torsade de pointes                              |
| Haloperidol       | 2–10 mg PO, IV, IM | 2–4 h    | 20 mg (based on side effect profile, ECG findings)           | Akathisia, dystonia, drowsiness, QT prolongation, torsade de pointes                              |
| Droperidol        | 2.5 mg IV          | 2–4 h    | Unknown (based on side effect profile, ECG findings)      | Akathisia, dystonia, drowsiness, QT prolongation, torsade de pointes                              |
| Ketamine          | 0.15–0.3 mg/kg IV  | Varies   | Dependent on infusion | Dizziness, agitation, emergence reaction, nystagmus, sensation of unreality, nausea, vomiting   |
| Nitrous Oxide     | 50/50 (%NO/%Oxygen mixture) | 3–5 min | Varies                | Nausea, vomiting, headache, euphoria, dizziness, tingling, oral distaste mild increase in intracranial pressure |
| Propofol          | 30–40 mg IV        | Varies (repeat 10 mg every 3–5 min as needed) | 120 mg per day         | Respiratory depression, hypotension, sedation, hypertriglyceridemia, pain at injection            |
| Sumatriptan       | 6 mg SQ            | Varies   | 12 mg SQ per day       | Tingling sensation, dizziness, hot flashes, palpitations, drowsiness, dysrhythmia                |
| Gabapentin        | 25–100 mg PO       | Varies   | 200 mg PO per day      |                                                                                                                                                        |
|                   | 300 mg PO (titrated up to 1200 mg three times per day) | 24 h (requires titration to effect) | 3600 mg per day        |                                                                                                                                                        |
| Pregabalin        | 50–75 mg PO (titrate up to 150–300 mg) | 12 h    | 600 mg per day (following slow titration) | Fatigue, dizziness, weight gain, ataxia, nystagmus, leukopenia, rhabdomyolysis                  |
| Dexmedetomidine   | 0.5–1 μg/kg IV     | Varies   | Dependent on infusion | Hypotension, bradycardia                                                                        |
In order to ensure adequate analgesia while minimizing the risk of adverse effects, titration of analgesic doses is recommended. In the emergency setting, a variety of opioids are available.

A variety of morphine delivery routes are available as safe alternatives when IV access cannot be obtained. Research comparing nebulized versus intravenous morphine has shown a 10-20 mg nebulized morphine (with repeat dosing every 10 min for a maximum of 3 boluses) had similar efficacy and an improved safety profile compared to IV morphine in patients with severe posttraumatic pain. Alternatively, 10 mg intramuscular (IM), 10 mg subcutaneous (SQ), or 10-20 mg rectal (PR) morphine may be administered every 4 h as needed for moderate to severe pain presentations.14

Oxycodone (OC) and hydrocodone (HC) were oral opioids marketed with the advantage of reduced first pass metabolism over oral morphine.15 Oxycodone can be administered as a stand-alone or in combination with acetaminophen (Roxicet, Percocet - 5/7.5/10 mg OC + 325 mg acetaminophen), or as an extended release formulation (OxyContin).16 Hydrocodone is typically administered in combination with acetaminophen (Lortab, Lorcet - 5/7.5/10 mg + 325 mg acetaminophen) or as an oral solution (Hyct - 7.5 mg OC + 325 mg acetaminophen). Both OC and HC are initially dosed at 5-10 mg with re-dosing every 3-6 h as needed.17

Despite the analgesic efficacy of OC/HC, several studies have demonstrated non-opioid alternatives to be non-inferior in reducing pain. In the treatment of acute extremity pain in the emergency setting, neither 5 mg oxycodone-325 acetaminophen nor 5 mg hydrocodone-300 mg acetaminophen were superior to 400 mg ibuprofen-1000 mg acetaminophen for pain reduction.18 Similarly, the addition of acetaminophen-oxycodone to 500 mg PO naproxen (twice daily) for acute, non-radicular low back pain was no more efficacious than naproxen alone. Further, the OC/HC-acetaminophen combination pills increase the risk of under-dosing acetaminophen when attempting to minimize opioid consumption or over-dosing acetaminophen when attempting to reach sufficient opioid equianalgesic effect. When available, alternative analgesic options (or acetaminophen alone) are recommended for acute pain presentations to maximize safety and efficacy.

Due to convenient oral formulations, OC/HC are commonly prescribed analgesics from the emergency room. However, the use of OC comes with an increased abuse potential. Data extrapolated from experiment on healthy volunteers has shown a higher likability (surrogate marker for abuse potential) and lower incidence of negative subjective effects with OC compared to either HC or morphine.11 Alternatively, morphine sulfate immediate release (MSIR) has a decreased likability (i.e., abuse potential), increased dysphoria,10,11 and a decreased risk of acetaminophen under-/over-dosing making it a preferred choice when a short outpatient analgesic course is required (e.g., 3-day supply of MSIR 15 mg every 6 h with plan for reevaluation if pain persists beyond three days).10,11

