

Supplementary file 4: Methodological Quality Appraisal of Included Studies

Introduction:

The methodological quality of the included studies was appraised using the most appropriate critical appraisal instrument according to study design. Joanna Briggs Institute (JBI) critical appraisal checklists were used for cohort studies, analytical cross-sectional studies, case series, qualitative studies and diagnostic accuracy studies. Because no JBI checklist exists specifically for Delphi consensus studies, the Conducting and REporting of DElphi Studies (CREDES) guidance was used to appraise the methodological reporting of the included Delphi study. Two reviewers independently completed the appraisal and resolved disagreements through discussion and consensus. The appraisal was undertaken to aid interpretation of the available evidence and was not used to determine study eligibility. Consistent with current guidance for scoping reviews, no study was excluded on the basis of methodological quality.

Sections of this supplementary file:

Table S4.1 Study design and appraisal tool

Table S4.2 Detailed JBI appraisal for every study

Table S4.3 Overall methodological appraisal summary

Table S4.1 Critical appraisal tools used:

Included study	Study design	Critical appraisal tool
Koning, Ellerbroek & Leenen (2015)	Case series	JBI Case Series Checklist
Kim et al. (2018)	Analytical cross-sectional	JBI Analytical Cross-sectional Checklist
Raux et al. (2019)	Retrospective cohort	JBI Cohort Checklist
Romero Pareja et al. (2020)	Retrospective validation study	JBI Diagnostic Test Accuracy Checklist
Hansen et al. (2021)	Case series	JBI Case Series Checklist
Lancet et al. (2021)	Analytical cross-sectional (simulation)	JBI Analytical Cross-sectional Checklist
Lin et al. (2021)	Analytical cross-sectional	JBI Analytical Cross-sectional Checklist
Malik et al. (2021)	Diagnostic accuracy study	JBI Diagnostic Test Accuracy Checklist
Heemskerk et al. (2022)	Retrospective cohort	JBI Cohort Checklist
Newgard et al. (2022)	Delphi consensus study	CREDES Delphi Guidance
Choi et al. (2022)	Case series	JBI Case Series Checklist
Saadatmand et al. (2023)	Qualitative	JBI Qualitative Checklist
Hansen et al. (2023)	Case series	JBI Case Series Checklist
Valiño et al. (2024)	Analytical cross-sectional	JBI Analytical Cross-sectional Checklist
Carenzo et al. (2024)	Analytical cross-sectional (simulation)	JBI Analytical Cross-sectional Checklist

Table S4.2 Detailed methodological appraisal:

First study: Kim et al. (2018) Design: Analytical cross-sectional Checklist: JBI Analytical Cross-sectional
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Criterion	Judgement	Justification
Inclusion criteria clearly defined	Yes	Eligibility criteria and study population were explicitly described.
Study subjects and setting described	Yes	National EMS registry and study setting adequately reported.
Exposure measured validly and reliably	Yes	Exposure (occurrence of MCIs) clearly defined using EMS database records.
Objective criteria used to measure outcomes	Yes	Response time derived from routinely collected EMS timestamps.
Confounding factors identified	Yes	Age, sex, region, time of day and day of week were identified.
Strategies to deal with confounding	Yes	Multivariable regression analysis performed.
Outcomes measured reliably	Yes	Standard EMS operational metrics used.
Appropriate statistical analysis	Yes	Linear regression appropriately applied.
Overall appraisal: Low methodological limitations		Principal methodological limitations: Administrative EMS registry database. Residual confounding cannot be excluded. Findings limited to a single national EMS system.

Second study: Koning, Ellerbroek and Leenen (2015)

Design: Case series

Checklist: JBI Case Series

Criterion	Judgement	Justification
Inclusion criteria clearly defined	Yes	Patients treated following the nursing home fire were clearly identified.
Condition measured in a standard, reliable way	Yes	Injury characteristics and clinical assessments were consistently reported using predefined criteria.
Valid methods used for identification of the condition	Yes	Data were obtained from ambulance records, hospital records and incident evaluation reports.
Consecutive inclusion of participants	Yes	All medically treated casualties from the incident were included.
Complete inclusion of participants	Yes	All identified casualties requiring medical care were accounted for.
Participant demographics clearly reported	Yes	Age, sex and relevant patient characteristics were described.
Clinical information clearly reported	Yes	Injury patterns, treatments and clinical outcomes were comprehensively reported.
Outcomes or follow-up clearly reported	Yes	Hospital admission, ventilation, mortality and discharge outcomes were reported.

