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Systematic Review

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Factors Associated With Delayed Pre-Hospital Times During Trauma-Related Mass Casualty Incidents: A Systematic Review

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Abstract

Objective: Critically injured patients have experienced delays in being transported to hospitals during Mass Casualty Incidents (MCIs). Extended pre-hospital times (PHTs) are associated with increased mortality. It is not clear which factors affect overall PHT during an MCI. This systematic review aimed to investigate PHTs in trauma-related MCIs and identify factors associated with delays for triaged patients at incident scenes.
Methods: This systematic review was performed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Web of Science, CINAHL, MEDLINE, and EMBASE were searched between January and February 2022 for evidence. Research studies of any methodology, and grey literature in English, were eligible for inclusion. Studies were narratively synthesized according to Cochrane guidance.
Results: Of the 2025 publications identified from the initial search, 12 papers met the inclusion criteria. 6 observational cohort studies and 6 case reports described a diverse range of MCIs. PHTs were reported variably across incidents, from a median of 35 minutes to 8 hours, 8 minutes. Factors associated with prolonged PHT included: challenging incident locations, concerns about scene safety, and adverse decision-making in MCI triage responses. Casualty numbers did not consistently influence PHTs. Study quality was rated moderate to high.
Conclusion: PHT delays of more than 2 hours were common. Future MCI planning should consider responses within challenging environments and enhanced timely triage decision-making.

In the last 2 decades, the number of mass casualty incidents (MCIs) has risen globally, with over 2 million fatalities and many more injured.[1] MCIs are short-term events that overwhelm local medical care systems, where the volume of patients exhausts available resources and capabilities.[2] The unprecedented number of recent major incidents has challenged the health systems, increased the need to review MCI responses, and review lessons from previous MCIs pre-hospital.[3] Time to initial response in mass casualty events is crucial in determining outcomes in the early stages of an injured patients' care.[4,5] The time from injury to reaching definitive care is known as pre-hospital time (PHT). An extended pre-hospital period is associated with increased mortality rates, and contemporary trauma systems strive to reduce PHT to improve patient outcomes.[4–6]

There is a lack of consensus about whether "scoop and run" (transporting patients as quickly as possible) or "stay and play" (stabilizing patients and initiating advanced treatment on scene) is most advantageous for patient outcomes.[7] Total PHT encompasses sequential intervals including pre-alarm, response, on-scene, and transport time.[8,9] Each interval is associated with unique activities that may impact total PHT.[8] Most pre-hospital care evidence focuses on response, on-scene, and/or transport time as the main indicators of PHT, and there is little previous research investigating the "pre-alarm interval," which is the time between injury and ambulance departure.[8,10] Therefore, the current understanding of total PHT delays is unclear. Previous MCIs show that PHT intervals were 2.5 times longer than standard non-MCI Emergency Medical Services (EMS) responses.[11] Single incident reports suggest that a number of factors have been implicated in extended PHTs during an MCI, including delays to EMS deployment, resource availability, and location.[8,11,12] These issues are not limited to low- or middle-income countries alone, and have also been reported in high-income settings, indicating that other factors may contribute to PHT delays.[11,12] In order to improve responses and outcomes for future incidents, it is important to investigate which factors are related to extended PHTs across published MCI reports. Therefore, this systematic review aimed to investigate the total PHT in different trauma-related MCIs and to identify factors associated with extended PHT for triaged patients at the MCI scene.

Methods

This systematic review was registered in the international prospective register of systematic reviews (PROSPERO) with registration number CRD42022288580. The review was performed according to The Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) recommendations in its conduct and reporting.[13]

Eligibility Criteria

Eligibility criteria and search strategies were developed using PEOS (Population, Exposure, Outcome, and Studies) (Table 1).

Sources of Information and Search Strategy

The search was conducted between January and February 2022 by 2 independent reviewers (FA and EKA). The following electronic databases were used to search for evidence: Web of Science (Thomson Reuters, New York, NY, USA), CINAHL Complete (EBSCO Information Services, Ipswich, MA, USA), MEDLINE (US National Library of Medicine, National Institutes of Health, Bethesda, MD, USA), and EMBASE (Elsevier, Amsterdam, Netherlands). Reference lists from identified articles were checked for missed publications. A grey literature search was conducted on the following databases: World Health Organization, Google Search, Google Scholar, and E-Theses Online Service. Reviewers (FA and EKA) searched The British Library to retrieve articles not available in full text from selected databases. The search terms were a combination of keywords and MeSH terms: "Mass Casualty Incidents," "Disasters," "Triage," "Priority," "Emergency Medical Services," "Ambulances," "Pre-hospital," "Delay," "Time". Keywords were combined with Boolean Operators "OR" to expand the initial searches and then "AND" to combine records retrieved during individual searches (Supplemental Table 1).

