REVIEW PAPER

Disaster Zone Management and Educational Framework in Major Incident Response: A Systematic Review of Evidence, Operational Frameworks, and Training Implications for Emergency Medical Services

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ABSTRACT

Background: Major incidents are events in which the number, severity, or logistical demands of casualties exceed immediately available resources. Effective management requires coordinated command systems, validated triage protocols, organized casualty clearing operations, structured transport coordination, and hazard-aware zonal management. Despite widespread adoption of operational frameworks, a comprehensive systematic synthesis spanning all operational domains—including zonal management and educational implications—has not been conducted.

Objectives: To systematically review and synthesise the evidence base underpinning major incident management across seven operational domains: incident classification and surge, command and control, first responder roles, triage systems, casualty clearing post operations, ambulance flow and transport, and zonal management in hazardous incidents, as well as the educational frameworks supporting these competencies.

Methods: A systematic search was conducted in PubMed, MEDLINE (Ovid), EMBASE, CINAHL, Cochrane Library, Scopus, and the WHO Global Health Library, supplemented by grey literature. Eligibility criteria included peer-reviewed studies, systematic reviews, validated clinical guidelines, and operational frameworks addressing major incident management, mass casualty triage, EMS preparedness, or disaster education published from January 2000 to March 2026. Two independent reviewers performed title/abstract and full-text screening. Data were extracted using a standardised form and synthesised narratively. Study quality was appraised using AGREE II (guidelines), AMSTAR-2 (systematic reviews), and the NIH quality assessment tools (primary studies). Evidence quality was graded using a GRADE-informed approach.

Results: Thirty-five primary references met full inclusion criteria across seven operational domains. Evidence supports hierarchical incident command structures (ICS/MIMMS/HICS), dynamic multi-stage triage protocols (START, SALT, Triage Sieve, SMART; JumpSTART for paediatrics), structured Casualty Clearing Post operations, coordinated ambulance flow management, integrated zonal management for hazardous incidents, and multi-modal simulation-based training. Evidence quality was Moderate to High for guidelines and systematic reviews; Low to Moderate for primary empirical studies. Significant gaps remain in RCT-level evidence for triage algorithm performance, context-specific preparedness in low-and-middle-income country (LMIC) EMS systems, and integration of zonal management with conventional triage protocols.

Conclusions: Major incident management effectiveness depends on evidence-based command structures, validated triage systems, organized casualty clearing, coordinated transport, and hazard-aware zonal management. Multi-modal simulation-based educational frameworks are essential for operationalising these competencies. Future research must prioritise prospective triage validation, LMIC-adapted preparedness tools, zonal protocol integration, and rigorous evaluation of training effectiveness.

Keywords: major incident management, mass casualty incidents, disaster zone management, triage systems, incident command system, emergency medical services, zonal management, CBRN, simulation-based training, disaster education, surge capacity, EMS preparedness

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1. INTRODUCTION

Major incidents are complex emergency events in which the number, severity, or logistical demands of casualties exceed immediately available resources, necessitating coordinated multi-agency response, structured command systems, and prioritisation of medical care (ALSG, 2018). Critically, the designation of a major incident is determined not by casualty numbers alone but by the imbalance between healthcare demand and operational capacity — a distinction with profound implications for how response systems are designed, trained, and evaluated (Lennquist, 2012).

Globally, the frequency and complexity of major incidents have increased due to rapid urbanisation, expanding transportation networks, industrial growth, climate-related disasters, and evolving security threats (Sendai Framework, 2015). Mass casualty road traffic collisions, structural collapses, industrial chemical releases, terrorist incidents, and infectious disease outbreaks have demonstrated that unstructured emergency responses lead to delayed triage, inefficient casualty distribution, and preventable mortality (Hick et al., 2004). These patterns underscore the imperative for evidence-based preparedness frameworks integrating scene safety, communication, triage, treatment, transport, and — in hazardous incidents — contamination control.

Emergency Medical Services (EMS) occupy a pivotal position in major incident response, functioning as the interface between the incident scene and the healthcare system. The actions of the first arriving ambulance crew are particularly determinative: early scene organisation, accurate situation reporting, and initiation of triage govern the effectiveness of all subsequent resource deployment (Cone & Koenig, 2005). Despite this recognised importance, the evidence base for individual operational components of major incident management has not been comprehensively and systematically synthesised across all domains.

Prior reviews have addressed specific elements — triage algorithm accuracy (Bazyar et al., 2022; Jenkins et al., 2008; Hussain et al., 2025), simulation-based training effectiveness (Ingrassia et al., 2021; Abualenain et al., 2024), hospital surge capacity (Hasan et al., 2023; Sheikhbardsiri et al., 2017), and incident command systems (Rimstad & Braut, 2015; Djalali et al., 2020) — but none has integrated these domains with zonal management and the educational framework required to operationalise them in a unified synthesis.

This systematic review addresses this gap by consolidating evidence across seven operational domains of major incident management, evaluating the quality of that evidence using validated tools, and identifying research gaps and educational implications relevant to EMS systems globally. Particular attention is given to resource-variable settings, including those in the Indian subcontinent, where adaptation of international frameworks to local operational realities is essential.

2. METHODS

2.1 Review Design and Registration

This systematic review was designed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021).The Cochrane Handbook for Systematic Reviews of Interventions informed methodological standards, adapted for a mixed evidence base incorporating clinical guidelines, systematic reviews, and primary empirical studies.

2.2 Eligibility Criteria (PICOS Framework)

Population: Emergency responders, EMS personnel, hospital staff, and healthcare systems involved in major incident or mass casualty management.

Interventions/Exposures: Any operational framework, protocol, training intervention, triage system, command structure, zonal management approach, or educational programme pertaining to major incident management.

Comparators: Alternative systems, unstructured management, routine care, or pre-/post-implementation comparisons where applicable.

Outcomes: Triage accuracy (sensitivity, specificity, over/under-triage rates); response time; casualty survival; command effectiveness; simulation performance; surge capacity; educational competency gains.

Study designs: Randomised controlled trials (RCTs), non-randomised comparative studies, observational studies, systematic reviews and meta-analyses, validated clinical guidelines, and expert consensus frameworks. Editorials, letters, and conference abstracts without full data were excluded.

Inclusion criteria: (1) Addressed major incident management, MCI triage, EMS preparedness, or disaster education; (2) presented original data, higher-order evidence synthesis, or validated operational guidelines; (3) published in English in peer-reviewed journals or by recognised international bodies; (4) published January 2000 – March 2026 (foundational pre-2000 works included where evidence-defining).

Exclusion criteria: (1) Editorials or commentaries without data; (2) exclusively long-term reconstruction or psychosocial recovery studies; (3) duplicate publications; (4) lacking methodological transparency or reproducibility.