Presenting site(s)/clinic(s) clearly reported	Yes	The incident location, EMS response and receiving hospitals were clearly described.
Appropriate statistical analysis	Yes	Descriptive analyses were appropriate for the case-series design.
Overall appraisal: Low methodological limitations		Principal methodological limitations: Single-incident case series. Retrospective use of routinely collected records. Limited generalisability to other MCI settings.

Third study: Raux et al. (2019) Design: Retrospective cohort Checklist: JBI Cohort		
Criterion	Judgement	Justification
Groups similar and recruited from the same population	Yes	Both groups comprised casualties from the same terrorist attacks and were recruited during the same study period.
Exposure measured similarly	Yes	Injury mechanism (gunshot or explosion) was consistently classified for all participants using the same data sources.
Exposure measured validly and reliably	Yes	Exposure was determined from multiple official sources, including EMS, hospital and incident records.
Confounding factors identified	Yes	Potential confounders, including injury mechanism, injury severity and incident characteristics, were recognised and discussed.
Strategies to deal with confounding	No	No multivariable adjustment or other analytical strategy was used to control for confounding.
Participants free of the outcome at baseline	Yes	Outcomes such as mortality, surgery and hospital resource use occurred after exposure classification.
Outcomes measured validly and reliably	Yes	Clinical outcomes were obtained from hospital records using standard trauma measures.
Follow-up time sufficient	Yes	Follow-up until hospital discharge was adequate to capture the reported outcomes.
Follow-up complete	Yes	Hospital outcomes were available for all included patients.
Strategies to address incomplete follow-up	Not applicable	Loss to follow-up was not reported as an issue because outcomes were measured during the index admission.
Appropriate statistical analysis	Yes	Appropriate comparative statistical analyses were performed for the study objectives.

Overall appraisal: Moderate methodological limitations	Principal methodological limitations: Retrospective observational design. No adjustment for potential confounding. Findings derived from a single terrorist incident.
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Fourth study: Romero Pareja et al. (2020) Design: Retrospective validation study Checklist: JBI Diagnostic Test Accuracy		
Criterion	Judgement	Justification
Consecutive or random sample enrolled	Unclear	The sampling strategy was not explicitly stated.
Case-control design avoided	Yes	A retrospective trauma registry cohort was used rather than a case-control design.
Inappropriate exclusions avoided	Unclear	Some exclusions were applied, but their potential impact was not fully discussed.
Index test interpreted independently of the reference standard	Yes	META criteria were retrospectively applied using predefined variables.
Threshold prespecified	Yes	META triage criteria were predefined before analysis.
Reference standard likely to correctly classify the target condition	Yes	Urgent surgical intervention and mortality provided clinically appropriate reference standards.
Reference standard interpreted independently of the index test	Unclear	Independent interpretation was not explicitly reported.
Same reference standard applied to all participants	Yes	All patients were assessed using the same reference standard.
All participants included in the analysis	Yes	All eligible patients were included in the final analysis.
Appropriate statistical analysis	Yes	Appropriate diagnostic accuracy measures and comparative analyses were performed.
Overall appraisal: Moderate methodological limitations	Principal methodological limitations: Retrospective validation using registry data. Limited reporting of sampling and independent assessment procedures. No prospective validation during live MCIs.	

Fifth study: Hansen et al. (2021)		
Design: Case series		
Checklist: JBI Case Series		
Criterion	Judgement	Justification
Inclusion criteria clearly defined	Yes	All casualties and EMS responses related to the Great Belt train accident were clearly identified.
Condition measured in a standard, reliable way	Yes	Operational and clinical data were collected using the CONFIDE framework and standard EMS records.
Valid methods used for identification of the condition	Yes	Data were obtained from dispatch records, patient records, air ambulance logs and official reports.
Consecutive inclusion of participants	Yes	All casualties associated with the incident were included.
Complete inclusion of participants	Yes	All fatalities and injured patients were accounted for.
Participant demographics clearly reported	Yes	Patient numbers and injury severity categories were described.
Clinical information clearly reported	Yes	Triage, treatment, transport and operational response were comprehensively reported.
Outcomes or follow-up clearly reported	Yes	Patient transport, hospital destination and operational outcomes were reported.
Presenting site(s)/clinic(s) clearly reported	Yes	The incident scene, EMS system and receiving trauma centres were clearly described.
Appropriate statistical analysis	Yes	Descriptive analyses were appropriate for the case-series design.
Overall appraisal: Low methodological limitations		Principal methodological limitations: Single-incident case series. Retrospective evaluation using operational records. Limited generalisability to other MCI settings.

