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Major Incident Hospital Simulations in Hospital Based Health Care: A Scoping Review

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Abstract

Major incidents are occurring in increasing frequency, and place significant stress on existing health-care systems. Simulation is often used to evaluate and improve the capacity of health systems to respond to these incidents, although this is difficult to evaluate. A scoping review was performed, searching 2 databases (PubMed, CINAHL) following PRISMA guidelines. The eligibility criteria included studies addressing whole hospital simulation, published in English after 2000, and interventional or observational research. Exclusion criteria included studies limited to single departments or prehospital conditions, pure computer modelling and dissimilar health systems to Australia. After exclusions, 11 relevant studies were included. These studies assessed various types of simulation, from tabletop exercises to multihospital events, with various outcome measures. The studies were highly heterogenous and assessed as representing variable levels of evidence. In general, all articles had positive conclusions with respect to the use of major incidence simulations. Several benefits were identified, and areas of improvement for the future were highlighted. Benefits included improved understanding of existing Major Incident Response Plans and familiarity with the necessary paradigm shifts of resource management in such events. However, overall this scoping review was unable to make definitive conclusions due to a low level of evidence and lack of validated evaluation.

Terrorism events, floods, bushfires, and even pandemics are occurring in increasing frequency over the past century.[1,2] In health care, these events can be grouped under the term *major incident* (MI). An MI can be defined as "an incident or event where the location, number, severity or type of live casualties, requires extraordinary resources" beyond the normal "resources of the emergency and health care services' ability to manage."[2–4]

Over the past decades, preparation for MIs has become a focus of concern for health-care systems. During such events, hospitals must "adapt to exceptional situations, and all activities must be coordinated to cope with the unavoidable chaos . . . Everything is different from routine, and responders need to be coordinated by people accustomed to these dynamics."[1]

These events must be analyzed from a systems perspective, to appreciate the complexity involved. A system can be defined as "a group of interacting, interrelated and interdependent components that form a complex and unified whole."[5] Systems thinking provides a set of tools to describe and analyze these networks. It is particularly useful in addressing complex problems, that cannot be solved by any 1 stakeholder. It focuses on organization learning and adaptive management, and is a vital tool in addressing complex public health issues, such as MIs.[5]

To reduce the chaos of these complex events, most Western health-care systems have developed a Major Incidence Response Plan (MIRP).[3,6] Generally MIRPs are rarely "stress tested" and often not known by most staff.[7,8] Practically, and ethically, it is only possible to test MIRPs by means of simulation. Thus, the methods to create high level scientific evidence are very limited.[9] In an MI simulation, the participating system "simulates the influx of a large number of patients" and the system responds to this stress.[10] Simulations vary in fidelity and scale.[11,12] Ideally simulations should be evaluated, and learnings fed back into the involved system in a Plan-Do-Study-Act cycle.[10,12]

Anecdotally, MI simulations are thought to help improve health-care system preparedness,[13,14] although it is difficult to objectively evaluate.[15] The majority of MI simulation research focuses on Emergency Department (ED) Triage, or prehospital care.[16–21] However, analyzing MI response from the perspective of a single department does not reflect the impact of these events on the hospital system as a whole. For example, after the 2005 London Bombings, the Royal London Hospital stood down from the formal declaration of an MI 5 h after the bombings started and reopened for normal services. However, at the time of reopening "*theatres were operating to full capacity and the intensive care unit had not received the patients it had already accepted from the MI.*"[22] Published expert opinion after this event identified that:

Table 1. Search terms

Search term 1	Boolean operator	Search term 2	Boolean operator	Search term 3
		PubMed		
Simulation training [MeSH Terms] Simulation	AND	Disaster planning [MeSH terms] Disaster medicine [MeSH terms]	AND	Major incident Mass casualty incident [MeSH terms]
		CINAHL		
Simulation Simulation learning	AND	Disaster medicine Disaster preparedness Disaster planning	AND	Major incident Mass casualty incident Mass casualty event Major critical incident Disaster

Note: Refer to Appendix 1 for full Boolean search string.

> "*Such actions have the potential to further overload pressured systems. Thus, the ongoing care of the patients admitted from the incident should form part of a major incident plan as the impact of their admission and treatment is beyond a period of a few hours.*"[22]

Thus, to determine how an MI may impact the hospital health-care system, wider whole hospital simulations must be performed. Locally, there is little published Australian data on hospital disaster preparedness.[23] Therefore, the aim of this scoping review of the international literature was to determine if whole hospital-based simulation improves hospital response capability to prepare for and manage major incidences, from an Australian health-care system perspective. A systems perspective was used in the analysis.