2.3 Information Sources and Search Strategy

A comprehensive systematic literature search was conducted across seven electronic databases: PubMed, MEDLINE (Ovid), EMBASE, CINAHL (EBSCO), Cochrane Central Register of Controlled Trials, Scopus, and the WHO Global Health Library. The search was conducted from January 2000 to March 2026. Grey literature sources were additionally hand-searched, including FEMA operational guidelines, WHO frameworks, the National Disaster Management Authority (NDMA) of India guidelines, and the Sendai Framework for Disaster Risk Reduction.

Search terms were structured using Medical Subject Headings (MeSH) and free-text keywords combined with Boolean operators (AND, OR, NOT). Core search string: ("major incident" OR "mass casualty" OR "multiple casualty" OR "disaster medicine" OR "MCI") AND ("triage" OR "incident command" OR "MIMMS" OR "ICS" OR "zonal management" OR "decontamination" OR "CBRN" OR "HazMat" OR "EMS" OR "emergency medical services" OR "ambulance" OR "surge capacity" OR "disaster education" OR "simulation training" OR "disaster preparedness"). Date, language (English), and human subject filters were applied. Reference lists of all included studies were hand-searched to identify additional eligible sources.

2.4 Study Selection

Records were imported into Rayyan systematic review management software and deduplicated. Two independent reviewers (Reviewer 1 and Reviewer 2) screened all titles and abstracts against the eligibility criteria. Full-text articles were retrieved for all potentially eligible studies. Disagreements were resolved by discussion or, if unresolved, by a third reviewer. Inter-rater agreement was calculated using Cohen's kappa statistic (κ). The selection process is reported in accordance with PRISMA 2020 (Table 1).

2.5 Data Extraction

A standardised data extraction form was developed and piloted on five included studies before full application. Extracted data included: study design and setting, study population, operational domain addressed, interventions and comparators, key findings, outcomes measured, and methodological limitations.

2.6 Quality Assessment

Study quality and risk of bias were assessed using validated domain-appropriate tools: AMSTAR-2 (Assessing the Methodological Quality of Systematic Reviews) for systematic reviews; AGREE II (Appraisal of Guidelines for Research and Evaluation) for clinical guidelines and operational frameworks; NIH Quality Assessment Tools for observational studies; and the Cochrane Risk of Bias Tool for RCTs. Overall evidence quality was graded using a GRADE (Grading of Recommendations, Assessment, Development and Evaluations)-informed approach, categorised as High, Moderate, Low, or Very Low.

2.7 Data Synthesis

Given the significant heterogeneity in study designs, populations, and outcome measures across included studies, formal meta-analysis was not appropriate. A thematic narrative synthesis was employed, following the principles outlined by Popay et al. (2006). Evidence was organised across seven pre-specified operational domains. Themes were identified deductively from the MIMMS and ICS frameworks and inductively from patterns across extracted data. A summary evidence matrix (Table 4) was constructed to facilitate quality appraisal, gap identification, and cross-domain comparison.

2.8 PRISMA Flow Diagram and Literature Selection

Table 1: PRISMA 2020 Literature Selection and Screening Summary

Stage	Details	Records (n)
Records identified via databases	PubMed, MEDLINE (Ovid), EMBASE, CINAHL, Cochrane, WHO, Scopus	344 (initial)
Records identified via hand search	Reference lists of included reviews, grey literature (FEMA, WHO, NDMA)	52
Duplicates removed	Removed using Rayyan systematic review software	71
Records screened (Title/Abstract)	Two independent reviewers screened all non-duplicate records	325
Records excluded after screening	Not relevant to MCI management, triage, EMS, or disaster education	248

Stage	Details	Records (n)
Full-text articles assessed	Retrieved for detailed eligibility assessment	77
Full-text excluded (with reasons)	Wrong population (n=8); wrong outcome (n=12); commentary/editorial (n=9); duplicate data (n=5)	34
Studies included in qualitative synthesis	Met all inclusion criteria; synthesised narratively across 7 domains	35+
Studies included — primary empirical	Original data studies (RCTs, observational, comparative)	12
Studies included — systematic reviews	Higher-order evidence sources	8
Studies included — guidelines/frameworks	ALSG, WHO, FEMA, NDMA validated operational frameworks	6
Studies included — expert consensus/textbooks	Recognised academic texts and consensus documents	9+

3. RESULTS

3.1 Overview of Included Studies

Thirty-five primary references met full inclusion criteria and were synthesised across seven operational domains. The evidence base comprised: 8 systematic reviews or meta-analyses (Bazyar et al. 2022; Hussain et al. 2025; Ruchholtz et al. 2025; Jenkins et al. 2008; Ingrassia et al. 2021; Abualenain et al. 2024; Hasan et al. 2023; Sheikhbardsiri et al. 2017); 4 scoping reviews/literature reviews (Pek et al. 2023; Mzahim et al. 2023; Guerrero et al. 2025; Rimstad & Braut 2015); 6 validated guidelines and international frameworks (ALSG 2018; FEMA/NIMS 2019; WHO 2007; WHO 2019; NDMA 2019; Sendai Framework 2015); 9 expert consensus texts and review articles (Lennquist 2012; Koenig & Schultz 2010; Hogan & Burstein 2007; Lomaglio et al. 2020; Hick et al. 2004; Cone & Koenig 2005; Auf der Heide 2006; Frykberg 2005; Christian 2019); and 5 primary empirical studies (Garner et al. 2001; Kahn et al. 2009; Biswas et al. 2022; Sarin et al. 2017; Djalali et al. 2020). Overall evidence quality was Moderate to High for systematic reviews and guidelines; Low to Moderate for primary empirical studies, with most primary studies limited by observational design, simulation settings, or small sample sizes.

3.2 Characteristics of Included Studies

Table 2: Characteristics of Included Studies

Author(s) & Year	Study Design	Topic/Domain	Key Findings	Evidence Level
Bazyar et al. (2022)	Systematic Review	Triage Accuracy	START, SALT, SMART, Sieve	High – SR

Author(s) & Year	Study Design	Topic/Domain	Key Findings	Evidence Level
			reviewed; only SMART accuracy >90%	
Hussain et al. (2025)	SR of SRs	Global Triage Systems	AI-assisted triage emerging; no single algorithm superior across all incident types	High – SR of SRs
Ruchholtz et al. (2025)	SR + CPG	MCI Management (Germany)	Evidence-based CPG update; RCTs on triage algorithms rare; training essential	High – SR/CPG
Rimstad & Braut (2015)	Literature Review	Medical ICS/Command	No optimal ICS identified; commander competence more critical than structure	Moderate – Review
Mzahim et al. (2023)	Scoping Review	HICS vs MIMMS	Both systems valid; HICS (USA) and MIMMS (UK) differ in structure; training key	Moderate – Scoping Review
Djalali et al. (2020)	SR	Hospital ICS Effectiveness	ICS improves coordination; communication gaps remain major limitation	Moderate – SR
Saadatmand et al. (2023)	SR	EMS MCI Preparedness	EMS training gaps prevalent globally; simulation improves performance	Moderate – SR
Hasan et al. (2023)	SR	Hospital Surge Capacity	Staff, stuff, space, system (4Ss) framework; barriers to surge identified	High – SR
Sheikhbardsiri et al. (2017)	SR (PRISMA)	Hospital Surge Capacity	Surge capacity components mapped; preparedness programs needed	Moderate – SR
Ingrassia et al. (2021)	SR	Simulation in Disaster Medicine	Simulated patients effective; multi-modal approaches recommended	Moderate – SR
Abualenain et al. (2024)	SR	Full-Scale Simulation Exercises	FSEs improve disaster preparedness; skills, confidence, coordination enhanced	High – SR
Pek et al. (2023)	Scoping Review	SimEx for Disasters/MCI	Full-scale exercises validate plans; debriefing essential; limited standardization	Moderate – Scoping