Fentanyl is 100-times more potent that morphine allowing for a quick onset and short duration when needed for rapid titration during severe pain unremitting to traditional analgesics. 0.5 mcg/kg IV fentanyl (25-50 mcg) every 30 min as needed is the recommended dosing for severe pain presentations in the emergency setting.12

A variety of fentanyl delivery routes are available as safe alternatives when IV access cannot be obtained. Research has shown 1.5 to 3.0 mcg/kg nebulized fentanyl as effective as IV fentanyl for acute abdominal and musculoskeletal pain in the emergency setting. Research comparing 2 mcg/kg nebulized fentanyl to 0.1 mg/kg IV morphine showed more rapid pain relief, higher patient and physician satisfaction, and similar rates of adverse effects when using fentanyl for acute abdominal pain.13 Though research is limited to the pediatric population, data has shown 1 to 2 mcg/kg intranasal (IN) fentanyl can be used for both safe and effective analgesia in the emergency setting116,117 and may also improve the door-to-analgesia time.118

Compared to morphine and hydromorphone, which are metabolized by the liver to active metabolites requiring renal clearance, fentanyl is metabolized by the liver to inactive metabolites that are relatively safer in the setting of renal failure.11 In contrast to other opioids, fentanyl has less gastrointestinal disturbance and histamine-induced hypotension making it a better choice in hemodynamically borderline patients.120

Hydromorphone (HM) is a highly lipophilic opioid, approximately 7-times more potent than morphine.121,122 A traditional regimen utilizing a “1 + 1” dosing protocol - 1 mg HM IV bolus given at baseline followed by a repeat 1 mg HM IV bolus at 15 min as needed - has shown clinically significant pain reduction and limited adverse effects in non-elderly patients presenting with moderate to severe acute pain.123 The “1 + 1” protocol is further supported by a data comparing the protocol to a baseline 2 mg IV bolus where both arms resulted in similar analgesic efficacy, though an opioid-sparing advantage in the “1 + 1” group where only one-third of the patients requested the second 1 mg dose.124 In opioid-naïve patients, however, initial doses as low as 0.25-0.5 mg IV HM should be administered to avoid nausea, pruritus, and rapid (over) sedation with early reassessment and titration as needed.12,125 Similar to morphine, the analgesic effect of HM lasts approximately 3-6 h.12,125

Hydromorphone has been cited as a recurrent source of preventable intravenous over-dosing,126 and caution should be taken when calculating the desired equianalgesic dose (see Fig. 2). Research has shown 2 mg IV HM is capable of causing desaturations (< 95% O2 saturation) in up to one-third of patients, though successfully reversed with oxygen via nasal cannula.127 Age is directly correlated with risk of desaturation and increased caution is advised with HM use among the elderly.127

Tramadol is a partial mu-opioid receptor (MOR) agonist with dual functionality as a serotonin and norepinephrine reuptake inhibitor (SNRI).128 The mu-opioid receptor affinity of tramadol and its more active metabolite O-desmethyltramadol (ODT, M1) are significantly less than that of morphine.129 The analgesic efficacy of tramadol has shown

Table 4

| Opioid           | Dose (oral) | Dose (IV) | Onset IV (oral) | Duration |
|------------------|-------------|-----------|-----------------|----------|
| Morphine (MSIR)  | 10-15 mg    | 0.1 mg/kg (5-10 mg) | 5-10 min (15-30 min) | 3-6 h (IV, oral) |
| Hydromorphone (Dilaudid) | 2 mg | 0.25-0.5 mg | 5-10 min (15-30 min) | 3-6 h (IV, oral) |
| Oxycodone (Percocet) | 5-10 mg | – | (15-20 min) | 3-6 h (PO) |
| Hydrocodone (Lorcet, Norco) | 5-10 mg | – | (15-20 min) | 3-6 h (PO) |
| Fentanyl | – | 0.5 mcg/kg (25-50 mcg) | 1-2 min | 0.5-1 h (IV) |
to be inferior to the combination regimen 500 mg acetaminophen-5 mg hydrocodone for acute musculoskeletal pain,\textsuperscript{130} non-superior to 1 mg/kg IV diclofenac for extremity injury,\textsuperscript{131} and non-superior to 5–10 mg IV morphine for limb pain.\textsuperscript{132} Tramadol toxicity results in nausea, agitation, tachycardia, confusion, hypertension, hypoglycemia, hyponatremia,\textsuperscript{133,134} and a lowered seizure threshold.\textsuperscript{125,135} Additionally, tramadol has shown to be a major contributor to abuse-related ED visits.\textsuperscript{136} Due to the increased risk of adverse effects, abuse potential, and non-superiority compared to analgesic alternatives, tramadol use is not recommend in the emergency setting.

Side effects common to all opioids include respiratory depression, miosis, cardiovascular depression (hypotension, bradycardia), pruritus (through central mu-receptor agonism and histamine release; seen in a minority of cases), urinary retention, and constipation/gastrointestinal motility depression.\textsuperscript{122,137} Respiratory depression is the leading preventable adverse side effect seen in the emergency setting secondary to over-dosing.\textsuperscript{126} Muscle (chest wall) rigidity is an adverse effect unique to fentanyl toxicity\textsuperscript{113} directly correlated to the overall dose and rate of administration.