Study Selection and Data Extraction

All articles selected from the database searches were imported into EndNote20 for Windows software (Clarivate Analytics, Philadelphia, PA, USA) to remove duplicates.[14] Following this, 2 independent reviewers (FA and EKA) exported the articles into Rayyan software to screen titles and abstracts.[15] Finally, full-text articles were assessed for inclusion against eligibility criteria. If there was any disagreement between the reviewers, a third independent reviewer (EC) was used for arbitration.

Quality Appraisal

Existing systematic review quality appraisal tools are either specific to a study methodology or focus on a specific patient cohort or case.[16] There is no tool specifically designed to assess quality in mass casualty/ mass case evidence, therefore, a quality assessment checklist was adapted from Joanna Briggs Institute (JBI) Critical Appraisal Tools for case reports and NHS Guidelines for Major Incidents and Mass Casualty Events (Table 2).[17,18] The checklist has 10 questions, each of which has 4 potential answers: Yes (Y), No (N), Unclear (U), and Not Applicable (NA). The quality assessment of the developed tool was calculated based on the percentage of questions answered with "Yes." According to the results of this checklist, each study was classified as low quality (< 50%), moderate quality (from 50% to 70%), and high quality (> 70%).[19] Quality appraisal was performed independently by 2 reviewers (FA and EKA).

Data Analysis

Meta-analysis was not possible due to heterogeneity in timing measures, or incomplete timings, therefore, a narrative synthesis was performed based on Cochrane's recommendations.[20] Studies that met the eligibility criteria were synthesized, focusing on methodological approach, relationships within and between studies and interpretation of findings. Studies were compared by location and design, incident types and setting, number of victims, and pre-hospital time, as well as responders, triage tools, mode of transportation, and mortality. The median and interquartile range (IQR) were calculated for each study that included PHT sequentially (per individual patient).

Definitions

(1) Mass Casualty Incident (MCI): A short-term event that overwhelms the local medical care systems with many patients that exhaust the available resources and capabilities.[2]
(2) Pre-hospital time (PHT): The interval between injury time to hospital arrival.
(3) MCI triage: A sorting process in an incident scene for casualties into classifications based on their injury severity to distribute limited resources rationally.[21]

Table 1. Eligibility criteria

	Inclusion	Exclusion
Population	• Casualties resulting from a trauma-related Mass Casualty Incident (MCI) in either civilian or military settings.	• Non-MCI patients.
Exposure	• Trauma-related mass casualty incidents e.g. train crashes, mass shootings, structural collapse, where MCI triage was implemented at the incident scene.	• Non-trauma-related MCIs, such as CBRN incidents (Chemical, Biological, Radiological and Nuclear).
Outcomes	• Primary: Total pre-hospital times. • Secondary: Factors associated with delayed pre-hospital time.	• Individual time components (e.g. only on-scene time, response time, or transportation time) • Estimated PHTs.
Studies	• Research studies of any methodology, with no restrictions on the date of publication. • Grey literature e.g. preprints, post-major incident reviews reports, guidelines, conference papers, and Doctoral (PhD) dissertations.	• Opinion papers, editorial articles, or letters. • Systematic reviews and Meta-analyses. • Publications in any language other than English.

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Table 2. The quality assessment checklist for included studies[a]

Focus	Checklist Questions
Incident Description	1. Did the study present a clear background of the incident in detail regarding its time, location, and scale?
	2. Was the study's rationale clearly stated?
	3. Was the pre-hospital care system that responded to the MCI clearly described?
	4. Were the EMS personnel that were on-scene described in terms of numbers of paramedics, EMTs, and physicians?
	5. Were the incident's characteristics, such as the number of injured patients and deaths described?
Incident Response	6. Were the time of the incident, response, extraction, evacuation, and transportation, clearly described and presented in a timeline?
	7. Were the type and severity of injuries pertaining to casualties that occurred at the scene described in detail?
	8. Were the pre-hospital assessment (triage) and treatment procedure (life-threatening interventions) clearly described?
Lessons learned from the incident	9. Does the study identify any gaps or other limitations in the pre-hospital responses?
	10. Does the report provide any recommendations or suggestions for consideration in future emergency plans to improve EMS response?