Author(s) & Year	Study Design	Topic/Domain	Key Findings	Evidence Level
Garner et al. (2001)	Comparative Study	Triage Algorithm Comparison	No single algorithm superior; Triage Sieve performed comparably to START	Moderate – Comparative
Kahn et al. (2009)	Retrospective Study	START Triage Accuracy	Significant over/under-triage rates; incident type & training affect performance	Moderate – Observational
Jenkins et al. (2008)	SR	MCI Triage Evidence	Evidence base weak; prospective validation lacking for most algorithms	Moderate – SR
Romig (2002)	Review/Practice Guideline	Pediatric Triage	JumpSTART adapts adult criteria for children; age-appropriate vital signs critical	Moderate – Guideline
Christian (2019)	Review Article	Triage	Dynamic reassessment essential; over-triage and under-triage persist	Moderate-High – Review
Frykberg (2005)	Review Article	Triage Principles	Triage performance training-dependent; balance between speed/accuracy critical	Moderate – Review
Auf der Heide (2006)	Review Article	Evidence-Based Disaster Planning	Evidence base for many disaster assumptions is weak; planning must be empirical	Moderate – Review
Hick et al. (2004)	Review Article	Surge Capacity & Transport	Surge capacity involves staff/stuff/space/system; communication central to success	Moderate-High – Review
Cone & Koenig (2005)	Review Article	CBRN Triage & Transport	CBRN incidents require modified triage; zonal transport alignment essential	Moderate – Review
Koenig & Schultz (2010)	Textbook/Consensus	Disaster Medicine, HazMat	Zonal management prevents secondary contamination; PPE and decon critical	High – Consensus
ALSG (2018)	Clinical Guideline	MIMMS/MCI Framework	Hierarchical command, CCP, triage, transport all codified as best practice	High – Guideline
Lennquist (2012)	Textbook/Consensus	Disaster Medicine	Context-dependence of MCI definition; surge capacity and phase management	High – Expert Consensus

Author(s) & Year	Study Design	Topic/Domain	Key Findings	Evidence Level
WHO (2007)	International Guideline	Mass Casualty Management	Zonal principles essential globally; surge planning and EMS coordination	High – Int'l Guideline
FEMA/NIMS (2019)	Policy Guideline	Incident Command System	ICS scalable, interoperable; span of control and unified command essential	High – Policy Guideline
Lomaglio et al. (2020)	Textbook Chapter	MCI Definitions	Distinction between MCI and disaster; surge and resource framing	Moderate – Consensus
Sendai Framework (2015)	International Policy	Disaster Risk Reduction	Priority actions for resilience, risk reduction, and preparedness globally	High – Int'l Policy
WHO (2019)	Int'l Framework	Health Emergency/DRM	Health Emergency and Disaster Risk Management Framework; country guidance	High – Int'l Framework
Biswas et al. (2022)	Cross-Sectional	MCI Training Effectiveness	Current training models improve performance; refresher training gaps identified	Moderate – Observational
Frontiers/Guerrero et al. (2025)	Scoping Review	Simulation Technology in DM Education	VR/AR, gamification and simulated patients all effective; multi-modal best	Moderate – Scoping
Frontiers/Elsenbast et al. (2025)	SR	XR Technology in EMS Training	XR improves EMS training outcomes; realism and fidelity key factors	Moderate – SR
Hogan & Burstein (2007)	Textbook	Disaster Medicine	Comprehensive disaster medicine reference; prehospital & hospital domains	Moderate-High – Consensus
Sarin et al. (2017)	Survey	Disaster Education in EM	Disaster training in US EM programs inconsistent; needs standardization	Moderate – Survey

SR = systematic review; CPG = clinical practice guideline; CBRN = chemical, biological, radiological, nuclear; MCI = mass casualty incident; DM = disaster medicine; XR = extended reality; VR = virtual reality; AR = augmented reality; HICS = Hospital Incident Command System; MIMMS = Major Incident Medical Management and Support.

3.3 Risk of Bias Assessment

Table 3: Risk of Bias Assessment for Primary Studies and Systematic Reviews

Study	Selection Bias	Performance Bias	Detection Bias	Reporting Bias	Overall
Bazyar et al. (2022) — SR	Low	Low	Moderate	Low	Low
Hussain et al. (2025) — SR of SRs	Low	Low	Low	Low	Low
Ruchholtz et al. (2025) — CPG	Low	Low	Low	Low	Low
Hasan et al. (2023) — SR	Low	Moderate	Low	Low	Low–Moderate
Abualenain et al. (2024) — SR	Low	Low	Moderate	Low	Low
Ingrassia et al. (2021) — SR	Low	Moderate	Moderate	Low	Moderate
Kahn et al. (2009) — Retrospective	High	Moderate	Moderate	Moderate	Moderate–High
Garner et al. (2001) — Comparative	Moderate	Moderate	Low	Low	Moderate
Jenkins et al. (2008) — SR	Low	Low	Low	Low	Low
Biswas et al. (2022) — Cross-Sectional	Moderate	Moderate	High	Moderate	Moderate–High
Sarin et al. (2017) — Survey	Moderate	High	High	Moderate	High
Rimstad & Braut (2015) — Literature Review	Low	Moderate	Moderate	Low	Moderate

Risk of bias assessed using AMSTAR-2 for systematic reviews (reported as Low/Moderate/High overall quality), and NIH Quality Assessment Tools for primary studies. For guidelines, AGREE II was applied (not shown in this table).

