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REVIEW

Analgesia in Military Mass-Casualty (MASCAL) Incidents: Evidence Synthesis and an Operational Triage-Linked Framework

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Abstract: Military mass-casualty (MASCAL) incidents impose severe constraints on analgesia delivery due to rapid triage, limited monitoring capacity, and heterogeneous provider qualifications. This review aimed to map current evidence on battlefield analgesics and identify options suitable for high-throughput MASCAL conditions. A scoping review was conducted following PRISMA-ScR methodology, including a systematic PubMed/MEDLINE search (2017-2023), dual-review screening, predefined eligibility criteria, and structured data extraction. Sixty-six articles met the inclusion criteria. Evidence indicates that transmucosal opioids – oral transmucosal fentanyl citrate (OTFC) and the sufentanil sublingual tablet (SST) – provide rapid, effective analgesia but require continuous observation, airway-rescue competence, and governance controls, which may limit their safe use in large-scale MASCAL operations. Ketamine demonstrates the most favorable operational profile, combining reliable analgesia with preserved airway reflexes, cardiovascular stability, flexible dosing routes, and minimal monitoring requirements. Cannabinoid preparations and α2-agonists lack sufficient evidence for acute trauma analgesia and present pharmacologic or safety limitations that preclude routine prehospital use. Based on these findings, we propose a triage-linked analgesia framework that aligns agent selection with provider level, monitoring capacity, and evacuation timelines. Overall, ketamine emerges as the primary analgesic option for MASCAL incidents, whereas transmucosal opioids should be reserved for trained personnel operating under protocolized oversight.

Keywords: Mass-casualty (MASCAL) events; Tactical Combat Casualty Care (TCCC); Oral transmucosal fentanyl citrate (OTFC); Sufentanil sublingual tablet (SST); Prehospital military medicine.

INTRODUCTION

Effective pain management is a critical component of combat casualty care, directly influencing survival, functional outcomes, and evacuation readiness. Pain is widely recognized as the fifth vital sign, and its timely, context-appropriate treatment becomes particularly challenging during military mass-casualty (MASCAL) incidents, where casualty volume exceeds medical capacity and constraints on personnel, monitoring, and time limit clinical decision-making [1]. For the purposes of this review, “prehospital” care includes all interventions from the point of injury to initial evacuation, and “analgesia” refers to pharmacologic strategies targeting acute pain and its physiologic consequences.

The development of Tactical Combat Casualty Care (TCCC) since 1996 has transformed battlefield medicine and substantially reduced preventable mortality during operations in Iraq and Afghanistan [2,3]. Current TCCC guidelines endorse a tiered analgesia strategy based on pain severity and provider qualification, including non-steroidal anti-inflammatory drugs (NSAIDs), ketamine, and oral transmucosal fentanyl citrate (OTFC). OTFC (800 µg) offers rapid, non-invasive analgesia without the need for intravenous access – an advantage of particular significance during MASCAL events characterized by accelerated triage and limited equipment availability [4,5].

However, OTFC – like all opioids – has a narrow therapeutic index and may cause respiratory depression, requiring airway-rescue capability and continuous observation. These risks are magnified in MASCAL conditions, where high casualty throughput and variable provider experience increase the likelihood of dosing or monitoring errors [6,7]. Concurrently, the broader global opioid crisis underscores the need for responsible opioid stewardship in operational environments [8-10],

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stimulating renewed interest in optimizing existing analgesics and evaluating potential adjuncts that could reduce opioid burden without compromising efficacy.

Military medicine, therefore, requires analgesic agents that are potent, fast-acting, logistically lightweight, and safe for use across multiple provider levels [3,11]. Because MASCAL scenarios differ fundamentally from routine battlefield care – particularly regarding triage prioritization, monitoring capability, and evacuation timelines – there is a need for an operationally grounded framework guiding analgesic selection during large-scale casualty surges. This review synthesizes current evidence on established and emerging analgesic modalities, evaluates their suitability for MASCAL environments, and proposes a triage-linked analgesia algorithm to support clinical decision-making during military mass-casualty incidents.

METHODS

This study was conducted as a scoping review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) [12]. The objective was to map contemporary evidence on pharmacologic analgesia relevant to military prehospital care, with specific emphasis on mass-casualty (MASCAL) conditions where resource constraints, rapid triage, and variable provider qualifications affect therapeutic choices.