Sixth study: Lancet et al. (2021)		
Design: Analytical cross-sectional (simulation study)		
Checklist: JBI Analytical Cross-sectional		
Criterion	Judgement	Justification
Inclusion criteria clearly defined	Yes	The simulation included predefined patient scenarios and participating transfer teams.
Study subjects and setting described	Yes	The simulation exercise, participating hospitals and consultation teams were clearly described.
Exposure measured validly and reliably	Yes	All teams assessed the same predefined patient scenarios under identical conditions.

Objective criteria used to measure outcomes	Yes	Transfer recommendations and agreement between teams were measured using standardised scenarios.
Confounding factors identified	Yes	Differences in local knowledge and clinical judgement were acknowledged as potential confounders.
Strategies to deal with confounding	No	No analytical adjustment for differences between teams was performed.
Outcomes measured reliably	Yes	Team decisions and agreement were systematically recorded using predefined outcomes.
Appropriate statistical analysis	Yes	Agreement statistics (including kappa) and descriptive analyses were appropriately applied.
Overall appraisal: Moderate methodological limitations		Principal methodological limitations: Simulation-based design rather than real MCI events. Small number of participating teams. No adjustment for team-level confounding.

Seventh study: Lin et al. (2021) Design: Analytical cross-sectional Checklist: JBI Analytical Cross-Sectional		
Criterion	Judgement	Justification
Inclusion criteria clearly defined	Yes	Eligible casualties from the Formosa Fun Coast explosion were clearly identified using predefined inclusion criteria.
Study subjects and setting described	Yes	The incident, EMS system, hospitals and study population were adequately described.
Exposure measured validly and reliably	Unclear	Exposure variables were reconstructed retrospectively from incident records rather than measured prospectively.
Objective criteria used to measure outcomes	Unclear	Hospital outcomes were objectively recorded, but apparent prehospital time was estimated rather than directly measured from EMS timestamps.
Confounding factors identified	No	Potential confounding factors were not explicitly identified or discussed.
Strategies to deal with confounding	No	No analytical adjustment for confounding variables was reported.
Outcomes measured reliably	Unclear	Some operational outcomes relied on reconstructed timelines because complete EMS time records were unavailable.
Appropriate statistical analysis	Yes	Appropriate descriptive and comparative statistical analyses were performed for the study objectives.
Overall appraisal: Moderate methodological limitations		Principal methodological limitations: Retrospective reconstruction of operational timelines.

	Limited control of confounding. Estimated rather than directly measured prehospital time. Single-incident study limiting generalisability.
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Eighth study: Malik et al. (2021)

Design: Diagnostic accuracy study

Checklist: JBI Diagnostic Test Accuracy

Criterion	Judgement	Justification
Consecutive or random sample enrolled	Yes	Consecutive eligible patients from the TARN registry were included according to predefined criteria.
Case-control design avoided	Yes	A retrospective trauma registry cohort was used rather than a case-control design.
Inappropriate exclusions avoided	Yes	Inclusion and exclusion criteria were clearly reported and consistently applied.
Index test interpreted independently of the reference standard	Yes	Triage tools were applied retrospectively using predefined physiological data, independent of the reference standard.
Threshold prespecified	Yes	Triage tool thresholds were predefined before analysis.
Reference standard likely to correctly classify the target condition	Yes	Priority 1 status was defined using predefined life-saving interventions, providing an appropriate reference standard.
Reference standard interpreted independently of the index test	Yes	The reference standard was based on recorded interventions rather than triage classifications.
Same reference standard applied to all participants	Yes	All participants were assessed using the same intervention-based reference standard.
All participants included in the analysis	Yes	All eligible patients with complete data were included in the analyses.
Appropriate statistical analysis	Yes	Appropriate diagnostic accuracy statistics, including sensitivity, specificity and predictive values, were reported.
Overall appraisal: Low methodological limitations		Principal methodological limitations: Retrospective application of triage tools. Trauma registry population rather than actual MCI casualties. External validation in live MCI settings remains required.