Methods

Search Strategy

A systematic style scoping review was undertaken in August 2022, according to the recommendations of the Preferred Reporting Items for Systemic Reviews and Meta-Analyses (PRISMA) and the Joanna Briggs Institute (JBI) Methodology, with the aim to tabulate all relevant literature.[24,25] The initial research question was reviewed against the population/problem, concept, and context (PCC) and FINER frameworks.[25,26] This research aimed to determine if whole hospital-based simulation improves hospital response capability to prepare for and manage major incidences, from an Australian perspective. A systematic search was then undertaken, using 2 databases: PubMed and CINAHL. An attempt was made to include the ERIC database; however, no results were returned.

As per the JBI methodology, an initial limited search was undertaken in each database to identify appropriate key and index terms. A second formal search was then performed, and these results were included. Slightly different search terms were used between databases, due to different tools offered by each. The ERIC database was included in the initial limited search; however, no appropriate results were returned despite numerous searches.

The search terms are provided in Table 1, and the eligibility criteria can be observed in Table 2.

The inclusion and exclusion criteria were predefined before beginning the scoping review (Table 2). Articles included must have evaluated the implications of the simulation on the health-care system (ie, not a pure feasibility study). Evaluation data must have been included. A broad scope of publication dates was included as these events are rare, and contemporary data were assumed to be minimal. Articles limited to the single departments were excluded.

Table 2. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Researched based in a similar health-care system as Australia Analyzing the use of simulation to improve response to major incidences from a HOSPITAL perspective Analyzing whole hospital response/health-care system response Peer reviewed interventional or observational research, with original data Based in similar health-care systems, compared with Australia Published between 2000 and 2022 Published in English	Articles limited to single departments (eg, limited to emergency departments) Articles limited to prehospital response Simulation performed for undergraduate education Mathematical or pure computer modelling simulation Dissimilar health-care system or population Guidelines, letters to the editor, recommendations, articles not based on original data Analyzing the feasibility of the simulation model only Published before 2000 Not published in English

The initial PubMed search returned 171 articles, and CINHAL returned 122 articles. These articles were combined then the title and abstracts were screened against the eligibility criteria. Refer to the PRISMA Flow diagram (Figure 1). After title and abstract screening, 54 relevant articles were identified for full text screening. Following this, 15 duplicates were identified and removed. Thus 39 articles proceeded to full text screening.

Prehospital or emergency department only simulation accounted for a significant proportion of articles returned in the search. However, these were not sufficient to answer the research question, and were excluded. Simulations based purely on mathematical and computational modeling were also excluded. This is justified by a 2008 study, which demonstrated that there were marked differences in patient benchmarks between computer simulation and live exercises.[28] Three papers were excluded as they were set in Saudi Arabia, which was assessed as too dissimilar to the Australian population and health-care system.[29–31] A further 3 studies were excluded as English translations were not available.[32–34] Thus, after full text screening, 11 relevant articles were retained. Reference lists from the included articles were snowballed to identify relevant papers. However, no new articles were identified.

Quality Assessment

All included articles were assessed for quality against the appropriate CASP checklist.[35] Of note, most articles were found