1. Conceptual framework and operational focus

Consistent with the definitions outlined in the Introduction, the review targeted studies applicable to:

- MASCAL environments, defined as incidents in which casualty volume exceeds available medical capacity [13].
- Prehospital military care, spanning the point of injury through the initial evacuation phases [3,14].
- Analgesia, referring to pharmacologic interventions for acute trauma pain with operational relevance [15].

The operational intent of the review was to support the development of a structured, triage-linked analgesia framework suitable for battlefield and MASCAL conditions [16,17].

2. Information sources

A structured literature search was performed in PubMed/MEDLINE, selected for its comprehensive indexing of military medicine, trauma, anesthesiology, emergency care, and pharmacology [18,19]. The search period spanned 1 January 2017 to 1 June 2023, reflecting recent developments in opioid stewardship, adjunct analgesia, and battlefield protocols [20,21].

Reference lists of eligible studies and pertinent reviews were also screened to identify additional sources [22].

3. Search strategy

The search combined Medical Subject Headings (MeSH) and free-text terms. Boolean operators were applied to optimize sensitivity [23]. The core strategy was:

("analgesia"[MeSH] OR "acute pain" OR "pain management") AND ("combat" OR "military" OR "battlefield" OR "prehospital") AND ("mass casualty" OR "MASCAL" OR "triage") AND ("opioids" OR "fentanyl" OR "sufentanil" OR "OTFC" OR "ketamine" OR "cannabinoids" OR "alpha-2 agonists").

The full list of search strings is provided in Appendix 1 (PRISMA-ScR Search Strategy) [24].

4. Eligibility criteria

Inclusion criteria:

- Studies examining acute pain management relevant to prehospital or battlefield settings [25];
- Evaluation of pharmacologic analgesics (opioids, ketamine, cannabinoid-based agents, α2-adrenergic agonists, or opioid-sparing strategies) [26];
- Findings with operational implications for military use or MASCAL environments [27];
- English-language publications, 2017-2023;
- Clinical, experimental, observational, or review methodologies applicable to austere decision-making contexts [28].

Exclusion criteria:

- Chronic pain studies;
- Non-trauma or elective surgery contexts;

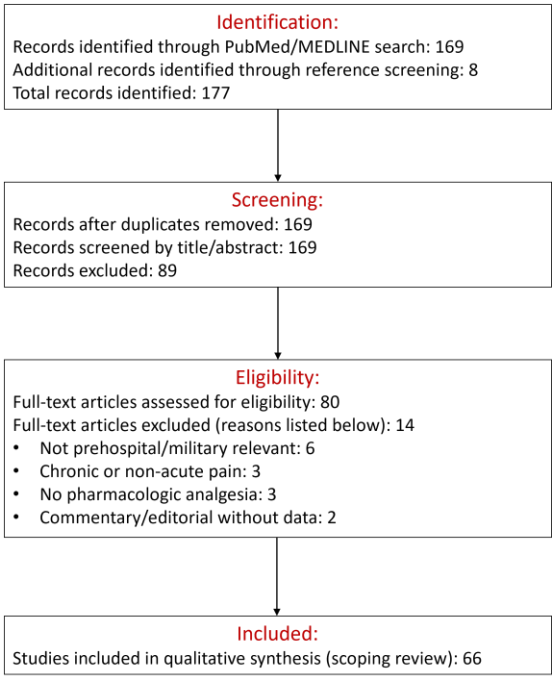
- Articles lacking prehospital or operational relevance;
- Narrative commentaries without substantive data;
- Non-English publications.

5. Selection of sources of evidence

Two reviewers independently screened titles and abstracts, followed by full-text review of potentially eligible studies [29]. Discrepancies were resolved through consensus. This dual-review approach ensured methodological rigor consistent with PRISMA-ScR recommendations [12].

The search yielded 169 records; after screening and full-text assessment, 66 studies met the inclusion criteria. The selection process is depicted in Figure 1 [30].

Figure 1: PRISMA-ScR flow diagram for study selection.



6. Data charting process

A standardized data-charting template was developed a priori [31]. Extracted variables included:

- Study characteristics and design;
- Population and operational context;
- Analgesic agent, dose, route, onset, and duration;
- Monitoring requirements;
- Adverse effects and operational risks;
- Applicability to MASCAL triage and resource limitations;
- Key findings and recommendations.