[a]The quality assessment tool was adapted from the following sources: the Joanna Briggs Institute (JBI) Critical Appraisal Tools for case reports,[17] and the NHS Guidelines for Major Incidents and Mass Casualty Events.[18]

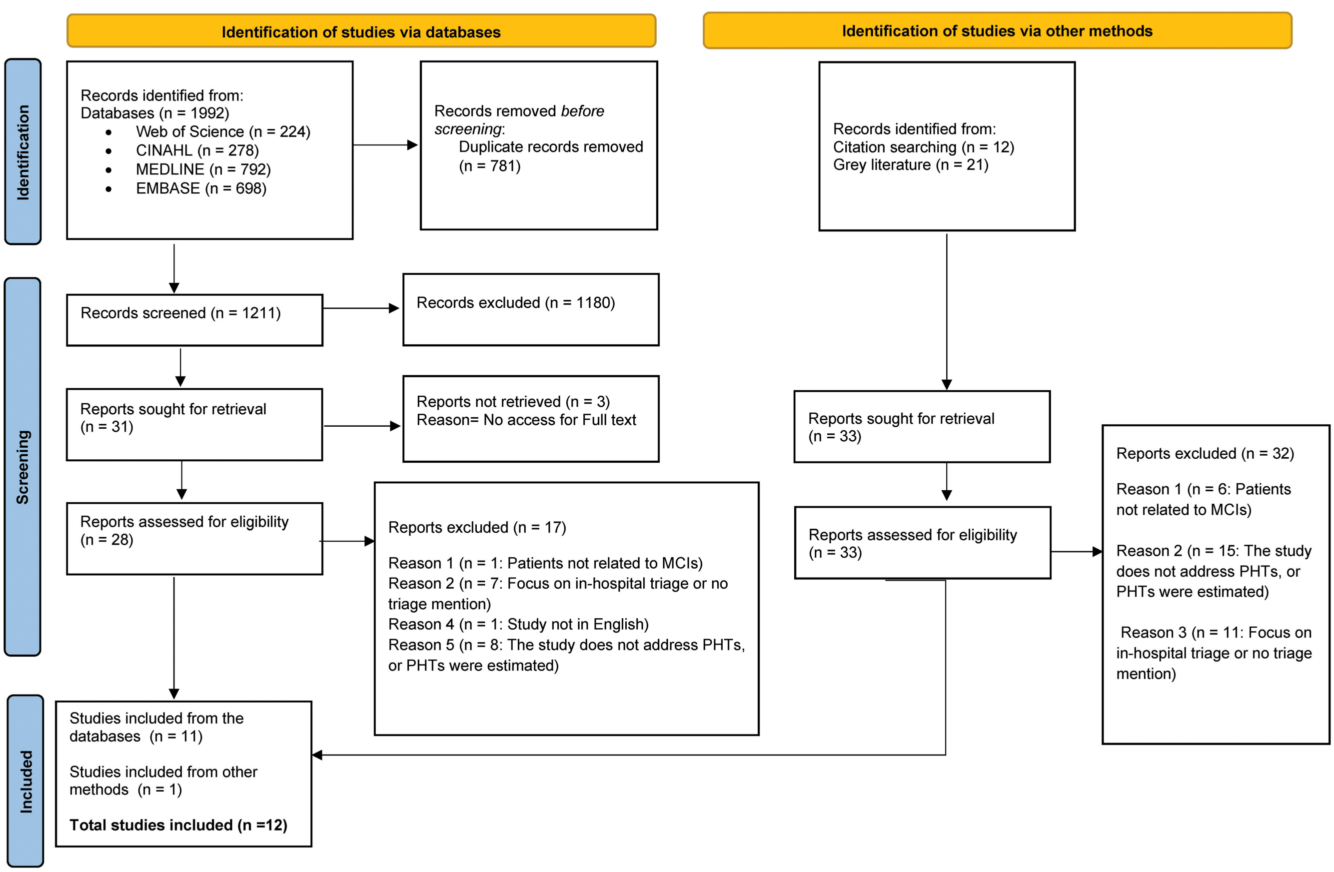

Figure 1. Modified PRISMA 2020 flow diagram for new systematic reviews, which included searches of databases and other sources. Abbreviation: PRISMA, Preferred Reporting Items of Systematic Reviews and Meta-Analysis.