3.4 Evidence Synthesis Matrix

Table 4: Evidence Synthesis Matrix by Operational Domain

Domain	Key Evidence	Quality (GRADE)	Identified Research Gaps
Incident Classification & Surge	Context-dependent MCI definition; surge = staff/stuff/space/system; phase model guides prioritisation (Lennquist 2012; Hick et al. 2004)	Moderate (Guideline + Expert Consensus)	RCT evidence absent; quantitative surge thresholds not validated across LMICs
Command & Control (ICS/MIMMS)	Hierarchical ICS reduces fragmentation; unified command improves interagency coordination; commander competence more critical than structure (ALSG 2018; Rimstad & Braut 2015; FEMA 2019)	Moderate–High (Guideline + SR)	No consensus on optimal ICS structure; performance measurement tools lacking; MIMMS vs HICS comparative evidence limited

Domain	Key Evidence	Quality (GRADE)	Identified Research Gaps
First Responder Roles	Windscreen survey and structured situation reports improve downstream resource allocation; role transition from clinical to command is training-dependent (ALSG 2018; Cone & Koenig 2005)	Low–Moderate (Expert Guidelines + Observational)	Prospective studies on first-crew decision-making rare; simulation-validated protocols lacking
Triage Systems	START, Sieve, SALT, SMART validated; no single algorithm superior; JumpSTART for paediatrics; accuracy <90% for most systems; dynamic reassessment critical (Bazyar 2022; Garner 2001; Kahn 2009)	Moderate (SR + Comparative Studies)	Prospective validation lacking; CBRN-modified triage under-studied; LMIC-adapted tools absent; AI triage emerging but unvalidated in real MCIs
Casualty Clearing Post	Structured CCP with dedicated officers reduces scene congestion; zonal separation of P1/P2/P3 supports accurate reassessment; documentation essential (ALSG 2018; Lennquist 2012)	Moderate (Guideline + Expert Consensus)	CCP design for mass gatherings and resource-limited settings unstudied; no validated CCP performance metrics
Ambulance Flow & Transport	Holding areas, transport officers, and structured hospital distribution reduce surge overload; prehospital-hospital communication critical (Hick 2004; Cone & Koenig 2005; ALSG 2018)	Moderate (SR + Case Studies)	Quantitative evidence on transport protocols scarce; self-presenting patient management protocols lacking; geographic constraints in LMICs unstudied
Zonal Management (CBRN)	Hot/warm/cold zoning prevents responder contamination; decontamination corridors essential; strict boundary discipline prevents hospital secondary contamination (Koenig & Schultz 2010; WHO 2007; Cone & Koenig 2005)	Moderate (Int'l Guidelines + Expert Consensus)	Integration with standard triage protocols under-evaluated; LMICs decontamination resource gaps; community decontamination protocols lacking
Educational Framework & Simulation	Simulation (full-scale, VR/AR, tabletop) improves responder skills, confidence, and triage accuracy; debriefing essential; multi-modal approaches recommended (Ingrassia 2021;	Moderate–High (Multiple SRs)	Standardisation of disaster education curricula lacking; long-term retention studies absent; LMIC-adapted training tools scarce

Domain	Key Evidence	Quality (GRADE)	Identified Research Gaps
	Abualenain 2024; Guerrero 2025)		
Hospital Surge Preparedness	4Ss framework operationalises surge; prehospital communication enables hospital activation; early distribution prevents overcrowding (Hasan 2023; Sheikhbardsiri 2017)	Moderate (SR + Observational)	Functional preparedness measurement tools inconsistent; surge capacity in low-resource hospitals understudied

GRADE evidence quality: High = multiple convergent high-quality studies; Moderate = mostly convergent, some methodological limitations; Low = limited or indirect evidence; Very Low = expert opinion only. LMIC = low-and-middle-income country.

4. DOMAIN-SPECIFIC RESULTS

4.1 Domain 1: Concept, Classification, and Surge Capacity in Major Incidents

Major incidents are characterised by a disruption in the balance between casualty needs and available response resources (ALSG, 2018). As established by Lennquist (2012), the classification of an incident as "major" is context-dependent: an event manageable in a well-resourced urban centre may overwhelm services in a rural or resource-limited environment. This relativity underscores that major incident classification is governed not by absolute numbers but by operational impact, logistical complexity, and system strain.

Lomaglio et al. (2020) further distinguish between mass casualty incidents (MCIs) and disasters: MCIs involve resource strain manageable within existing EMS structures, whereas disasters cause massive infrastructure disruption requiring external assistance. Mechanistic classification encompasses mass casualty trauma incidents, hazardous material incidents, security and intentional events (including active shooter and explosive incidents), and public health emergencies. Complexity-based classification further distinguishes simple, compound, and catastrophic incidents.

A central operational concept is surge capacity, defined by Hick et al. (2004) as the ability of healthcare systems to expand beyond routine operations across four domains: staff, stuff (equipment/supplies), space, and system (organisational). The systematic review by Hasan et al. (2023) — which searched seven databases and included 13 peer-reviewed studies — confirmed that surge capacity preparedness activities in all four domains are essential, and identified communication failures and coordination gaps as the predominant barriers to effective surge response. Sheikhbardsiri et al. (2017) similarly found, in a PRISMA-guided systematic review, that surge capacity is the most critical component of hospital preparedness and that preparedness programmes must be revised and updated regularly.

Temporal phase recognition — impact, response, stabilisation, and recovery — is essential because triage priorities, command strategies, and resource requirements evolve dynamically across phases (Lennquist, 2012). The Sendai Framework for Disaster Risk Reduction (2015–2030) underscores global policy commitment to strengthening disaster risk management across these phases, including priority actions for resilience-building, early warning systems, and capacity development — principles directly applicable to EMS preparedness planning.

4.2 Domain 2: Command and Control Structures

Effective command and control form the organisational backbone of major incident management (ALSG, 2018). Evidence from Rimstad & Braut (2015) — a comprehensive literature review of 6,049 identified records with 76 included sources — found that most incident command systems (ICSs) are hierarchical and based on military principles, and that linking chains of command across cooperating agencies is a fundamental challenge. Critically, this review found that commander competence and experience are more determinative of ICS effectiveness than the specific structure or system adopted. No single ICS was found to be clearly superior to others.

The FEMA National Incident Management System (NIMS) and ICS (2019) provide a scalable, interoperable command framework now used internationally. Key ICS principles — unified command, span of control (recommended 3–7 direct reports), common terminology, and modular organisation — are supported across multiple operational guidelines (FEMA 2019; ALSG 2018). Mzahim et al. (2023), in a scoping review comparing HICS (Hospital Incident Command System, used in the USA) and MIMMS (UK-based), found both systems provide valid frameworks with different structural emphases: HICS is more hospital-centric and administratively structured, while MIMMS emphasises prehospital medical command integration. Both require dedicated training to operationalise effectively.

Djalali et al. (2020), in a systematic review on factors affecting hospital ICS effectiveness, identified communication gaps, inadequate training, limited resource integration, and staff unfamiliarity with ICS roles as the four primary barriers to effective command performance. Within the medical response framework, designation of triage, treatment, and transport officers enhances operational clarity and ensures systematic patient flow (Cone & Koenig, 2005). Maintaining situational awareness through continuous perception, comprehension, and projection of incident conditions is consistently identified as a critical command competency (ALSG 2018; Rimstad & Braut 2015).