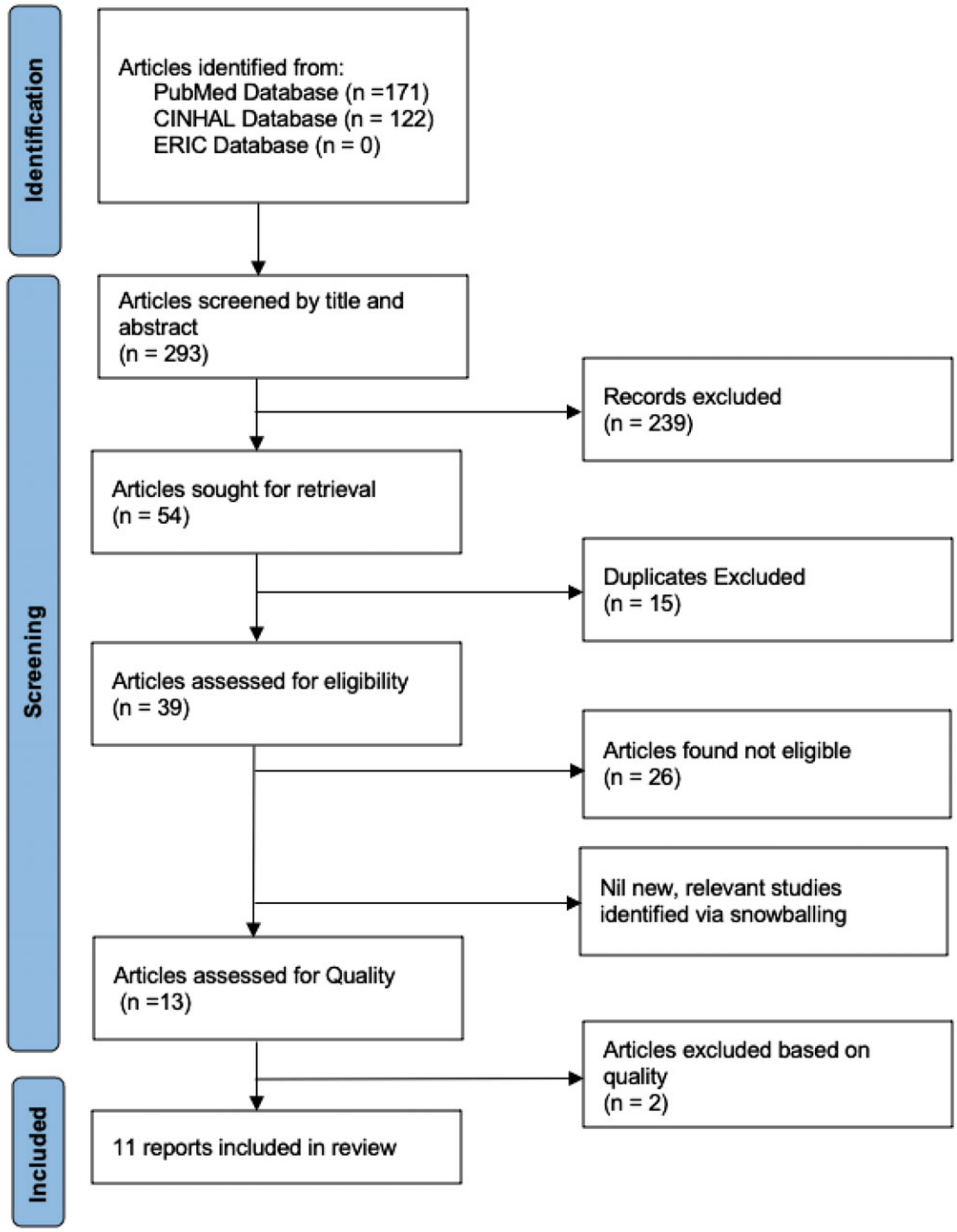

Figure 1. PRISMA flow diagram for systematic reviews.[27]

to be of low evidence strength, likely due to ethical and procedural difficulties in this topic.

However, 2 studies were excluded for further quality concerns. A 2014 United States article was excluded, due to a very significant risk of selection bias and low strength of evidence. Self-reported perception of knowledge improvement was assessed by a post course questionnaire only, of which only 20 participants completed, despite a whole hospital simulation being conducted at 3 Los Angeles Hospitals with staff from all 3 hospitals participating.[36] Another 2018 Dutch study was excluded as the primary outcome recorded was not considered valid by the authors of this review, and there were significant sources of bias. The original Dutch authors retrospectively evaluated 32 MI simulation reports from Dutch hospitals and identified the difference in the number of items of improvements identified in different reports. Measuring the number of areas of improvement identified, with no actual evaluation into these areas, is not a valid outcome measurement. The study was thus excluded as it lacks internal validity.[10] Please refer to Appendix 2 for further details.

Data Extraction and Synthesis

Author 1 of this review independently reviewed the relevant articles identified from the search strategy, described above. As per the JBI protocol for scoping reviews,[25] data were extracted from each article under key characteristics and main conceptual categories.

Results

Study Characteristics

After a scoping systematic literature search, and the application of the exclusion and inclusion criteria listed in Table 1, a total of 11 relevant articles were identified, as can be seen in Table 3.

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Table 3. Characteristics of 11 included studies from international scoping review