Results

Study Selection and Data Extraction

Initial database searches resulted in 1992 documents (Figure 1), of which 781 duplicates were removed. The title and abstract screening revealed 31 potential studies meeting eligibility criteria. Of these, 3 studies were not available in full text. Therefore, full-text screening was carried out on the remaining 28 studies, of which 17 were excluded, and 11 papers met the inclusion criteria. One study was included from the citation and grey literature search, resulting in 12 studies for analysis.

Study Characteristics

Study methodologies comprised 6 retrospective observational cohort studies,[22–27] and 6 case reports (Table 3).[28–33] Two studies

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Table 3. Characteristics for the included studies in the systematic review

Author Name, Year	Country	Study Design	Incident Type, Location, Year	Victims Number	Total Deaths	On-scene Deaths	In-hospital Deaths	Responders	Triage Tool	Pre-hospital Time
Sollid 2012[22]	Norway	Observational retrospective study	TA: Car bomb attack and a mass shooting incident, Norway 2011	>77	77	N/A	N/A	Physicians, paramedics, anesthesiologists, nurses	N/A	Incident 1—first patient: 26 mins Incident 2—first patient: 2 hr 33 mins; last patient: 4 hr 6 mins
Travers 2019[23]	France	Observational retrospective study	Military Combat, Sahel, 2013-2018	183	18 (9.8%)	11 (6.0%)	7 (3.8%)	Trained Combatants, pre-hospital physicians, nurses	The NATO's triage system	Median 130 mins (IQR70 minutes to 252 min)
McLeod 2007[24]	Birmingham, UK	Observational retrospective study	Combat, Afghanistan 2006-2007	528	N/A	12 (2.3%)	N/A	Paramedics, physicians, emergency nurses	SIEVE	Median 120 mins
Welling 2008[25]	The Netherlands	Observational retrospective study	Fire accident, The Netherlands 2001	245	14 (5.7%)	4 (1.6%)	10 (4.1%)	N/A	Derived From the Dutch Ambulance Protocol	Median Severely injured 220 mins Non-severely injured 247 mins
Kahn 2009[26]	California, USA	Observational retrospective study	Train crash, USA 2002	265	2 (0.8%)	1 (0.4%)	1 (0.4%)	Paramedics	START	Median Red patient 77.4 mins (95% CI 70.2 -100.2 mins) Yellow patient 141 mins (95% CI 135 -150 mins) Green patient 139.8 mins (95% CI 139.8-139 mins)
Raux 2019[27]	France	Observational retrospective study	TA: Suicide bombing attack and a mass shooting incident, Paris 2015	543	130 (24%)	123 (22.7%)	7 (1.3%)	EMTs, Tactical physicians	Derived from the NATO sorting scale	Median 194 mins (121 mins –248 mins)
O'Keefe 1999[28]	Virginia, USA	Case report	Balcony collapse, USA 1997	17	2 (11.8%)	1 (5.9%)	1 (5.9%)	Emergency physicians, EMTs	START	Median 35 mins (IQR 25 mins to 42 mins)[c]
Mulvey 2021[29]	Canada	Case report	Bus rollover, Canada 2020	27	3 (11.1%)	3 (11.1%)	0 (0.0%)	Paramedics, pre-hospital physicians	START	Median Critical patients 488 mins (IQR 394 mins to 735 mins)[c]
Postma 2011[30]	The Netherlands	Case report	Flight crash, The Netherlands 2009	135	9 (6. 7%)	9 (6. 7%)	0 (0.0%)	Emergency medical personnel	SIEVE	210 mins (range 75-330 mins)
Ming-Wei 2021[31]	Taiwan	Case report	Dust explosion, Taiwan 2015	499	12[a] (2.4%)	N/A	N/A	EMTs	N/A	Mean 232.19 mins
Raiter 2008[32]	Israel	Case report	TA: Suicide bombing attack, Israel 2006	91	9 (9.9%)	6 (6.6%)	3[b] (3.3%)	Physicians, paramedics	N/A	First and last patients (20 mins,74 mins)
Leiba 2006[33]	Israel	Case report	TA: Bombing at a Nightclub, Israel, 2005	56	5 (8.9%)	2 (3.6%)	3 (5.4%)	Physicians, paramedics, medics, volunteers	Simple and Quick	Last patients (81 mins, 118 mins)[d]

Abbreviations: IQR, Interquartile range; mins, minutes; N/A, The information was not reported; TA, terrorist attack; 95%CI, 95% confidence interval.
[a]Mortality data from a different study that reported the same incident but did not meet eligibility criteria.[34]
[b]Patients already dead on hospital arrival (transported via private vehicles).
[c]The reviewers calculated the IQR median for any case report that included all patients' PHT sequentially (per individual patient).
[d]PHTs were reported for every patient in two different hospitals.