Ninth study: Heemskerk et al. (2022) Design: Retrospective cohort Checklist: JBI Cohort		
Criterion	Judgement	Justification
Groups similar and recruited from the same population	Yes	Both MCI and non-MCI patients were identified from the same statewide EMS database over the same study period.
Exposure measured similarly	Yes	MCI status and triage documentation were consistently recorded using the same EMS reporting system.
Exposure measured validly and reliably	Yes	Exposure was determined using routinely collected EMS registry data with predefined operational variables.
Confounding factors identified	Yes	Patient, incident and transport characteristics that could influence prehospital time were identified and considered.
Strategies to deal with confounding	Yes	Multivariable regression analyses were performed to adjust for potential confounding variables.
Participants free of the outcome at baseline	Yes	Exposure (MCI status and triage documentation) occurred before the measured prehospital time outcomes.
Outcomes measured validly and reliably	Yes	Prehospital intervals were derived from routinely recorded EMS timestamps.
Follow-up time sufficient	Yes	Follow-up until hospital arrival was sufficient for the operational outcomes evaluated.
Follow-up complete	Unclear	The extent and impact of missing EMS operational data were not fully reported.
Strategies to address incomplete follow-up	Unclear	No specific methods for handling incomplete or missing operational records were described.
Appropriate statistical analysis	Yes	Appropriate comparative and multivariable statistical analyses were performed.
Overall appraisal: Moderate methodological limitations		Principal methodological limitations: Retrospective registry-based design. Potential misclassification from routine EMS documentation. Incomplete reporting of missing operational data.

Tenth study: Newgard et al. (2022) Design: Delphi consensus study Checklist: CREDES (Conducting and REporting of DElphi Studies)		
Criterion	Judgement	Justification

Rationale for using the Delphi method clearly stated	Yes	The Delphi method was appropriately justified to establish national research priorities.
Expert panel appropriately selected	Yes	An interdisciplinary panel of civilian and military experts was recruited using predefined eligibility criteria.
Delphi process clearly described	Yes	Four Delphi rounds, question generation, prioritisation and consensus procedures were comprehensively reported.
Consensus criteria predefined	Yes	Consensus was defined a priori using a $\geq 60\%$ agreement threshold.
Rating scale clearly described	Yes	A nine-point Likert scale was used throughout the Delphi process.
Iterative feedback provided	Yes	Participants received structured feedback across successive Delphi rounds before re-rating priorities.
Response and participation reported	Yes	Panel participation and progression through all Delphi rounds were clearly documented.
Ethical considerations addressed	Yes	Ethical approval and institutional oversight were reported.
Data analysis transparent	Yes	Consensus procedures, ranking methods and thematic categorisation were clearly described.
Final consensus clearly presented	Yes	High-, medium- and low-priority research questions were comprehensively reported.
Limitations acknowledged	Yes	The authors discussed limitations related to expert opinion and panel composition.
Conclusions supported by findings	Yes	Conclusions appropriately reflected the consensus-derived research priorities.
Overall appraisal: Low methodological limitations		Principal methodological limitations: Consensus reflects expert opinion rather than empirical evidence. Findings may be influenced by the composition of the expert panel. Research priorities may not be directly generalisable to all EMS systems.

Eleventh study: Choi et al. (2022) Design: Case series Checklist: JBI Case Series		
Criterion	Judgement	Justification
Inclusion criteria clearly defined	Yes	All casualties and EMS activities related to the Sejong Hospital fire were included.