Authors	Date	Country	Participants	Study Design	Outcome Measures	*Critical Analysis*	*Level of Evidence*
Bartley BH, Stella JB, Walsh LD[38]	2006	Australia	50 participants surveyed Single site	A **quasi-experimental study** with no control: at a single site 50 key stakeholders (out of a population of 170 of interest) were included for evaluation pre and post intervention. The intervention consisted of a 1 hour lecture followed by a compressed time disaster simulation 5 days later. The events included in the simulation were not described.	Factual knowledge was assessed by means of the survey, with an improved from an 18% pass rate to 50% ($P = 0.002$), and improvement in all participants. Individuals that attended at least one component showed greater improvement. Self-assessment of personal and departmental preparedness demonstrated improvement	**Strength**: Some objective measurement of improvement, besides pure self-perception. **Limitations**: Weak level of evidence as non-controlled, non-randomized quasi experimental study. Validity in factual knowledge improvement after 2 wk as a measurement of long-term knowledge retention is doubtful. Low number of participants. Limited engagement with both phases of intervention. Retrospective self-evaluation is prone to bias, and not an objective measurement of systems improvement.	IV
Bird R, Braunold D, Dryburgh-Jones J, Davis J, Rogers S, Sohrabi C, et al.[2]	2020	England	29 patients identified for early discharge, from a total of 73 staffed beds (pediatric) Single site	A **prospective cohort study**: A single site, whole hospital simulation of a MI was performed in a PEADIATRIC hospital, and a pre-set ward discharge criteria was applied. The simulation involved a chemical gas exposure. Of the identified (real world) patients, they were virtually "discharged." Once the simulation was complete their actual admission was followed for 7 days to determine if the discharge was appropriate.	Time to identification and discharge during the simulation was assessed, and outcomes post "virtual" discharge. The authors proposed a system that facilitated faster discharge and were able to discharge 15 of the identified 29 appropriate patients within the simulation. Of the "suitable" patients identified, only 6 remained an inpatient after 1 week of the exercise. A tier system was proposed.	**Strengths**: The study proposes a novel intervention that could offer serious improvements in hospital function and flow during an MI. **Limitations**: It is limited by the small sample size, and unclear assessment of appropriate identification of 'virtually' discharged patients. External validity is limited by the research only occurring at a single site. Unclear if can be extrapolated for an adult population.	III
Castoldi L, Greco M, Carlucci M, Montan KL, Faccinacani R[1]	2022	Italy	258 participants surveyed Single site.	A **quasi- experimental study** with no control: over a 2-y period at a single site, 7 simulations were held using the MACSIM course to train staff on the implementation of the hospitals MI plan. The MACSIM is a scientifically validated simulation course. Each simulation course had an average of 37 participants. Simulations involved varying events.	Self-reported perceptions of knowledge and skills in MI management was assessed by means of pre and post course questionnaires. All staff reported significant improvement in "self-perception of knowledge and skills in MCI management." MACSIM was found to be an efficient way to train hospital staff in MCI management.	**Strengths**: Large number of participants, course run multiple times to minimize selection bias, utilization of validated simulation. **Limitations**: Weak level of evidence, as noncontrolled, non-randomized quasi experimental study. Retrospective self-evaluation is prone to bias, and not an objective measurement of systems improvement.	IV
Davids MS, Case C Jr, Hornung R 3rd, Chao NJ, Chute JP, Coleman CN, et al.[42]	2010	USA	37 hospital sites Simulation 1: 426 staff members (9.5 median per center) Simulation 2: 601 staff members (11.5 per center)	A **mixed methods prospective observational study**: 2 tabletop simulations analyzing surge capacity for radiation victims within a health-care network, involving 37 academic hospitals. The tabletop exercises were distributed to each center, who then performed the simulation themselves. A post simulation survey was then completed for each center assessing surge capacity across the network. In simulation 1 the network was called to collectively accept 5000 victim transfers, with each site voluntarily accepting admissions. Simulation 2 instead mandated acceptance of 300 victims per center. It focused on "approaches to coping with the mandatory acceptance" of these patients.	In simulation 1, centers were required to report their capacity for accepting simulation victims, with only 1757 victims (of a total 5000) being voluntarily accepted. The number of victims accepted by each center varied widely (ranging from 3 to 200). Acceptance was below each centers previously reported capacity. Staffing was also identified as an issue Simulation 2 centers identified plans to increase bed availability, with various strategies proposed. There was no evaluation of if hospitals were "successful" in accepting the 300 mandatory patients.	**Strengths**: Appeared to be an effective thought exercise in developing inpatient bed surge capacity and demonstrating a difference between apparent and recorded capacity at a single point in time. Strong systems focus, with reflection improvement in communication across the system. **Limitations**: No evaluation in simulation 2 into how the proposed strategies would actually improve surge capacity. Thus, unable to assess impact of proposed strategies	IV

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Table 3. (*Continued*)