4.3 Domain 3: Role of the First Arriving Ambulance Crew

The first arriving ambulance crew plays a decisive and often underestimated role in major incident management. Rather than prioritising immediate clinical care, this crew must adopt a scene management role: assessing environmental hazards, acquiring situational awareness through a structured windscreen survey, and transmitting an accurate initial situation report (ALSG, 2018). Evidence from Cone & Koenig (2005) supports that accurate early reporting improves resource allocation and reduces command establishment delays.

The windscreen survey enables estimation of casualty numbers, identification of incident mechanism, recognition of potential hazards, and assessment of resource requirements — all essential inputs for subsequent command decision-making. The first crew's responsibilities extend to initiation of primary triage (beginning with ambulatory casualty segregation), identification of CCP and ambulance staging locations, and early hazard communication. In CBRN incidents, early identification of contamination risk determines the need for zonal control and specialist response.

The transition from individual patient management to a leadership and coordination role is recognised as psychologically and professionally challenging for clinicians trained in direct care delivery (ALSG, 2018). Biswas et al. (2022) found that structured training programmes addressing this role transition improve first responder performance and confidence during simulated major incidents, supporting the importance of this competency within disaster education frameworks.

4.4 Domain 4: Triage Systems in Major Incident Management

4.4.1 Overview and Conceptual Framework

Triage is the cornerstone of major incident medical response, enabling casualty prioritisation under resource constraints. Unlike routine emergency care, major incident triage prioritises population-level survival benefit over individual clinical optimisation — a fundamental ethical shift (Garner et al., 2001). Primary triage is performed at or near the incident scene, emphasising speed and reproducibility using physiological parameters. Secondary triage at structured treatment areas improves accuracy and guides transport decisions (ALSG, 2018).

4.4.2 Systematic Review Evidence on Triage Accuracy

Bazyar et al. (2022), in a PRISMA-guided systematic review of 13 studies published from 2000 to 2021, evaluated the accuracy of major incident triage systems globally. The review found that the START, modified START (mSTART), SALT, SMART, CareFlight, ASAV, Modified Physiological Triage Tool (MPTT), Triage Sieve, and ESI systems all demonstrated accuracy, sensitivity, and specificity below 90%. Only the SMART triage system achieved overall accuracy exceeding 90%, though this finding was limited to specific incident contexts.

Hussain et al. (2025) — a systematic review of systematic reviews conducted up to June 2025 — examined prehospital global triage system accuracy. Analysing four eligible systematic reviews, they found that conventional systems (START, JumpSTART, SALT, MPTT) and emerging AI-assisted approaches show variable performance depending on incident type, casualty mix, provider training, and system constraints. No single algorithm was universally superior, reinforcing the context-dependence of triage performance.

Garner et al. (2001), in a foundational comparative analysis, evaluated multiple triage algorithms during simulated mass casualty incidents and similarly found no algorithm demonstrably superior across all incident types. The Triage Sieve performed comparably to START in most scenarios, supporting the practical utility of both systems.

Kahn et al. (2009), in a retrospective empirical study, evaluated START triage accuracy in a real mass casualty incident and documented significant rates of both over- and under-triage, with algorithm performance heavily influenced by responder experience, incident mechanism, and environmental conditions. Jenkins et al. (2008), in a systematic review calling for an evidence-based approach to MCI triage, noted that most triage models lack prospective validation and that the evidence base remains predominantly observational.

Ruchholtz et al. (2025), updating the German clinical practice guideline for MCI management based on a systematic search to August 2021, identified that RCTs comparing triage algorithms are extremely rare, and that training interventions and logistics remain the strongest modifiable predictors of MCI response effectiveness.

4.4.3 Paediatric Triage

Children present unique triage challenges due to age-dependent physiological variations and communication limitations. Romig (2002) established JumpSTART as a modification of START incorporating age-appropriate vital sign thresholds and a mouth-to-barrier breathing step, which significantly improves accuracy in paediatric casualties. Failure to account for paediatric physiological differences leads to systematic over- or under-triage affecting outcomes.

4.4.4 Dynamic Triage and CBRN Modifications

Christian (2019) emphasised the dynamic nature of major incident triage, requiring repeated reassessment as patient conditions, resources, and environmental hazards evolve. Frykberg (2005) identified that standard triage algorithms may not account for delayed symptom onset in chemical and toxic exposures, necessitating modified approaches for CBRN incidents. Contamination-aware triage — assessing decontamination priority alongside clinical priority — represents an emerging but under-studied competency area (Cone & Koenig, 2005).

4.5 Domain 5: Casualty Clearing Post Organisation

The Casualty Clearing Post (CCP) functions as the operational hub for secondary triage, organised treatment, and coordinated evacuation during major incidents. Its structured organisation — with distinct areas for Priority 1 (immediate), Priority 2 (urgent), Priority 3 (delayed), and expectant casualties — enables systematic patient flow, reduces scene congestion, and supports accurate reassessment (ALSG, 2018).

Designation of functional officers within the CCP — including triage, treatment, and documentation officers — provides operational clarity and supports effective resource utilisation. Evidence from Lennquist (2012) and ALSG (2018) consistently emphasises that CCP establishment must occur early in incident response, as delayed organisation leads to scene chaos and uncontrolled casualty movement toward healthcare facilities. Documentation within the CCP is essential for casualty tracking, continuity of care, and post-incident evaluation.

The CCP location should be accessible, away from primary hazards, and capable of expansion as casualty volumes increase. Integration of CCP operations with command structures, ambulance flow management, and hospital communication systems is a consistent recommendation across major incident guidelines. In hazardous incidents, the CCP must be situated within the cold zone to ensure contamination-free patient management.

4.6 Domain 6: Ambulance Flow and Transport Coordination

Transport coordination determines when, how, and where casualties are moved, directly influencing treatment delays, resource utilisation, and patient outcomes (Cone & Koenig, 2005). Unstructured ambulance flow leads to traffic congestion, duplication of transport effort, and uneven hospital distribution — a pattern documented across multiple major incident case reports. Structured transport coordination is essential to maintain operational efficiency and support balanced healthcare system utilisation (Hick et al., 2004).

Key structural components include the ambulance holding area (a designated staging zone preventing uncontrolled vehicle entry), the casualty loading point (interface between the CCP and transport vehicles), and the transport officer (responsible for assigning ambulances based on triage priority and coordinating hospital destinations). The transport officer must maintain real-time situational awareness of ambulance availability and hospital capacity, communicating directly with receiving facilities to enable activation of internal disaster protocols (ALSG, 2018).

Balanced hospital distribution is essential to prevent overwhelming individual facilities. Hick et al. (2004) documented that structured transport coordination significantly improves healthcare system resilience and reduces treatment delays. Factors disrupting transport coordination include ambulance shortages, traffic congestion, self-evacuating casualties bypassing triage, geographical barriers, and communication failures. Saadatmand et al. (2023), in a systematic review of EMS MCI preparedness, identified transport coordination as one of the most frequently reported operational deficiencies in real-world major incident responses.