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Table 4. Quality assessment of included studies

Study Design	Studies	Questions										Quality Assessment (%)
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	
Observational study	Sollid 2012[22]	Y	Y	Y	Y	U	Y	N	U	Y	Y	**70% (Moderate)**
	Travers 2019[23]	NA	Y	Y	N	Y	Y	Y	Y	Y	Y	**89% (High)**
	McLeod 2007[24]	NA	Y	Y	N	U	Y	N	Y	Y	N	**56% (Moderate)**
	Welling 2008[25]	Y	Y	Y	N	Y	N	Y	Y	Y	Y	**80% (High)**
	Kahn 2009[26]	Y	Y	U	N	Y	N	N	Y	Y	Y	**60% (Moderate)**
	Raux 2019[27]	Y	Y	U	N	Y	Y	Y	U	Y	Y	**70% (Moderate)**
Case report	O'Keefe 1999[28]	Y	Y	Y	Y	Y	N	Y	Y	Y	N	**80% (High)**
	Mulvey 2021[29]	Y	Y	Y	U	Y	Y	Y	Y	Y	Y	**90% (High)**
	Postma 2011[30]	Y	Y	N	N	Y	U	Y	Y	Y	Y	**70% (Moderate)**
	Ming-Wei 2021[31]	Y	Y	Y	N	U	Y	N	Y	Y	Y	**70% (Moderate)**
	Raiter 2008[32]	Y	Y	Y	Y	Y	Y	Y	Y	U	N	**80% (High)**
	Leiba 2006[33]	Y	U	Y	Y	Y	Y	Y	U	N	N	**60% (Moderate)**

were conducted in the USA,[26,28] 2 in Israel,[32,33] 2 in France,[23,27] and 2 in the Netherlands,[25,30] while the remaining were conducted within the UK,[24] Canada,[29] Norway,[22] and Taiwan.[31] Incidents were varying in nature and included terrorist attacks (n = 4)[22,27,32,33] and military operations (n = 2)[23,24] (Supplemental Figure 1). The remainder focused on single incidents involving a balcony collapse,[28] a train crash,[26] a bus rollover,[29] and a building fire,[25] as well as a flight crash,[30] and a non-intentional explosion.[31] Two studies focused on single transportation modes: air ambulances in French military operations,[23] and ground ambulances in Paris attacks, while the rest involved air, and ground ambulances. EMS providers (paramedics, emergency medical technicians EMTs, and physicians) were involved in all studies. Additionally, nurses and emergency physicians responded to 3 MCIs,[22,24,28] and anesthesiologists responded to the terrorist attacks in Norway.[22]

In total, 2589 patients were included, and overall mortality was 14.7% (n = 269). Most patients were formally triaged at the scene (2237, 86.4%), and "non-triage" occurred where victims were immediately transported or self-presented to the hospital.[22,26] Of the triaged patients, 482 (29.0%) were red (critical, P1), 522 (35.6.5%) were yellow (delayed, P2), 475 (32.4%) were green (minor, P3), and 172 (10.8%) were black (dead-on-scene, P4) (Supplemental Table 2). The START (Simple triage and rapid treatment) system was implemented in 3 mass incidents in North America (USA and Canada),[26,28,29] and the SIEVE system was utilized in 2 European MCIs (UK and The Netherlands).[24,30]

Quality Appraisal

Of the 6 observational studies, 4 papers were rated as moderate quality,[22,24,26,27] and 2 were deemed high quality.[23,25] For the case reports, 3 were deemed to be of moderate quality,[30,31,33] while 3 reports were graded as high quality (Table 4).[28,29,32]

Pre-hospital Times in Mass Casualty Incidents

Most studies documented pre-hospital times of 2 hours or longer,[23,24,26,27,29–31] although PHTs were reported variably as means, medians, and sequences (per individual patient) (Table 3). Three studies focused on reporting the PHTs for individual patients who were of particular note (first and/ or last arrivals).[22,32,33] Two of the studies used sub-grouped medians that were based on triage classifications.[25,26]

In studies where average timings were reported or calculated by the reviewer, the shortest time to arrival at a hospital was a median of 35 minutes, following the balcony collapse in the USA where 16 people were injured (Figure 2).[28] The longest reported time was 488 minutes, when 12 critically injured patients were evacuated following the bus rollover in Canada.[29] Otherwise, timings ranged from 120 minutes (UK military incident) to 233.5 minutes for the fire incident in the Netherlands (Figure 2).[24,25]