Davidson RK, Magalini S, Brattekås K, Bertrand C, Brancaleoni R, Rafalowski C, et al.[40]	2019	Italy	Single site whole hospital simulation	A **prospective observational study** involving a simulated chemical gas exposure. An initial scoping tabletop exercises with participants from 11 countries was performed, however, the results were not included in study This was followed by full scale simulation in a large hospital in Italy, with the aim to test the current hospital surge response during an MI.	Outcomes were recorded by a team of 8 evaluators, and post simulation semi structured interviews in the form of a debriefing. Key areas were identified, with lessons learned grouped into categories of staff, stuff, structure, and system. Issues identified were constructive and varied, including issues with decontamination, understanding of command structure, communication, resource allocation.	**Strengths**: Full scale simulation with detailed qualitative feedback on multiple aspects for improvement **Limitations**: Very specific feedback and lessons, to a specific site. No real evaluation into the "success" of simulation against the aim to test the hospitals MIRP. Overall valuable example of how simulation can be used to determine issues and bottlenecks in a health-care system. However due to its specificity, limited ability to directly generalize conclusions.	IV
Harris C, Bell W, Rollor E, Waltz T, Blackwell P, Dallas C.[39]	2015	Atlanta, USA	Region wide for Atlanta metropolitan area: involving 22 hospital sites	A **prospective observational study** involving a region wide simulation of a chemical gas exposure. The simulation locations were assessed by trained evaluators, although the criteria and technique for evaluation was	Trained evaluators were employed throughout the simulation to "capture response data . . . and note deviations from accepted emergency operations plans, policies and procedures." It is important to note the authors did not provide any further explanation about how this assessment occurred, and if there were any pre-set criteria.	**Strengths**: The study had a strong systems focus, analyzing the response from a regional perspective. Some key lessons are likely to be valuable **Limitations**: Concerns exist about the poor explanation of evaluation. There appears to be no attempt to reduce inter-evaluator variability, and no clear standardization of assessment criteria. The results are poorly presented, making independent assessment difficult. The reader is highly reliant on the included discussion. Limitations exist with external validity. It was solely performed in the USA, which limits the ability to extrapolate to the Australian Health-care system.	IV
Khorram-Manesh A, Lönroth H, Rotter P, Wilhelmsson M, Aremyr J, Berner A, et al.[41]	2017	Sweden	Independent evaluation of Single site simulation	A **prospective observational study**: A simulated foreign military attack resulted in 28 casualties presenting to a civilian hospital with typical war injuries. The study aimed to analyze the outcomes of civilian and military collaboration in a mutual simulation.	Independent evaluators completed qualitative and qualitative assessments on a predefined template at various locations throughout the hospital, identifying key strengths and weaknesses. Communication was identified as the largest area of improvement in multiple locations. Another area of concern included a lack of compatibility between military and civilian equipment.	**Strengths**: Independent, contemporary observational evaluation is prone to less bias than retrospective self-evaluation, although is still possible. Strong systems focus, with valuable lessons to improve systems functionality. **Limitations**: Unclear external validity given a single site study, set in Sweden. Also limited ability to extrapolate this data given military involvement - relevant to specific situations, but not all MIs.	IV
Kilma DA, Seiler SH, Peterson JB, Christmas AB, Green JM, Fleming G,et al.[11]	2012	USA	17 hospital sites included – operation of simulation independently assessed	A **prospective observational study** involving a multiagency, multijurisdictional, multidisciplinary simulation exercise including 17 hospitals. Each hospital was independently assessed by third party contractors, to identify deficiencies	Third party contracted evaluators assessed each hospital in 5 key areas: communications, command structure, decontamination, staffing, and patient tracking. None of the hospitals were compliant in all 5 areas, with common deficiencies including communications, tracking system deficiencies, lack of working knowledge of radio systems, deficient decontamination, inadequate staffing, and suboptimal command structure.	**Strengths**: A very strong study analyzing the deficiencies in multiple hospitals in response to the same event, with independent evaluation against a predetermined criterion. Strong systems analysis and critique, with valuable lessons. **Limitations** exist with external validity. It was solely performed in the USA, which limits the ability to extrapolate to the Australian Health-care system.	IV (

(*Continued*)

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Table 3. (*Continued*)