4.7 Domain 7: Zonal Management in Hazardous Major Incidents

Hazardous major incidents involving chemical, biological, radiological, or environmental threats require structured operational segregation through zonal management (Koenig & Schultz, 2010). The internationally recognised three-zone framework — hot (exclusion), warm (contamination reduction), and cold (support) — balances rapid casualty rescue with responder safety and secondary contamination prevention.

The hot zone encompasses the area of active hazard exposure and restricts access to specially trained, PPE-equipped personnel. Operational priorities emphasise hazard identification, rapid casualty extraction, and essential life-saving interventions, with prolonged treatment deferred to safer environments. The warm zone serves as the decontamination corridor, where staged processes including clothing removal, gross water irrigation, and technical decontamination using specialised solutions prevent spread to transport vehicles and healthcare facilities. Decontamination triage within the warm zone determines casualty prioritisation for decontamination resources.

The cold zone supports advanced medical care, ambulance staging, CCP operations, and command functions following adequate decontamination. Strict boundary discipline between warm and cold zones is essential to prevent secondary contamination of responders and hospitals. WHO (2007) guidelines reinforce that zonal principles must be embedded within standard mass casualty management systems globally. Koenig & Schultz (2010) documented that failures of zonal discipline during real chemical incidents have led to secondary contamination of hospital emergency departments, amplifying incident impact and disrupting routine services.

Cone & Koenig (2005) emphasised that transport coordination in CBRN incidents must align with zonal boundaries, ensuring ambulances operate only within clean zones and that contaminated patients are not transported before adequate decontamination. Integration of zonal management within the broader incident command structure — with dedicated safety officers and hazard assessment teams — is essential for sustained effectiveness (ALSG, 2018; WHO 2019).

5. EDUCATIONAL FRAMEWORK AND TRAINING IMPLICATIONS

5.1 Rationale for Structured Disaster Education

Major incident management is a competency-dependent discipline: the effectiveness of command structures, triage systems, and casualty organisation depends critically on the knowledge, skills, and decision-making capabilities of individual responders. Auf der Heide (2006) demonstrated that many foundational assumptions underlying disaster response planning lack empirical validation, and that training quality is among the most modifiable determinants of response effectiveness. Rimstad & Braut (2015) confirmed that commander competence — itself a product of education and experience — is more determinative of ICS effectiveness than structural or procedural factors alone.

Sarin et al. (2017), in a national survey of US emergency medicine residency programmes, found that disaster training was inconsistently delivered across programmes, with significant variation in content, format, and assessment. This finding illustrates the global challenge of standardising disaster education across diverse healthcare systems. A comprehensive educational framework must therefore address technical knowledge, situational awareness, leadership competencies, interagency communication, and ethical decision-making under resource constraints.

5.2 Simulation-Based Training

Simulation-based education is the most extensively evidenced training modality for disaster medicine competency development. Ingrassia et al. (2021), in a systematic review of simulated patient use in disaster medicine training, confirmed that simulation is an effective teaching tool that improves triage accuracy, clinical skills, and team coordination when appropriately designed and debriefed.

Abualenain et al. (2024), in a PRISMA-compliant systematic review of 28 published studies on full-scale simulation exercises (FSEs) in hospital disaster preparedness, found that FSEs consistently improve participants' skills, confidence, and familiarity with disaster protocols. The review confirmed that multi-dimensional evaluation approaches and post-exercise debriefing are essential to maximise learning outcomes.

Pek et al. (2023), in a scoping review of full-scale simulation exercises for disaster and MCI response covering 2001–2021, found that FSEs validate plans, identify coordination gaps, and improve multi-agency collaboration, but that standardisation of exercise design, evaluation frameworks, and debriefing protocols is lacking across studies.

Emerging technologies are expanding simulation modalities. Guerrero et al. (2025), in a comprehensive scoping review of simulation technology in disaster medicine education, found that virtual reality (VR), augmented reality (AR), extended reality (XR), and gamification platforms improve learner engagement and skill acquisition, with multi-modal approaches yielding the strongest outcomes. Biswas et al. (2022) confirmed that current training models improve performance but identified significant gaps in refresher training frequency and long-term skill retention.

5.3 Core Competency Domains for Disaster Education

Based on the synthesised evidence, core competency domains for major incident management education include:

- Scene safety assessment, hazard recognition, and personal protective equipment selection in CBRN incidents
- Windscreen survey and initial situation reporting using structured formats (e.g., METHANE — Major incident declaration, Exact location, Type of incident, Hazards, Access, Number of casualties, Emergency services)
- Primary triage implementation: Triage Sieve, START, and SALT; with JumpSTART for paediatric casualties
- Secondary triage at CCPs, dynamic reassessment, and expectant patient management
- Command structure roles within ICS/MIMMS/HICS frameworks; span of control principles
- Casualty Clearing Post organisation, zone delineation, patient flow management, and documentation
- Ambulance flow coordination: holding area management, loading point operations, and transport prioritisation
- Zonal management in CBRN incidents: hot/warm/cold zone principles and decontamination protocols
- Ethical decision-making under resource scarcity; over/under-triage trade-offs; expectant patient management
- Interagency communication, standardised situation reporting, and hospital notification protocols
- Hospital surge capacity activation: staff, stuff, space, and system augmentation

5.4 Adaptation for Resource-Variable EMS Systems

Educational frameworks must be adapted to the operational realities of specific EMS environments. In resource-variable systems — including many regions of India, where the National Disaster Management Authority (NDMA, 2019) has established a national framework but regional implementation varies significantly — training must account for differences in equipment availability, communication infrastructure, interagency coordination capacity, and hospital capability.

WHO (2019) recommendations for health emergency and disaster risk management emphasise country-specific adaptation of international frameworks, with particular attention to primary healthcare integration, community-level preparedness, and resource-appropriate implementation. Adaptation may include development of simplified triage tools validated for local resource levels, training programmes addressing informal transport systems and bystander involvement, and simulation exercises using available rather than ideal-scenario resources.

5.5 Continuous Professional Development and Quality Evaluation

Disaster preparedness is not a static competency. Regular refresher training, after-action reviews following real major incidents, and engagement with updated evidence and guidelines are essential components of a sustained educational framework. Auf der Heide (2006) emphasised that evidence-based disaster planning requires systematic evaluation of preparedness activities — not merely their implementation. Evaluation through structured competency testing, simulation performance metrics, and inter-rater assessment following exercises enables gap identification and programme refinement.

6. DISCUSSION

6.1 Principal Findings

This systematic review synthesised evidence from 35 primary references across seven operational domains of major incident management. The evidence base is strongest for command and control frameworks — where multiple high-quality guidelines and systematic reviews converge on ICS/MIMMS/HICS as the standard of care, with unified command, span of control, and communication infrastructure as critical determinants of effectiveness (ALSG 2018; FEMA 2019; Rimstad & Braut 2015; Djalali et al. 2020). Triage evidence is of moderate quality, with consistent findings across systematic reviews and comparative studies that no single algorithm is universally superior, that most systems achieve accuracy below 90%, and that prospective validation remains limited (Bazyar et al. 2022; Hussain et al. 2025; Garner et al. 2001). Simulation-based training evidence is the most rapidly expanding domain, with multiple recent systematic reviews confirming effectiveness of full-scale exercises, VR/AR technologies, and simulated patient approaches (Ingrassia et al. 2021; Abualenain et al. 2024; Guerrero et al. 2025).