Two reviewers independently extracted data to ensure accuracy and completeness [32].

7. Synthesis of results

Due to heterogeneity across study designs and outcome measures, results were synthesized narratively [33]. Evidence was categorized into:

1. Opioid analgesics in battlefield and MASCAL settings;
2. Dissociative analgesia and ketamine-based regimens;
3. Opioid-sparing and adjunctive agents, including cannabinoids and α2-adrenergic agonists;
4. Governance and monitoring requirements across provider levels;
5. Operational implications for triage-linked decision-making in MASCAL environments.

These findings informed the development of:

- Table 1: Analgesic options and operational characteristics;
- Table 2: Triage-linked MASCAL analgesia workflow [34].

RESULTS

A total of 66 studies met the inclusion criteria and were analyzed. Evidence was organized into four domains relevant to analgesia in prehospital battlefield and mass-casualty (MASCAL) environments: (1) opioid analgesics, (2) dissociative analgesia with ketamine, (3) opioid-sparing adjuncts including cannabinoids and α_2-adrenergic agonists, and (4) operational considerations related to provider capabilities, monitoring, and governance.

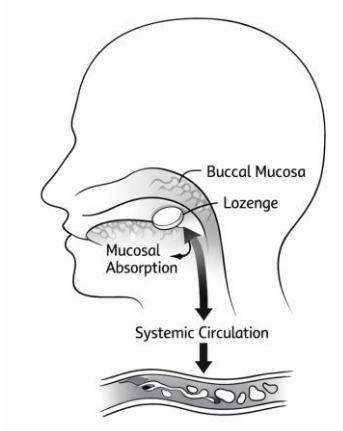
1. Opioid analgesics in battlefield and MASCAL Settings

1.1. Oral Transmucosal Fentanyl Citrate (OTFC)

OTFC 800 µg consistently demonstrated rapid analgesic onset (5-10 min) and operational advantages due to non-invasive buccal administration (Figure 2) [35,36]. Studies highlighted its suitability in settings where intravenous access is impractical, aligning with TCCC analgesia guidance [4,5,37]. Preliminary experience in civilian mass-casualty responses also supported its usefulness in resource-limited environments [38].

However, multiple studies emphasized OTFC's narrow therapeutic index and potential for respiratory depression, particularly in settings lacking sustained monitoring [6,39]. Case series and guideline analyses underscored the need for airway-rescue capability and close observation, with concerns about dosing control during high-throughput MASCAL conditions [7,40]. Data from Operation HERRICK further illustrated the practical challenges of opioid administration in austere combat environments [41].

Figure 2: Conceptual illustration of buccal (oral transmucosal) opioid administration.



Schematic representation of a solid transmucosal dosage form positioned against the buccal mucosa. The active compound is absorbed directly through the oral mucosal vasculature into the systemic circulation, providing rapid analgesic onset without the need for intravenous access. The illustration is author-generated and intended for explanatory purposes only.

1.2. Sufentanil Sublingual Tablet (SST)

SST 30 µg demonstrated rapid absorption (Figure 3), favorable pharmacokinetics, and a comparatively advantageous therapeutic index [42,43]. Studies reported a median three-hour duration of effect and reduced dosing errors due to the single-dose applicator design [44,45]. Reviews consistently confirmed analgesic efficacy in acute pain settings [46].

Operational analyses suggested potential advantages over OTFC, including greater dosing accuracy and lower incidence of euphoria-related side effects [47]. However, regulatory guidance (DSUVIA™, DZUVEO™) mandates administration under trained supervision, which limits applicability for lower-level providers during MASCAL events [48,49]. Intranasal sufentanil showed promise but requires further validation for emergency use [50].

1.3. Other opioids

Evidence for intravenous fentanyl or morphine in austere prehospital settings was limited [51]. Logistical and safety barriers – including the need for intravenous (IV) access, risk of hypotension, and continuous monitoring – restricted their relevance to MASCAL care [52,53]. No included study supported widespread IV opioid administration by non-physician personnel during mass-casualty events [54]. Analyses of care during the Afghanistan conflict highlighted complexities surrounding prehospital opioid use [55], and systematic reviews reinforced the need for caution when employing opioids for acute prehospital pain [56].