Authors	Date	Country	Participants	Study Design	Outcome Measures	*Critical Analysis*	*Level of Evidence*
Murphy JP, Kurland L, Rådestad M, Rüter A.[44]	2020	Sweden	6 hospital sites	A **prospective observational study**. Involving 6 consecutive tabletop simulation exercises at 6 hospitals. The simulations involved bomb blasts and active shooter scenarios. The participants at each site were the designated hospital incident command groups (HICGs). The aim of the study was to assess associations between decision making skills and staff procedure skills.	The HICGs were assessed against the Disaster Management Indicator Instrument, which included observed and included variables. The same 2 observers were present in all simulations and collected the data. A statistically significant correlation was found between proactive decision-making skills and staff procedure skills ($p = 0.014$)	**Strengths**: Focus on HICGs, and systems focus. Assessment against a preestablished criteria. Reduction in interobserver variability. Strong study design, with clear conclusion that has implications for clinical practice. **Limitations**: Limited scope, small number of participants. Weak level of evidence. Unclear applicability to Australian setting.	IV
Nilsson H, Vikström T, Rüter A.[9]	2010	Sweden	18 management groups evaluated, with each group comprised of 6 – 8 participants	A **prospective observational study** conducted during 9 educational simulations, evaluating 18 management groups during 18 standardized simulation exercises. Simulated event not described.	Evaluation of each simulation was made "with a set of 11 measurable performance indicators" on a scale of 0 to 2. The evaluators were 3 independent, trained observers. The selected indicators were derived from modelling conducted by the National board of Health and Welfare in Sweden The average total score was 14/22, with participants soring best for declaring major incidence and deciding on level of preparedness for staff. Identified areas of improvement.	**Strengths**: Objective, standardized evaluation of multiple management groups. Trained, standardized evaluation reduced measurement error and bias. **Limitations**: Selected indicators have not been validated against response to a real-world MI. Overall, well designed study that demonstrates an evaluation method that could serve as a quality control tool for disaster management, however not validated against real world response.	IV
Tallach R, Schyma B, Robinson M, O'Neill B, Edmonds N, Bird R, et al.[7]	2022	USA	Single site – whole hospital simulation 300 participants first simulation, 400 participants second.	A **prospective observational study** involving 2 whole hospital simulations (one high fidelity, one low fidelity). All participants engaged in a post simulation semi structured interview, with a post simulation survey distributed.	A semi structured interview was held with all participants afterward in the form of a debrief, with the collection of qualitative data. Post simulation surveys were also distributed afterward with response rates of 48% and 67% per simulation. Each simulation identified latent errors and system safety concerns, including "communication, role allocation and area allocation." On the post simulation surveys overall 88% and 93% of respondents agreed they were better prepared for their role in a MI.	**Strengths**: A well-designed observational simulation study, analyzing hospital response from a systems perspective. Clearly identified learning framework. Mixed methods approach facilitated more in-depth feedback. Strong focus on systems improvement **Limitations**: Retrospective self-evaluation is prone to bias, and not an objective measurement of systems improvement. Moderate survey response is also a source of bias. Limitations in generalizability, given single site in the United Kingdom. Also, low level of evidence	IV

Although the date range for inclusion was set as the past 20 y, the majority of articles ($n = 10$; 91%) were published in the past 12 y. Only 1 article included was based in Australia. Of the other articles, 4 were based in Sweden, 3 in the United States of America (USA), 2 in Italy, and 1 in England. The type and size of simulation used in the articles varied greatly, from tabletop exercises to multijurisdictional simulations. Where described, all simulations appeared to have involved a man-made MI.

Of the included articles, 8 were prospective observational study designs, 2 used quasi-experimental study design, with pre- and postsimulation evaluation. All 11 articles examined mixed populations, including both adult and pediatric patients. Assessed against the National Health and Medical Research Council (NHMRC) Evidence Hierarchy, 10 articles were all found to be of level 4 evidence with a high chance of bias.[37] One study, a prospective cohort design which examined a purely pediatric cohort, was found to be level 3 evidence.[2] Overall, there was a significant paucity in high level data.

Across the 11 included articles, there was a significant amount of heterogeneity in study designs, outcome measures, and evaluation techniques. No 2 articles used the same evaluation technique or outcome measures, making direct comparison difficult. In addition, a mixture of qualitative and quantitative measures were used across articles.

Common Themes Identified

The aim of this scoping review was to determine if whole hospital-based simulation improved hospital response capability to prepare for and manage MIs, from an Australian health-care system perspective. From a single site outlook, the 2020 Italian article provides the best example.[1] Over a 2-y period, 7 whole hospital simulations were held using a preestablished course to train staff on the implementation of the hospitals MI plan. Overall, the authors found it to be an efficient way to train hospital staff in MI management, although the article was assessed as representing a low level of evidence.

This is supported by the other articles. In general, participants in the simulations self-reported improvement or increased understanding.[1,7,38] Of interest, in a 2022 English article which involved a whole hospital simulation with more than 700 staff participants, further exercises were requested by the participants. They found "the simulations mimicked real responses and that exercising as a whole system was beneficial."[7] The only Australian study located in the literature that used a whole hospital simulation found that participation in MI simulations improved factual knowledge among participants.[38] Benefits of MI simulation reported in the included articles have been summarized in Box 1.