A detailed summary of commonly used opioid analgesic options in the emergency setting can be found in Table 4.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
Drug & Indication & IN amount (cc) & Peak onset (min) & Duration (min) & Adverse effects \\
\hline
Dexmedetomidine (100 mcg/ml) & Analgesia, procedural sedation & 0.7–1.5 & 0.7–1.5 & 20 & Bradycardia, hypotension \\
Ketamine (100 mg/ml) & Analgesia & 0.5–1 & 0.5–1 & 5–10 & Distaste, hypersalivation, emergency reaction \\
Fentanyl (50 mcg/ml) & Analgesia & 15–30 & 15–30 & 20–25 & Nasal irritation, rhinitis, respiratory depression, nausea, vomiting \\
Hydromorphone (2 mg/ml) & Analgesia & 2–4 mg & 2–4 mg & 1–2 & Nasal irritation, rhinitis, respiratory depression, nausea/vomiting \\
\hline
\end{tabular}
\caption{Common intranasal analgesics used in the emergency setting. For optimal delivery divide the total dose equally among each nostril to maximize absorption surface area. Total volume per nostril should not exceed 1–2 cc to avoid run off.}
\end{table}

\section*{11. Future emergency analgesic options}

\textbf{Dexmedetomidine (DXMT):} The alpha-2-adrenergic receptor agonist DXMT produces analgesia by dampening the centrally-activated sympathetic response.\textsuperscript{138} DXMT utilization has expanded from its classic role as a sedative among mechanically ventilated patients in intensive care settings, to a promising analgesic adjunct.\textsuperscript{138} DXMT can be delivered IV or IN with recommended dosing of 0.5–1.0 μg/kg IV (1–2 μg/kg intranasal).\textsuperscript{138} Concomitant DXMT use has been shown to reduce opioid (oxycodone) consumption, decrease opioid side effect profile, and improve patient satisfaction in the postoperative setting.\textsuperscript{139} When combined with regional nerve blocks (ropivacaine, bupivacaine) 1 μg/kg dexmedetomidine has resulted in a prolonged duration of sensory blockade\textsuperscript{140} and a shorter time to anesthesia onset.\textsuperscript{141} At this time, however, a high drug cost has limited research and utilization of DXMT in the emergency setting and its use remains an emerging concept in need of further research.

\textbf{Buprenorphine:} Buprenorphine is a partial opioid receptor agonist approximately 25–100 times more potent than morphine.\textsuperscript{142} A higher binding affinity and slower dissociation rate of buprenorphine result in a longer duration of action compared to other opioids.\textsuperscript{143} Predominantly used to treat opioid withdrawal and opioid use disorder,\textsuperscript{144,145} research has shown buprenorphine can successfully treat neuropathic pain,\textsuperscript{142} cancer pain,\textsuperscript{142,146} and post-operative pain.\textsuperscript{147} One randomized trial found 2 mg sublingual buprenorphine to be as effective as 30 mg IV ketorolac for acute renal colic relief but with increased nausea, vomiting, and dizziness in the buprenorphine group.\textsuperscript{148} A separate randomized trial found 2 mg sublingual buprenorphine to be as effective as 0.1 mg/kg IV morphine for acute renal colic relief, again with increased dizziness.\textsuperscript{149} Furthermore, 0.4 mg sublingual buprenorphine has been shown to be as effective and safe as 5 mg IV morphine for acute bone fractures in the emergency setting.\textsuperscript{150} Additional research is needed to understand the full utility of analgesic buprenorphine in the emergency setting.

\textbf{Intranasal Analgesics:} Intranasal (IN) analgesic delivery is a safe, simple, and effective method of analgesic administration that bypasses
oral absorption and first-pass metabolism with onset comparable to IV administration. Analgesics commonly used intranasally include fentanyl, ketamine, dexmedetomidine, and hydromorphone (see Table 5 for a descriptive listing of commonly used intranasal analgesics). IN administration allows for quick delivery of low-volume, high-concentrate analgesics without the need for IV access or site sterilization. Though topical administration is also feasible, mucosal atomizer devices (MAD) are preferred to optimize distribution of approximately 0.5–1.0 cc analgesic per nostril. IN analgesic research has predominantly focused on the pain reduction among the pediatric population where IV access is often limited. Future studies are required to determine the efficacy and feasibility of IN analgesics among the adult population in acute emergency settings.

12. Conclusion

The presentation of pain within the emergency department is an inevitable part of every shift. Despite under or improper utilization of pain medication, a wide variety of analgesic options exist for the effective management of pain in every proportion. Utilizing the multi-modal Channels-Enzymes-Receptors Targeted Analgesia (CERTA) approach to pain allows providers to take advantage of a variety of analgesic options at reduced doses, thereby optimizing the safety and efficacy of the analgesic regimen. By developing a familiarity with the various analgesic options at their disposal emergency providers may formulate a safe, effective, balanced analgesic combination unique to each patient presentation.

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