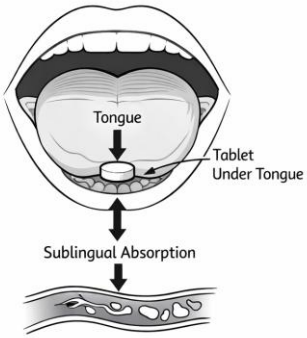
2. Dissociative Analgesia: Ketamine

Ketamine was the most consistently supported agent across the reviewed literature [57,58]. Multiple military and civilian trauma studies confirmed reliable analgesia with preserved airway reflexes and cardiovascular stability [59,60]. Rapid onset (minutes) and multiple administration routes (IV; intramuscular; IN, intranasal) enabled effective use across variable provider skill levels [61,62]. Studies specific to combat casualty care demonstrated strong safety and efficacy profiles [63-65].

Evidence from high-throughput or resource-limited settings reported minimal need for airway intervention [66,67]. Adverse effects – including dysphoria and emergence reactions – were infrequent at analgesic doses and typically manageable with reassurance or adjunct benzodiazepines [68,69]. No significant incidence of respiratory depression was reported at standard analgesic dosing [70]. Systematic reviews supported ketamine's favorable benefit-to-risk ratio for prehospital acute pain [71,72].

Overall, ketamine emerged as the most operationally robust analgesic for MASCAL environments, requiring minimal monitoring while maintaining safety [73,74]. Intranasal ketamine has been highlighted as a simple, logistically advantageous option for battlefield analgesia [75].

Figure 3: Conceptual representation of sublingual tablet administration.



Diagrammatic depiction of sublingual placement of a tablet beneath the tongue. The medication dissolves and is absorbed through the highly vascularized sublingual mucosa, facilitating rapid systemic uptake and analgesic effect. The figure is an original author-created schematic for educational clarification.

3. Opioid-sparing and adjunctive agents

3.1. Cannabinoid-based agents

Cannabinoid preparations (THC, CBD, mixed formulations, oromucosal sprays) demonstrated mixed and generally low-quality evidence for acute pain [76,77]. Systematic reviews noted analgesic effects comparable to placebo in trauma and postoperative contexts [78,79], with some studies reporting increased postoperative pain or hypotension when used as adjuncts [80,81].

Critically, no included study supported cannabinoid use in prehospital trauma or MASCAL environments [82]. Unpredictable onset, variable pharmacokinetics, and psychoactive effects were consistently identified as limiting factors [83,84]. No article recommended cannabinoid use for operational analgesia outside controlled trials [85]. Emerging research on cannabis-derived terpenes remains experimental and lacks relevance to acute trauma care [86,87].

2.2. α2-Adrenergic agonists: Clonidine and Dexmedetomidine

Clonidine and dexmedetomidine were primarily evaluated in perioperative or intensive care contexts [88,89]. Clonidine demonstrated modest opioid-sparing effects [90,91], while dexmedetomidine produced sedation and sympatholysis but carried risks of bradycardia and hypotension requiring continuous monitoring [92,93].

No included study supported dexmedetomidine for prehospital trauma or MASCAL settings [94], and monitoring demands preclude use by non-physician providers [95]. Clonidine showed theoretical adjunctive value but lacked operational data supporting field application [96].

4. Operational and provider-level considerations

Across studies, provider training, monitoring capability, and environmental constraints were consistently identified as the decisive factors shaping analgesic suitability [97,98]. Recurring themes included:

- Essential airway-rescue capability when using opioids, particularly OTFC or SST [99,100].
- Increased risks associated with sedative or respiratory-depressant agents in low-monitoring MASCAL settings [101,102].
- Wide variation in provider qualifications (CLS, medic, physician) influencing safe medication use [103,104].
- Impact of analgesic choice on evacuation timelines and triage throughput [27,105].

Additional studies described organizational challenges during mass-casualty incidents, including hospital flow during terrorist attacks [106], triage simplification [107], and the need for multinational coordination [108]. Military triage research provided insights relevant to MASCAL planning [109-111].

Evidence-based prehospital pain management guidelines [115] and long-term battlefield experiences [116–120] further informed operational considerations.

Only ketamine and single-dose transmucosal opioids (OTFC, SST) demonstrated consistent evidence supporting use in austere environments [94,117]. No other analgesic showed sufficient safety or operational feasibility for widespread prehospital use without substantial governance measures [118]. The operational characteristics of all evaluated agents appear in Table 1.