Of the studies that reported the PHTs of individual patients,[22,32,33] the first victims of a Norwegian car bombing arrived at trauma centers 26 minutes after the first incident (Figure 2).[22] Similarly, first patients arrived 20 minutes after a Tel Aviv bomb attack in 2006.[32] The most prolonged times for final patient arrival was 118 minutes following a nightclub bombing in 2005, and 246 minutes after the Norwegian mass shooting event.[33] Two civilian MCIs with the largest numbers of casualties reported pre-hospital times of 194 and 232 minutes respectively (Table 3).[27,31] However, this volume-delay association was not observed across all MCIs, and the incident with the most prolonged times involved only 27 patients (Table 3).[29] Similarly, there was no obvious relationship between PHTs and proportion of deaths (Figure 2, Table 3), although 3 studies failed to report mortality data.[22,24,31]

Factors associated with delayed pre-hospital time

Difficult access to incident locations

Inaccessibility to the incident site due to geographical location or obstruction was the main reason for patient triage and transportation delays in 3 studies.[28–30] The Columbia icefield bus rollover occurred in an extreme environment, and despite having access to aeromedical services and physicians in the field, the steep slopes challenged the response teams resulting in a prolonged PHT of more than 4 hours for the first critical patient (Figure 3).[29] At the Schiphol air crash, the evacuation and transportation for the first patient was delayed 74 minutes due to extremely muddy conditions.[30] Similarly, road obstructions following a balcony collapse prevented EMS providers from reaching injured patients, which extended the pre-hospital period to a median of 35 minutes (Figure 3).[28]

Delay to secure hot zones

Four studies reported that safety considerations had a crucial impact on extending the pre-hospital period during MCI triage

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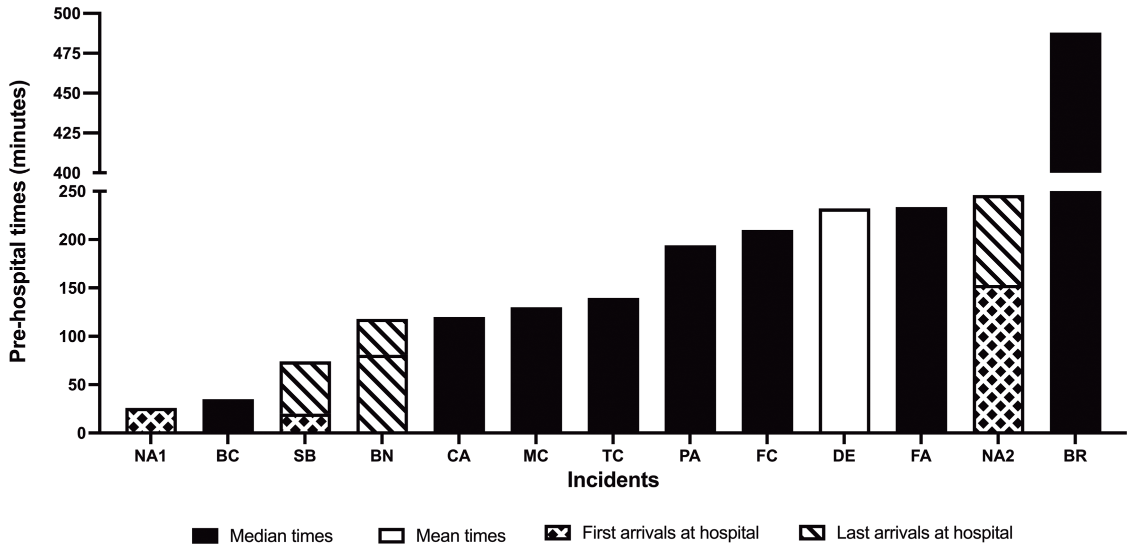

Figure 2. Bar chart shows pre-hospital time in minutes for mass casualty incidents included in the review. Abbreviations: NA1, 1st incident of Norway attacks (Car bombing) 2011; BC, Balcony collapse in Virginia 1997; SB, Bombing attack in Tel Aviv, Israel 2006; BN, Bombing at a nightclub, Israel 2005; CA, UK military operations, Afghanistan 2006-2007; MC, French military combat, Sahel region 2013-2018; TC, California train crash 2002; PA, Bombing attack and a mass shooting incident, Paris 2015; FC, Flight accident, The Netherlands 2001; DE, Dust explosion, Taiwan 2015; FA, Fire accident, The Netherlands 2001; NA2, 2nd incident of Norway attacks (Mass shooting) 2011; BR, Bus rollover, Canada 2020.