Condition measured in a standard, reliable way	Unclear	Data were obtained from multiple sources, but a standardised assessment framework was not consistently described.
Valid methods used for identification of the condition	Yes	Information was collected from official records, hospital records, site surveys and interviews.
Consecutive inclusion of participants	Yes	All identified casualties from the incident were included.
Complete inclusion of participants	Yes	Fatalities and injured patients were comprehensively accounted for.
Participant demographics clearly reported	Unclear	Aggregate casualty characteristics were reported, but detailed demographic information was limited.
Clinical information clearly reported	Yes	Triage, evacuation, transport and injury severity were clearly described.
Outcomes or follow-up clearly reported	Yes	Mortality, injury severity and operational response outcomes were reported.
Presenting site(s)/clinic(s) clearly reported	Yes	The incident location, EMS response and receiving hospitals were adequately described.
Appropriate statistical analysis	Yes	Descriptive analyses were appropriate for the case-series design.
Overall appraisal: Moderate methodological limitations		Principal methodological limitations: Single-incident case series. Limited demographic reporting. Retrospective reconstruction using multiple information sources.

Twelfth study: Saadatmand et al. (2023) Design: Qualitative study Checklist: JBI Qualitative		
Criterion	Judgement	Justification
Congruity between the stated philosophical perspective and research methodology	Unclear	A qualitative content analysis approach was described, but the underlying philosophical perspective was not explicitly stated.
Congruity between the research methodology and the research question	Yes	The qualitative methodology was appropriate for exploring EMS preparedness components during MCIs.
Congruity between the research methodology and data collection methods	Yes	Purposive sampling and semi-structured interviews were appropriate for the study objectives.
Congruity between the research methodology and data analysis	Yes	Conventional content analysis was systematically applied to identify categories and themes.

Congruity between the research methodology and interpretation of results	Yes	The interpretations were consistent with the reported findings and participant quotations.
Researcher located culturally or theoretically	No	The researchers' theoretical position and relationship to the research setting were not explicitly described.
Influence of the researcher on the research addressed	No	Researcher reflexivity and its potential influence on data collection and interpretation were not discussed.
Participants and their voices adequately represented	Yes	Representative quotations supported the identified themes and categories.
Ethical approval obtained	Yes	Ethical approval and informed consent procedures were clearly reported.
Conclusions supported by the analysis	Yes	Conclusions were consistent with the qualitative findings and identified preparedness components.
Overall appraisal: Moderate methodological limitations		Principal methodological limitations: Philosophical perspective not explicitly stated. Limited reporting of researcher reflexivity. Findings derived from a single national context, limiting transferability.

Thirteenth study: Hansen et al. (2023) Design: Case series Checklist: JBI Case Series		
Criterion	Judgement	Justification
Inclusion criteria clearly defined	Yes	All casualties and EMS activities related to the Field's shopping centre mass shooting were clearly identified.
Condition measured in a standard, reliable way	Yes	Clinical and operational data were collected using predefined EMS records and major incident evaluation criteria.
Valid methods used for identification of the condition	Yes	Data were obtained from dispatch records, EMS reports, hospital records and official operational documents.
Consecutive inclusion of participants	Yes	All casualties associated with the incident were included.
Complete inclusion of participants	Yes	Fatalities and injured patients were comprehensively accounted for.
Participant demographics clearly reported	Yes	Casualty characteristics and injury severity were adequately described.
Clinical information clearly reported	Yes	Triage, treatment, transport and command activities were comprehensively reported.

Outcomes or follow-up clearly reported	Yes	Patient outcomes, hospital destinations and operational performance were clearly described.
Presenting site(s)/clinic(s) clearly reported	Yes	The incident scene, EMS response system and receiving trauma centres were clearly described.
Appropriate statistical analysis	Yes	Descriptive analyses were appropriate for the case-series design.
Overall appraisal: Low methodological limitations		Principal methodological limitations: Single-incident case series. Retrospective use of operational records. Limited generalisability to other MCI settings.

Fourteenth study: Valiño et al. (2024) Design: Analytical cross-sectional Checklist: JBI Analytical Cross-sectional		
Criterion	Judgement	Justification
Inclusion criteria clearly defined	Yes	Inclusion and exclusion criteria for intentional vehicle-ramming MCIs were clearly defined.
Study subjects and setting described	Yes	The incident characteristics, study setting and data sources were adequately described.
Exposure measured validly and reliably	Unclear	Exposure variables were reconstructed from open-source databases, media reports and mapping tools.
Objective criteria used to measure outcomes	Yes	Standard definitions were used for MCIs, fatalities and casualties.
Confounding factors identified	Yes	Incident-related variables (e.g., vehicle speed, route distance and crowd size) that could influence outcomes were recognised.
Strategies to deal with confounding	No	No multivariable adjustment or other strategy to control for confounding was performed.
Outcomes measured reliably	Unclear	Outcome data were compiled from multiple secondary sources, with potential variability in reporting accuracy.
Appropriate statistical analysis	Yes	Appropriate correlation and regression analyses were performed for the exploratory objectives.
Overall appraisal: Moderate methodological limitations		Principal methodological limitations: Reliance on open-source data. Limited adjustment for confounding. Retrospective observational design. Limited sample size of incidents.