Table 1: Operational Characteristics of Analgesic Options for Military Prehospital and MASCAL Environments.

Agent	Onset	Duration	Route(s)	Dose Guardrails	Monitoring Requirements	Reversal / Mitigation	Key Operational Advantages	Contraindications / Limitations
OTFC, 800 µg	5-10 min	30-60 min	Transmucosal	One lozenge only; remove if AMS develops	Requires the ability to monitor respirations; airway-rescue capability	Naloxone	No IV needed; rapid relief; simple administration	Narrow therapeutic index; risk of respiratory depression in low-monitoring settings
SST, 30 µg	~15 min	≈3 h	Sublingual	Single-dose applicator; no immediate redosing	Opioid monitoring; avoid in AMS / hypoxia	Naloxone	Accurate dosing; higher therapeutic index than OTFC	Requires trained supervision; regulatory restrictions for unsupervised use
Ketamine (analgesic dose 0.1-0.3 mg/kg IV or 0.3-0.5 mg/kg IM/IN)	Minutes	20-40 min	IV, IM, IN	Avoid repeated full-dose boluses	Minimal airway monitoring; no airway-rescue required routinely	Benzodiazepines for dysphoria	Preserves airway reflexes; stable hemodynamics; safe for low-monitoring MASCAL	Emergence reactions in a small %; avoid in severe HTN

NSAIDs (e.g., Meloxicam, Ibuprofen)	20-40 min	4-8 h	PO	Standard dosing	No special monitoring	None	Safe profile; suitable for mild–moderate pain	Slow onset; contraindications in bleeding, renal injury, or dehydration
α_2-Agonists (Clonidine)	30-60 min	Several hours	PO, transdermal, adjunct	Not the primary agent	BP/HR monitoring required	None specific	Adjunct opioid-sparing effect	Hypotension, bradycardia; limited field evidence
Dexmede-tomidine	Slow (IV infusion)	Variable	IV	Requires titrated infusion; not suitable for bolus	Continuous HR/BP/O_2 monitoring	None	Sedation + analgesia synergy	Not suitable for prehospital or MASCAL settings; hemodynamic instability
Cannabinoids (various)	Variable (slow)	Variable	PO, oromucosal spray	Not standardized dosing for acute trauma	Cognitive monitoring	None	Limited/no acute analgesia evidence	Not recommended; unpredictable effects

* Abbreviations: IV, intravenous; IM, intramuscular; IN, intranasal; PO, per os (orally); BP, blood pressure; HR, heart rate; O2, oxygen saturation; AMS, altered mental status; HTN, hypertension.

DISCUSSION

Effective analgesia in military mass-casualty (MASCAL) incidents requires agents that balance potency, safety, rapid onset, and logistical feasibility under limited monitoring and variable provider proficiency. The findings of this scoping review demonstrate that, despite significant advances in combat casualty care, only a narrow subset of pharmacologic options meets the operational requirements of prehospital battlefield and MASCAL environments [3,37]. These results closely align with prior analyses of TCCC-based pain management and highlight the persistent trade-off between clinical effectiveness and field applicability [5]. Table 2 provides a triage-linked framework mapping analgesic selection to provider qualifications and minimum monitoring thresholds during MASCAL operations.

Table 2: MASCAL Workflow Linking Triage Category to Permissible Analgesic Agents, Provider Level, and Minimum Monitoring.

Triage Category	Permissible Analgesic Agents	Provider Level	Minimum Monitoring Requirements	Evacuation Implications
Immediate (Red)	Ketamine (IV/IM/IN); OTFC; SST (only if airway stable); limited IV opioids (physician only)	Medic / Physician	Respiratory rate; mental status; SpO_2 if available	Rapid evacuation; avoid agents requiring prolonged observation
Delayed (Yellow)	Ketamine; OTFC; SST; NSAIDs	CLS / Medic / Physician	Periodic airway check; RR; mental status	Analgesia should not delay triage assignment or evacuation timing
Minimal (Green)	NSAIDs; PO analgesics only	CLS	No continuous monitoring required	Evacuate after higher-priority categories
Expectant (Black)	Symptom-relief analgesia (ketamine IM/IN as available)	Medic / Physician	Comfort-focused monitoring	Analgesia should not divert resources from salvageable casualties

* Abbreviations: CLS, Combat Lifesaver (basic medical training); Medic (advanced tactical medic); Physician (medical officer). IV, intravenous; IM, intramuscular; IN, intranasal; OTFC, oral transmucosal fentanyl citrate; SST, sufentanil sublingual tablet; NSAIDs, non-steroidal anti-inflammatory drugs; PO, per os; RR, respiratory rate; SpO2, peripheral oxygen saturation.