Zonal management evidence remains primarily guideline-based (Koenig & Schultz 2010; WHO 2007; Cone & Koenig 2005), with limited prospective evaluation of integration with standard triage protocols — a significant gap given the increasing frequency and complexity of CBRN-risk incidents globally. Hospital surge capacity evidence, while supported by two systematic reviews (Hasan et al. 2023; Sheikhbardsiri et al. 2017), reveals persistent fragmentation: surge preparedness activities are documented but inconsistently implemented, and measurement tools lack standardisation across healthcare settings.

6.2 Comparison with Existing Reviews

This review extends and integrates prior domain-specific reviews by consolidating evidence across seven operational domains in a unified synthesis. Bazyar et al. (2022) and Hussain et al. (2025) focused specifically on triage algorithm accuracy, while this review contextualises triage within the broader management framework. Similarly, Ingrassia et al. (2021) and Abualenain et al. (2024) focused on simulation training, while this review situates educational evidence within an operational competency framework spanning all major incident domains. No prior systematic review has integrated zonal management, CCP operations, and transport coordination evidence with triage and training evidence in a single synthesis.

6.3 Research Gaps and Future Directions

Several critical research gaps were identified. First, prospective, controlled evaluation of triage algorithm accuracy across diverse real-world incident types and healthcare settings is urgently needed. Most existing evidence is retrospective or simulation-based. Second, the integration of zonal management protocols with conventional triage systems — particularly in resource-variable settings — requires both operational evaluation and validated training tools.

Third, context-specific research examining major incident management in LMIC and Indian EMS environments is markedly limited. The NDMA (2019) framework provides structural guidance, but empirical evaluation of implementation effectiveness, regional adaptation, and training impact is lacking. Fourth, casualty flow dynamics — including the impact of self-presenting casualties, informal transport systems, and bystander involvement — require prospective study to inform transport coordination protocols. Fifth, long-term retention of simulation-based training competencies and optimal refresher training intervals remain understudied.

Future research priorities should include: multicentre prospective studies evaluating triage performance under real MCI conditions; development and validation of LMIC-adapted triage tools; rigorous RCTs of simulation training interventions with standardised outcome measures;

evaluation of AI-assisted triage in real prehospital settings; and assessment of integrated zonal management-triage protocols in CBRN scenarios.

6.4 Implications for EMS Practice and Policy

The findings have direct implications for EMS training programmes, clinical protocols, and preparedness policy. Adoption of standardised ICS/MIMMS/HICS frameworks, regular interagency simulation exercises, validated triage tools, and structured CCP operations should be embedded within national EMS education standards. Policy frameworks should address communication infrastructure investment, development of context-specific training resources, and establishment of after-action review systems following real major incidents.

In India, the National Disaster Management Act (2005) and NDMA (2019) guidelines provide a structural foundation. Expanding simulation-based training programmes, strengthening prehospital-hospital communication systems, and developing validated training resources adapted to regional operational realities offer the most evidence-supported pathways to improved disaster response capacity.

6.5 Limitations

Several limitations should be acknowledged. First, formal meta-analysis was precluded by evidence heterogeneity; narrative synthesis, while systematic, carries a higher risk of subjective interpretation. Second, the restriction to English-language publications may exclude relevant research from non-English-speaking disaster medicine contexts. Third, the evidence base for several domains (CCP operations, first responder roles) relies heavily on expert consensus and guidelines rather than primary empirical data, limiting confidence in effect estimates. Fourth, grey literature search, while conducted, may not have captured all relevant operational guidance. Fifth, rapid evolution of disaster medicine evidence — particularly in simulation technology — means that some findings may not fully reflect the most recent publications.

7. CONCLUSION

This systematic review provides the most comprehensive synthesis to date of evidence across seven operational domains of major incident management — incident classification and surge, command and control, first responder roles, triage systems, casualty clearing post organisation, ambulance flow and transport, and zonal management in hazardous incidents — integrated with a structured educational framework.

The evidence confirms that hierarchical incident command structures (ICS/MIMMS/HICS), dynamic multi-stage triage protocols, organised CCP operations, coordinated ambulance flow, and integrated zonal management are supported by convergent guideline-level and moderate empirical evidence. Multi-modal simulation-based training — including full-scale exercises, VR/AR technologies, and structured debriefing — is supported by multiple recent systematic reviews as the most effective modality for operationalising these competencies.

Critical research gaps persist, particularly in prospective triage validation, LMIC-adapted preparedness research, zonal protocol integration, and long-term training retention. Addressing these through rigorous, multi-centre, longitudinal research is essential to advance the evidence base for disaster medicine practice globally. For EMS systems in India and resource-variable environments worldwide, investment in structured disaster education, standardised command frameworks, and evidence-based preparedness planning — adapted to local operational realities — will be critical to improving responder safety, optimising casualty outcomes, and strengthening healthcare system resilience in the face of future major incidents.

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DATA AVAILABILITY STATEMENT

No new primary data were generated or analysed in this study. All data supporting the conclusions are available within the article. The search strategy and full database-specific search strings used in this systematic review are provided as Supplementary Material (see Appendix A). The PRISMA 2020 checklist is provided as Supplementary Material (see Appendix B).

PATIENT AND PUBLIC INVOLVEMENT

No patients or members of the public were involved in the design, conduct, reporting, or dissemination of this systematic review, as no primary human data were collected.

SUPPLEMENTARY MATERIALS

The following supplementary materials are submitted alongside this manuscript: Appendix A — Full database-specific search strings (PubMed, MEDLINE, EMBASE, CINAHL, Cochrane, Scopus, WHO Global Health Library). Appendix B — PRISMA 2020 Flow Diagram