Box 1. Benefits of MI simulation

- Improved understanding of roles in an MI[1,7,39]
- Improved understanding of MIRP[1,7]
- Familiarity with paradigm shift of managing resources to maximize survival[1,7,39,40]
- Identification of latent errors and systems safety issues[7,11,40,41]
- Identification of areas of improvement[7,11,40–42]
- Testing surge capacity from a resource perspective[11,40–42]
- Testing clinical tools for MI[2]

Some articles evaluated an entire region's response to MI by means of simulation. For example, the 2012 USA prospective observational study completed a full-scale regional exercise, which included 17 participating hospitals. All 17 hospitals considered the simulation exercise outcomes across the whole hospital. This massive exercise was used to evaluate the region's response and identified key areas that required improvement. Similar areas of improvement were identified in the other 11 included articles; these have been summarized in Box 2.

Box 2. Areas of improvement identified by MI simulation

- Communication[7,11,40,41]
- Lack of working knowledge of MIRP[7,11,39–41]
- Staffing, and medical resources[7,11,40,41]
- Command structure[11]
- Lack of compatibility between prehospital and hospital teams, or between departments.[41]
- Improved security during events[39]
- Engagement with community partners and first responders[39,43]
- Documentation[7]
- Media strategy[9]

Some articles identified unique points, through more novel study designs. Refer to Appendix 3 for further information.

Discussion

Improving MI preparedness and management is a topic of significant public health concern. However, there is little published data evaluating management in real-world events. Some recommendations have been published after specific events; but these are examples of expert opinion only.[13,14,45–47]

Simulation has long been thought to be an effective tool to assist this preparation, although it is difficult to objectively evaluate.[13–15] Unfortunately, similar to previous publications,[48] this scoping review has also demonstrated a paucity of strong data. Studies were generally either quasi-experimental or prospective observational design. Although they contribute preliminary insights, these designs do not have randomization, a limited control of confounding variables, and no control group. This weakens the scientific strength of the evidence, and it must all be interpreted with caution.

In general, retrospective self-evaluation demonstrated improvement of MI simulation management, and increased understanding of MIRP.[1,7,38] Participants in a 2022 study stated that "the simulations mimicked real responses and that exercising as whole system was beneficial."[7] Thus simulations seem to improve staff confidence, which is important and beneficial. While performance is not a substitute for capacity, "individual, leader, and team confidence play essential roles in achieving success and the absence of confidence has been connected with failure."[49] Simulations appeared to be useful tools for identifying areas of improvement, as can be seen in Box 2. While these studies were highly heterogenous, similar themes of improvement were found, suggesting potential generalizability.

Simulations of a variety of fidelity were performed. Due to common deficiencies across the region, the 2012 USA study found that "tabletop exercises are inadequate to expose operational and logistic gaps in disaster response. Full scale regional exercises should routinely be performed to adequately prepare for catastrophic events."[11] From a systems perspective, it would be ideal to regularly run large scale exercises to truly stress the networks involved. However practically these exercises are expensive, time and resource consuming.[12] Other studies used lower fidelity techniques as they believed "the resource investment and expense of high-fidelity simulation was not justified."[7] At this stage, there is not enough evidence to support 1 approach over the other. However, despite fidelity level, all studies included found some benefit or identified areas of improvement.

As identified in the 2010 Swedish study "monitoring health-care quality may be difficult without the use of clinical indicators."[9] This is further emphasized by the existing literature on MIs and simulation, which has found demonstrating the effectiveness of such exercises difficult.[10,12] In this literature review, all studies evaluated their simulation differently. In future, to accurately evaluate the effectiveness of these activities clinical indicators must be developed. The proposed indicators in the 2010 Swedish study are 1 possibility, but they must be externally validated.

Review Strengths and Limitations

This is the first known scoping review on MI simulations in hospital-based health care that considers a whole hospital or regional response to MIs. It provides preliminary insights into the areas of benefit and possible improvements that could be made to MI simulation. To ensure rigor in our process, this scoping review followed the JBI manual, carried out pilot searches to refine search terms, and predefined inclusion and exclusion criteria before screening.

However, the generalizability of these scoping review findings to different international health-care systems is a limitation of concern. Only 1 study identified in this review was performed in Australia. Four studies were performed in Sweden, and 1 in the United Kingdom. Arguably, these countries have comparable health-care system.[50] However, this review also included 3 American studies, which has a vastly different health-care system and limits the generalizability of the American study findings.[50] Thus, conclusions from these articles must also be interpreted with caution, when considering within the context of different health-care systems. This concern is reinforced further by acknowledging the essential role and influence of the key elements of the systems thinking framework.

There were other limitations to this scoping review. The database search was performed by a single author, which may introduce a bias regarding the "relevant" articles included. Additionally, the author was unable to include or analyze 3 articles published in another language.[32–34] Another limitation that should be acknowledged is the small number of included articles; however, this may be reflective of the current literature deficit in this field.

To support the value of simulation in MI preparation and management, further research must be performed. Specifically clinical indicators of MI management should be validated, which would allow more scientific and objective evaluation of MI simulation in the future.