1. Opioids: Benefits and persistent operational limitations

Opioids remain central to battlefield analgesia due to their established efficacy and familiarity among military personnel [4]. OTFC provides rapid, non-invasive analgesia compatible with TCCC priorities [5,36], but its narrow therapeutic index and risk of respiratory depression require airway-rescue capability and frequent observation – conditions difficult to maintain during high-throughput MASCAL operations [6,36,40]. These limitations increase vulnerability to dosing variability and monitoring gaps when administered by lower-level providers or during large casualty influxes [7].

SST offers advantages over OTFC, including a higher therapeutic index and reduced dosing variability [43]. However, regulatory mandates for trained supervision (EMA/FDA) restrict its use among providers such as combat lifesavers and medics during MASCAL events [44,45,48,49]. No included study supported unsupervised SST use in mass-casualty settings.

2. Ketamine as the most operationally feasible agent

Ketamine demonstrated the strongest evidence base across prehospital, trauma, and operational contexts [59]. Its preservation of airway reflexes, cardiovascular stability, and flexible administration routes make it uniquely suited for MASCAL conditions with limited monitoring capacity and variable provider skill [62]. No study reported significant respiratory compromise at analgesic doses, and psychoperceptual effects were infrequent and manageable [68]. These findings reinforce existing TCCC guidance and consensus statements positioning ketamine as the cornerstone of battlefield analgesia [57,121,122].

3. Cannabinoids and α2-adrenergic agonists: Insufficient evidence for field use

Although cannabinoids have been proposed as opioid-sparing agents, high-quality systematic reviews consistently demonstrate no clinically meaningful benefit for acute trauma pain, with effects comparable to placebo [78]. Their variable onset, psychoactive properties, and risk of hypotension render them inappropriate for prehospital or MASCAL use [80]. None of the included studies recommended cannabinoid use for operational trauma analgesia [79].

Similarly, α2-agonists demonstrated sedative and analgesic-sparing effects in controlled clinical settings [89], but all studies required continuous monitoring for bradycardia and hypotension [90,92,93]. Dexmedetomidine is clearly unsuitable for MASCAL conditions, while clonidine lacks operational evidence for prehospital trauma care [96]. The review found no support for deploying α2-agonists as primary or adjunct analgesics in MASCAL environments.

4. Operational implications: training, monitoring, and governance

Operational constraints consistently shaped analgesic appropriateness across included studies [99]. Limited monitoring, variable provider competency, and accelerated triage cycles restrict the safe use of many agents during MASCAL incidents [101]. These findings echo longstanding recommendations emphasizing strict governance, standardized dosing protocols, and provider-level limitations to minimize risk during battlefield analgesia [37,123].

A triage-linked algorithm integrating casualty category, provider qualification (CLS, medic, physician), and minimum monitoring requirements is therefore essential [40,125,126]. Opioids – whether OTFC or SST – should be limited to providers trained in airway management and supported by naloxone availability [99,100]. In contrast, ketamine's superior safety profile permits broader application across provider levels under austere conditions [57,62]. These findings directly inform the MASCAL workflows and decision tables (Tables 1 and 2). Additional work on prolonged field care indicates the need for specialized protocols when monitoring is extended or evacuation is delayed [127], while ongoing research continues to refine intranasal ketamine use for battlefield analgesia [128].

5. Synthesis and future directions

This review identifies a persistent gap between available analgesics and the operational demands of MASCAL military care [118]. Among evaluated agents, only ketamine and single-dose transmucosal opioids demonstrated sufficient feasibility for large-scale prehospital application [58,74,129]. Future research should prioritize:

- controlled field comparisons of OTFC and SST under MASCAL conditions [43];
- evaluation of opioid-sparing strategies that do not require continuous monitoring [77,81];
- development of simplified provider-level dosing schemas to reduce error risk [103];
- integration of portable physiological monitoring technologies for austere environments [102].