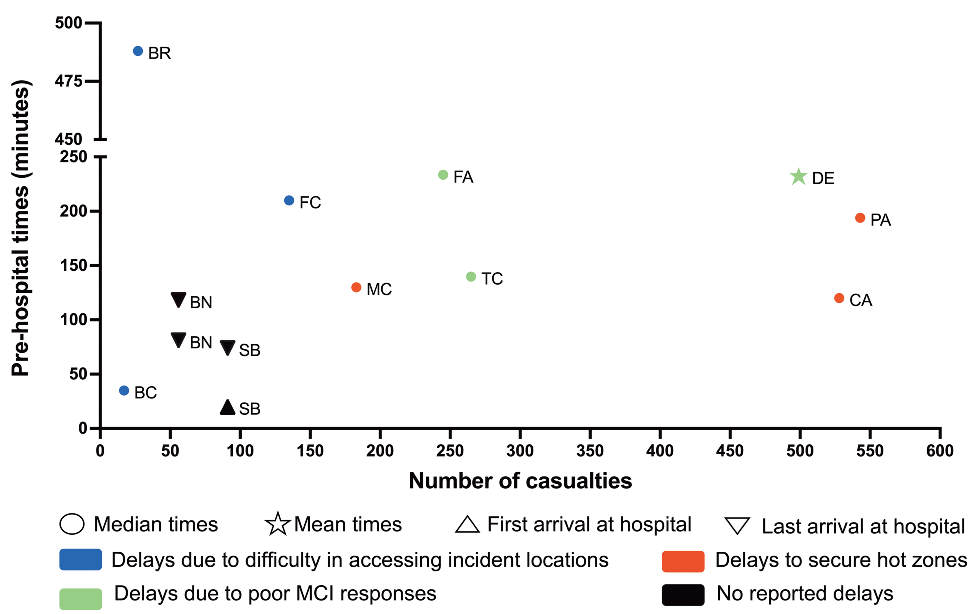

Figure 3. Scatterplot represents factors associated with delays by pre-hospital times and number of casualties.[a] Abbreviations: BC, Balcony collapse in Virginia 1997; BR, Bus rollover, Canada 2020; BN, Bombing at a nightclub, Israel 2005; SB, Bombing attack in Tel Aviv, Israel 2006; FC, Flight accident, The Netherlands 2001; MC, French military combat, Sahel region 2013-2018; FA, Fire accident, The Netherlands 2001; TC, California train crash 2002; DE, Dust explosion, Taiwan 2015; PA, Bombing attack and a mass shooting incident, Paris 2015; CA, UK military operations, Afghanistan 2006-2007.
[a]The terrorist attacks in Norway 2011 were not included in the graph as the number of casualties was not reported.

responses.[22–24,27] In the Utoya Island mass shooting, the EMS responders had difficulty triaging wounded victims due to the ongoing shooting at the scene, and Helicopter Emergency Medical Service (HEMS) units could not land near the site, resulting in delays in securing the scene for 30 minutes.[22] In a similar civilian event, Paris terrorist attacks involved active shooting and hostage-taking, which took 3 hours for police and tactical teams to secure the scene and evacuate casualties (Figure 3).[27] Two military studies reported delays due to tactical responses,[23,24] 1 within the battlefield, where deployments were intentionally extended for safety concerns.[23] The other study reported extended PHT of 5 hours due to safety considerations when transporting victims from the incident scene.[24]

Adverse decision-making in MCI responses

Several studies found that uncertainty in MCI responses and triage misclassification were associated with prolonged times to care (Figure 3).[25,26,31] In the Taiwan color-dust explosion, although triage was implemented effectively at the scene, EMS providers did not follow the triage decisions to prioritize severely injured for

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transportation to hospital.[31] As a result, the average pre-hospital time for severely injured patients was higher than for moderately injured patients (274.55 and 198.37 minutes, respectively).[31] Similarly, there was no distinction regarding transportation priorities for different patient classifications following a fire incident because the response units failed to initiate effective triage response.[25] During the rail crash in California, the triage response incorporated significant rates of over-triaging, which led to transferring critically injured patients with non-urgent patients (over-triaged) to the hospital as the same transportation priority.[26]

Discussion

This systematic review investigated pre-hospital timings and factors affecting PHT delays during mass casualty events. MCIs were heterogeneous in nature and PHT varied greatly. Most MCIs reported pre-hospital timing delays of more than 2 hours, with the longest spanning over 8 hours. Three main factors were associated with prolonged PHTs including incident location, safety, and adverse decision-making in MCI responses. Overall, the quality of studies was rated as moderate to high.