Conclusions

This scoping review of the international literature aimed to determine if whole hospital-based simulation improves hospital response capability around MIs. Definitive conclusions were unable to be made, due to the low number of relevant articles identified, the lack of data, and the general paucity of strong scientific evidence. In general, all articles had positive conclusions with respect to the use of MI simulations. Several benefits were identified, and areas of improvement for future highlighted. However overall, there was a lack of validated evaluation, little evidence to definitively conclude that simulations improved preparation or management for real world MIs. Further research is required to optimize future responses to MI events.

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Appendix 1: Search Strings

PubMed search:

((simulation training[MeSH Terms]) OR (simulation)) AND ((disaster planning[MeSH Terms]) OR (disaster medicine[MeSH Terms])) AND ((major incident) OR (mass casualty incident[MeSH Terms]))

CINHAL search:

((major incident) or (mass casualty incident) or (mass casualty event) or (major critical incident) or (disaster)) AND ((disaster medicine) OR (disaster preparedness) OR (disaster planning)) AND ((simulation) OR (simulation learning))

ERIC search

((major incident) or (mass casualty incident) or (mass casualty event) or (major critical incident) or (disaster)) AND ((disaster medicine) OR (disaster preparedness) OR (disaster planning)) AND ((simulation) OR (simulation learning))

Nil results

((major incident) or (mass casualty incident) or (mass casualty event)) AND ((simulation) OR (simulation learning))

Nil results

((disaster medicine) OR (disaster preparedness) OR (disaster planning)) AND ((simulation) OR (simulation learning))

Nil results

Appendix 2: Excluded Articles after Quality Assessment

Paper 1: **Burke RV, Kim TY, Bachman SL, *et al*.** Using mixed methods to assess pediatric disaster preparedness in the hospital setting. *Prehosp Disaster Med*. 2014;29(6):569-575.[36]

This article was excluded, due to a very significant risk of selection bias and low strength of evidence. In this study, a whole hospital simulation was conducted in 3 Los Angeles Hospitals, with staff from all 3 hospitals participating. Self-reported perception of knowledge improvement was assessed by a post course questionnaire only, of which only 20 participants completed. It was not disclosed by the authors how many individuals participated in the simulation. However, given the simulation occurred over 3 hospitals, involving the whole site, it is likely to be a significant number. Given the weak study design, and undisclosed survey completion rates, this study quality was found to be very low and was thus excluded from this review.

Paper 2: **Verheul ML, Dückers M, Visser BB, *et al*.** Disaster exercises to prepare hospitals for mass-casualty incidents: does it contribute to preparedness or is it ritualism? *Prehosp Disaster Med*. 2018;33(4):387-393.[10]

This paper was excluded, as the primary outcome recorded is not valid, and there were significant sources of bias.[10] The authors retrospectively evaluated 32 MI simulation reports from Dutch hospitals, with each hospital supplying 2 reports (with a mean time of 26.1 mo between reports). The authors identified the number of items of improvement suggested in the initial report and compared this with the number of items of improvement suggested in the later report. The data had several limitations: they were collected retrospectively from heterogenous evaluation formats. They were also limited by the initial evaluators; the authors themselves identified no clear selection criteria and training among evaluators. However, most significantly, it is doubtful that the primary outcome of interest, the number of areas of improvement identified, accurately reflects improvement in MI management. There was no actual evaluation on improvement of areas identified, just the number identified. Given the data were collected by evaluators with no standardization, there are numerous possibilities for this difference. For example, improved engagement with the simulation, self-reflection from previous simulations, and differences between evaluators. Measuring the number of areas of improvement identified, with no actual evaluation into these areas, is not a valid outcome measure. The study was thus excluded as it lacks internal validity.

Appendix 3: Unique Points Identified

The 2020 English pediatric study focused on a unique aspect of MI preparation, improving pediatric discharges. The authors developed a discharge criterion that could be applied to hospital inpatients at the start of a MI to identify appropriate early discharges, thus increasing the hospitals surge capacity.[2] This is a unique tool with clinical implications, which was appropriately evaluated by means of simulation in a Plan-Do-Act evaluation model. Not only does this article provide evidence to support this technique being implementation in other sites, but it also provided an excellent example in how to implement and evaluate new clinical tools from a systems perspective in major incidences.

The 2020 Swedish study also had a unique perspective, demonstrating by means of tabletop simulations that there was a correlation between proactive decision-making skills and staff procedural skills.[44] While this study had a narrow focus, it did provide a clinically relevant outcome. This study provides evidence to support clinical, procedural staff being more highly involved in the command structure of MIs (where proactive decisions are required).