Given current evidence, operational doctrine must rely on agents with both pharmacologic validity and demonstrated field feasibility [11,37]. This review provides an evidence-based foundation for updated, triage-linked analgesia protocols specifically designed for military mass-casualty environments.

CONCLUSION

Effective analgesia in military mass-casualty (MASCAL) incidents requires agents that combine rapid onset, operational feasibility, and safety under conditions of limited monitoring and variable provider capability. This scoping review identified ketamine and single-dose transmucosal opioids (OTFC, SST) as the only pharmacologic options with consistent support for prehospital battlefield use, with ketamine demonstrating the most robust safety profile and flexibility. Evidence for cannabinoids and α2-adrenergic agonists remains insufficient for field implementation, particularly in environments requiring hemodynamic stability and predictable dosing.

A persistent gap remains in structured, triage-linked analgesia algorithms tailored to MASCAL operations. Standardized protocols aligned with provider qualifications, operational constraints, and evacuation priorities are essential for reducing adverse events and improving casualty flow. Future operational research should refine governance measures, evaluate emerging agents, and strengthen evidence-based battlefield pain management.

Actionable Recommendations for Military MASCAL Analgesia

1. Implement a triage-linked analgesia algorithm

Align analgesic choice with triage category and provider level, integrating protocols into SOPs and TCCC training.

2. Prioritize ketamine as first-line MASCAL analgesia

Utilize IV/IM/IN ketamine across provider levels; standardize dose cards to reduce variability.

3. Restrict opioid use to trained personnel with airway-rescue capability

Use OTFC and SST only when monitoring is feasible; ensure naloxone availability at all echelons of care.

4. Avoid cannabinoids and α2-agonists in prehospital or MASCAL care

Current evidence does not support their operational adoption outside controlled clinical environments.

5. Strengthen documentation and provider training

Use simplified field documentation and focused training on opioid safety, ketamine effects, and MASCAL-specific decision-making.

Conflicts of interest and sources of funding

The authors declare no conflict of interest.

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Authors' contribution

Conceptualization, G.S., and A.N.; methodology, G.S., and A.N.; investigation, G.S., and A.N.; resources, G.S., and A.N; data curation, A.N.; writing – original draft preparation, G.S.; writing – review and editing, A.N., and D.D.; visualization, A.N.; supervision, D.D.; project administration, A.N., and D.D. All authors have read and agreed to the published version of the manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable

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APPENDIX 1. PRISMA-SCR SEARCH STRATEGY

Database Searched

PubMed/MEDLINE
Date of last search: **1 June 2023**
Time window: **1 January 2017 – 1 June 2023**

1. MeSH Terms and Keywords Used

Analgesia / Pain

PubMed/MEDLINE

- “analgesia”[MeSH]
- “acute pain”
- “pain management”
- “trauma pain”

Military / Battlefield / Prehospital

- “battlefield”
- “combat”
- “military”
- “prehospital”
- “tactical combat casualty care”
- “TCCC”

Mass-Casualty Context

- “mass casualty”
- “MASCAL”
- “triage”

Analgesic Agents

- “opioids”
- “fentanyl”
- “oral transmucosal fentanyl citrate”

- “OTFC”
- “sufentanil”
- “sublingual sufentanil”
- “ketamine”
- “cannabinoids”
- “CBD”
- “THC”
- “alpha-2 agonists”
- “clonidine”
- “dexmedetomidine”

2. Full Search String Used in PubMed

Primary combined search:

("analgesia"[MeSH] OR "acute pain" OR "pain management")
AND ("combat" OR "battlefield" OR "military" OR "prehospital")
AND ("mass casualty" OR "MASCAL" OR "triage")
AND ("opioids" OR "fentanyl" OR "OTFC" OR "sufentanil" OR "ketamine"
OR "cannabinoids" OR "CBD" OR "THC"
OR "alpha-2 agonists" OR "clonidine" OR "dexmedetomidine")

3. Filters Applied

- Publication date: 2017-2023
- Language: English
- Species: Humans (when applicable)

4. Search Validation

The search strategy was tested iteratively to confirm:

- Retrieval of sentinel articles known to be relevant to battlefield analgesia
- Inclusion of key TCCC analgesia guideline papers
- Capture of opioid-sparing adjunct literature

Reference lists of eligible articles were screened to ensure completeness.