REFERENCES

1. Advanced Life Support Group (ALSG). Major Incident Medical Management and Support (MIMMS): The Practical Approach at the Scene. 3rd ed. London: Wiley-Blackwell; 2018.
2. Abualenain J, Alhajaji R, Alsulimani LK. A systematic review of the efficacy of full-scale simulation exercises in enhancing hospital disaster preparedness. J Med Law Public Health. 2024;4(3):419-446. doi:10.52609/jmlph.v4i3.133.
3. Auf der Heide E. The importance of evidence-based disaster planning. Ann Emerg Med. 2006;47(1):34-49. doi:10.1016/j.annemergmed.2005.05.009.
4. Bazyar J, Farrokhi M, Salari A, Safarpour H, Khankeh HR. Accuracy of triage systems in disasters and mass casualty incidents: a systematic review. Arch Acad Emerg Med. 2022;10(1):e34. doi:10.22037/aaem.v10i1.1526.
5. Biswas S, Bahouth H, Solomonov E, Waksman I, Halberthal M, Bala M. Preparedness for mass casualty incidents: the effectiveness of current training model. Disaster Med Public Health Prep. 2022;16(5):2120-2128. doi:10.1017/dmp.2021.83.
6. Christian MD. Triage. Crit Care Clin. 2019;35(4):575-589. doi:10.1016/j.ccc.2019.06.009.
7. Cone DC, Koenig KL. Mass casualty triage in the chemical, biological, radiological, or nuclear environment. Eur J Emerg Med. 2005;12(6):287-302. doi:10.1097/00063110-200512000-00006.
8. Djalali A, Hosseinijenab V, Peyravi M, et al. Factors affecting the effectiveness of hospital incident command system: findings from a systematic review. Iran J Public Health. 2020;49(2):219-228. doi:10.18502/ijph.v49i2.3081.
9. Federal Emergency Management Agency (FEMA). National Incident Management System (NIMS) and Incident Command System (ICS) Resources. 3rd ed. Washington DC: FEMA; 2019.
10. Frykberg ER. Triage: principles and practice. Scand J Surg. 2005;94(4):272-278. doi:10.1177/145749690509400404.
11. Garner A, Lee A, Harrison K, Schultz CH. Comparative analysis of multiple-casualty incident triage algorithms. Ann Emerg Med. 2001;38(5):541-548. doi:10.1067/mem.2001.119053.
12. Guerrero JGU, Körber M, Andjelovic T, et al. Simulation technology use in disaster medicine education and training: a scoping review. Front Disaster Emerg Med. 2025;3:1636285. doi:10.3389/femer.2025.1636285.
13. Hasan MK, Nasrullah SM, Quattrocchi A, Arcos González P, Castro Delgado R. Hospital surge capacity preparedness in disasters and emergencies: protocol for a systematic review. Int J Environ Res Public Health. 2022;19(20):13437. doi:10.3390/ijerph192013437. [Protocol paper — cited for methodological transparency; the full review is Reference 14. Not counted as a primary included study.]
14. Hasan MK, Nasrullah SM, Quattrocchi A, Arcos González P, Castro Delgado R. Hospital surge capacity preparedness in disasters and emergencies: a systematic review. Public Health. 2023 Nov. doi:10.1016/j.puhe.2023.09.001.
15. Hick JL, Hanfling D, Cantrill SV. Health care facility and community strategies for patient care surge capacity. Ann Emerg Med. 2004;44(3):253-261. doi:10.1016/j.annemergmed.2004.04.011.
16. Hogan DE, Burstein JL. Disaster Medicine. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 2007.
17. Hussain A, Bhatti D, Farouk M, et al. Accuracy and timeliness of prehospital global triage system protocols in mass disasters: a systematic review of systematic reviews. Cureus. 2025;17(9). doi:10.7759/cureus.412519.
18. Ingrassia PL, Pigozzi L, Bono M, Ragazzoni L, Della Corte F. Use of simulated patients in disaster

medicine training: a systematic review. Disaster Med Public Health Prep. 2021;15(1):99-104. doi:10.1017/dmp.2019.111.

19. Jenkins JL, McCarthy ML, Sauer LM, et al. Mass-casualty triage: time for an evidence-based approach. Prehosp Disaster Med. 2008;23(1):3-8. doi:10.1017/s1049023x00005520.
20. Kahn CA, Schultz CH, Miller KT, Anderson CL. Does START triage work? An outcomes assessment after a disaster. Ann Emerg Med. 2009;54(3):424-430. doi:10.1016/j.annemergmed.2008.12.035.
21. Koenig KL, Schultz CH. Disaster Medicine: Comprehensive Principles and Practices. Cambridge: Cambridge University Press; 2010.
22. Lennquist S. Medical Response to Major Incidents and Disasters: A Practical Guide for All Medical Staff. Berlin: Springer; 2012.
23. Lomaglio L, Ansaloni L, Catena F, Sartelli M, Coccolini F. Mass casualty incident: definitions and current reality. In: Kluger Y, Coccolini F, Catena F, Ansaloni L, editors. WSES Handbook of Mass Casualties Incidents Management. Cham: Springer; 2020.
24. Mzahim B, Alfayez A, Alasmari H. Incident management system comparison: hospital incident command system versus major incident medical management and support. Saudi J Health Sci. 2023;12(3):175-183. doi:10.4103/sjhs.sjhs_144_22.
25. National Disaster Management Authority (NDMA). National Disaster Management Plan. New Delhi: Government of India; 2019.
26. Pek JH, Ng WM, Liu N, et al. Use of simulation in full-scale exercises for response to disasters and mass-casualty incidents: a scoping review. Prehosp Disaster Med. 2023;38(6):732-742. doi:10.1017/S1049023X23005903.
27. Rimstad R, Braut GS. Literature review on medical incident command. Prehosp Disaster Med. 2015;30(2):205-215. doi:10.1017/S1049023X15000035.
28. Romig LE. Pediatric triage: JumpSTART and the pediatric triage tape. Ann Emerg Med. 2002;40(1):102-108. doi:10.1067/mem.2002.124391.
29. Ruchholtz S, Kuhne CA, Lewan U, et al. Management of mass casualty incidents: a systematic review and clinical practice guideline update. Eur J Trauma Emerg Surg. 2025;51:16. doi:10.1007/s00068-024-02722-z.
30. Saadatmand V, Marzaleh MA, Abbasi HR, Peyravi MR, Shokrpour N. Emergency medical services preparedness in mass casualty incidents: a systematic review. Am J Disaster Med. 2023;18(1):79-91. doi:10.5055/ajdm.2023.0444.
31. Sarin RR, Cattamanchi S, Alqahtani A, et al. Disaster education: a survey study to analyze disaster medicine training in emergency medicine residency programs in the United States. Prehosp Disaster Med. 2017;32(4):368-373. doi:10.1017/S1049023X17000206.
32. Sendai Framework for Disaster Risk Reduction 2015–2030. Geneva: United Nations Office for Disaster Risk Reduction; 2015. Available at: https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030.
33. Sheikhbardsiri H, Raeisi AR, Nekoei-Moghadam M, Rezaei F. Surge capacity of hospitals in emergencies and disasters with a preparedness approach: a systematic review. Disaster Med Public Health Prep. 2017;11(5):612-620. doi:10.1017/dmp.2016.178.
34. World Health Organization (WHO). Mass Casualty Management Systems: Strategies and Guidelines for Building Health Sector Capacity. Geneva: WHO; 2007.
35. World Health Organization (WHO). Health Emergency and Disaster Risk Management Framework. Geneva: WHO; 2019. Licence CC BY-NC-SA 3.0 IGO.
36. Elsenbast C, et al. Extended reality technology in emergency medical services training: a systematic review. Front Emerg Med. 2025.