The extended interval from injury time to definitive care is a known detriment associated with poor patient outcomes.[6] Previous pre-hospital studies focused solely on transport timeframes in non-MCI EMS responses.[35–37] However, these studies cannot convey the complexity of factors affecting PHTs within an MCI. In this review, PHTs were varied with most being at least 2 hours or longer; MCIs were heterogeneous in terms of cause, EMS provision, transportation, and distance to health care. It is therefore challenging to combine the findings given the heterogeneity of events and there was no specific characteristic of the type of MCI associated with delays e.g., type of incident or number of casualties.

The complexity of the incident site was a significant factor associated with delayed pre-hospital intervals. This was mainly observed in major events situated in remote areas such as high slopes or where road obstructions prohibited pre-hospital provider access. Physical accessibility is a common feature in incidents occurring in remote regions.[38] Following a multi-scene transportation MCI involving difficult access and prolonged distances to trauma centers, use of air ambulance services was recommended to reduce transportation times from remote or challenging settings.[39] Whilst HEMS services have been included in Norwegian mass casualty plans for some time,[40] a recent systematic review reported that air-medical services units are not consistently included in MCI plans, even those with logistical and geographical challenges, and decisions are generally made on a case-by-case basis.[41] The high cost of HEMS may also prohibit their use in low-income countries or very remote regions.

Scene safety and security considerations had a significant impact on triage delays in this review, which led to prolonged transportation times to definitive care. Reports of MCIs involving mass casualty shootings highlight the risks to responders, the need for safe inner cordon interventions and support for lower-level hospitals who may be required to admit casualties if access to higher level facilities is restricted.[42,43] Safety issues at incident scenes rely on police enforcement to secure the area as quickly as possible, yet this may be challenging in some settings. The most effective solution might come from an integrated response within MCI plans, involving police jurisdictions, EMS, and fire departments.[44]

Adverse triage responses were also associated with longer times to definitive care. Rapidly sorting several victims and identifying a priority for care is fraught with difficulty during unpredictable accidents.[42] Misclassification, i.e., incorrect triage level, is associated with significant delays for critically injured patients.[43,44] Where EMS providers followed the "To see is to send" policy despite triage decisions, this conflicted with the ultimate goal of optimizing immediate transportation for critical patients and resulted in inappropriate distribution to facilities. This was previously described in the Virginia Tech Shootings' findings which found that over-triaging increased the mortality of critical victims by 20%.[44] Within this systematic review it was unclear as to why EMS triage decision-making was potentially sub-optimal. Education and training may help to increase knowledge and confidence, resulting in improved triage decision-making.[44] Simulated flow models may also help to identify the effects of decision-making in response to an MCI, in a safe, large-scale environment.[45]

Limitations

This review has several limitations. First, the eligibility criteria were limited only to evidence in English, and excluded non-English papers may have provided other information on factors which impact PHT in an MCI. Second, PHTs in the studies were reported variably, and some did not measure this period for all injured patients. We are therefore unable to discuss all potential confounders or factors affecting PHT. Lastly, existing quality assessment tools were not relevant to this review due to the nature of the topic, therefore, we had to adapt current tools to assess quality in the included studies.

Conclusion

This systematic review revealed that MCIs were heterogenous in nature and PHTs were significantly varied. Currently, most published MCIs have a PHT of 2 hours or longer. The incident location and scene safety are associated in delayed PHT. Adverse MCI triage decisions appear to have challenged responders resulting in longer PHTs. Future studies should focus on how MCI planning can mitigate the causes of pre-hospital delays.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/dmp.2023.187

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Author contribution. The review protocol was developed by FA and revised by EC. FA and EKA performed the literature search, data extraction, and quality assessment. FA analyzed and interpreted the results. FA wrote the paper and EC revised the drafted manuscript. KB was involved in the critical revision of the manuscript. All authors reviewed and approved the final draft.

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Competing interests. The authors declare no conflicts of interest.

Abbreviations. EMS, Emergency Medical Services; HEMS, Helicopter Emergency Medical Services; MCI, Mass Casualty Incident; PHT, Pre-hospital Time; PRISMA, Preferred Reporting Items for Systematic Review and Meta-Analysis; START, Simple Triage and Rapid Treatment

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