Fifteenth study: Carenzo et al. (2024)		
Design: Analytical cross-sectional (simulation study)		
Checklist: JBI Analytical Cross-sectional		
Criterion	Judgement	Justification
Inclusion criteria clearly defined	Yes	Eligibility criteria for full-scale MCI simulation exercises were clearly defined.
Study subjects and setting described	Yes	The simulation programme, participating responders, casualties and exercise setting were comprehensively described.
Exposure measured validly and reliably	Yes	Exposure variables, including responder experience and casualty characteristics, were collected using standardised simulation protocols.
Objective criteria used to measure outcomes	Yes	Triage accuracy and triage-to-scene departure time were measured using predefined START criteria and standardised casualty cards.
Confounding factors identified	Yes	Responder experience, casualty characteristics and exercise variables were recognised as potential confounders.
Strategies to deal with confounding	Yes	Multivariable regression analyses were used to adjust for relevant variables.
Outcomes measured reliably	Yes	Triage performance and operational outcomes were measured using standardised exercise records.
Appropriate statistical analysis	Yes	Appropriate multinomial and regression analyses were performed.
Overall appraisal: Low methodological limitations		Principal methodological limitations: Simulation-based design rather than live MCI events. Findings may not fully reflect operational conditions during real incidents. Generalisability to live MCI settings may be limited.

Table S4.3 Summary of methodological appraisal:

Study	Appraisal tool	Overall appraisal	Principal methodological limitation
Kim et al. (2018)	JBI Analytical Cross-sectional	Low methodological limitations	Administrative EMS registry database
Koning, Ellerbroek & Leenen (2015)	JBI Case Series	Low methodological limitations	Single-incident case series
Raux et al. (2019)	JBI Cohort	Moderate methodological limitations	No adjustment for potential confounding

Romero Pareja et al. (2020)	JBİ Diagnostic Test Accuracy	Moderate methodological limitations	Retrospective validation study
Hansen et al. (2021)	JBİ Case Series	Low methodological limitations	Single-incident case series
Lancet et al. (2021)	JBİ Analytical Cross-sectional	Moderate methodological limitations	Simulation-based design
Lin et al. (2021)	JBİ Analytical Cross-sectional	Moderate methodological limitations	Reconstructed operational timelines
Malik et al. (2021)	JBİ Diagnostic Test Accuracy	Low methodological limitations	Retrospective application of triage tools
Heemskerk et al. (2022)	JBİ Cohort	Moderate methodological limitations	Retrospective registry-based design
Newgard et al. (2022)	CREDES Delphi Guidance	Low methodological limitations	Expert consensus methodology
Choi et al. (2022)	JBİ Case Series	Moderate methodological limitations	Single-incident case series
Saadatmand et al. (2023)	JBİ Qualitative	Moderate methodological limitations	Limited researcher reflexivity
Hansen et al. (2023)	JBİ Case Series	Low methodological limitations	Single-incident case series
Valiño et al. (2024)	JBİ Analytical Cross-sectional	Moderate methodological limitations	Reliance on open-source data
Carenzo et al. (2024)	JBİ Analytical Cross-sectional	Low methodological limitations	Simulation-based design

Summary and conclusion:

Overall, the methodological quality of the included studies was generally acceptable. Most studies clearly described their populations, settings and outcome measures and used analytical methods appropriate to their respective study designs. However, the evidence base was dominated by retrospective observational studies, simulation-based studies and single-incident case series, limiting causal inference and generalisability. Common methodological limitations included limited control for confounding, reliance on administrative, registry or secondary data sources, and the absence of prospective validation. These methodological considerations should be taken into account when interpreting the findings of this scoping review.