

A systematic review and analysis of learning from major incidents and mass casualty events over the last five years

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Abstract

The dawn of the 21st century has seen a dramatic increase of mass casualty events internationally, with a number of aetiologies. The key with any healthcare evolution is to identify whether lessons learned are being implemented to help to mitigate future events. This article will explore the lessons learned from mass casualty events over the last five years.

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Introduction

Helmuth von Moltke, the 19th-century Chief of the Prussian General Staff, was quoted as saying: “No battle plan survives contact with the enemy”.¹ This article will demonstrate that von Moltke’s insight can also be applied to planning and preparedness for mass casualty events. The dawn of the 21st century ushered in an era of increasing terror-related mass casualty events. Analysis of the response to the devastating atrocities in New York on 11 September 2001 highlighted the need for co-ordinated mass casualty event planning at the national and local level in addition to inter-agency co-operation.²

Since 2001, the world has seen a rise in the number of such events and the threat of indiscriminate attacks at major urban population centres remains at an all-time high.³ The United States has reported 85 separate mass terror-related mass casualty events since 2001 whilst Europol recorded 142 attempted or completed attacks across its member states in 2016 alone.^{4,5} Over the last 5 years in particular, a wave of attacks has spread through Europe and the United States, targeting civilians in Brussels, Nice, Paris, Berlin, London, Manchester, Boston and Las Vegas, to name but a few.^{6–12}

Mass casualty events occurring in major cities in Europe and the United States present a challenge for emergency medical services, whether they be the result of terrorist activity or large-scale accidents. Terrorist attacks often involve multiple ballistic and blast injuries in densely populated urban centres, creating an imbalance between clinical need and available resources.¹³ As such, plans and strategies must be put in place to raise the level of preparedness. Prior to 2001, early efforts centred on a cyclical model of disaster planning which included 5 phases; Prodromal (preparation phase); Impact (the event itself); Rescue (the post-event response); Recovery (long term management of the consequences of the event); and Quiescent (resolution phase and analysis).¹⁴ It was quickly noted that this approach had to be improved in the wake of

spikes in mass casualty events, with emergency services and medical personnel needing to shift from a normal operational framework to one able to provide care to the maximum number of injured victims.^{2,15}

The aims of this review were to conduct an analysis of highlighted themes extracted from the literature to provide an overview of the lessons learned from recent incidents. This review will also propose future recommendations to increase preparedness for mass casualty events.

Methods

Search strategy

In order to fully address this question, two approaches were taken. First, a comprehensive systematic literature review was undertaken to identify articles concerning mass casualty event analysis. Secondly, an in-depth analysis of eight recent mass casualty events was carried out to assess the response critically. These were chosen specifically for the high volume of publication and information available about the medical response.

Literature review

A systematic literature search was performed on PubMed, the Cochrane Database of Systematic Reviews and Scopus for all articles concerning mass casualty events analysis from 15 December 2012 to 15 December 2017. A comparative search of the grey literature was also carried out. The search utilised the Medical Subject Headings (MeSH), including: ‘mass casualty’/mass casualties’, ‘major incident/major incidents’, in one field and either ‘analysis’ OR ‘review’ in the other. Both pre-hospital and in-hospital responses were included for this review.

Inclusion criteria

We included all articles in English (or with English translations available) published over the last 5 years, from 15 December

2012 to 15 December 2017 inclusive. For selection, the articles had to contain an analysis or review of the response to either individual or multiple mass casualty events. Also included were systematic reviews of such articles.

Exclusion criteria

We excluded articles that did not address the research question, i.e. no analysis was made of the response to the event, or opinions/comments/interviews were included that did not relate to the actual response. Surveys, questionnaires, simulations, protocol templates, preliminary study designs and articles not available as full texts were also excluded. Many articles were found to have too narrow a focus, for example assessing the computer system,¹⁶ radiology department response,¹⁷ tourniquet availability¹⁸ or nursing experiences¹⁹ rather than giving a broader systematic review of the response.

Article identification

Among 612 unique articles identified through the literature search, 72 were selected after abstract review. Following full text review, eight of these were selected for inclusion in the analysis. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines were followed and are included below.²⁰

Justification of search strategy

A two-part breakdown of the search strategy and analysis was undertaken in order to present a balanced view of the academic research surrounding mass casualty events as well as to highlight the response to the eight selected mass casualty events and their aftermath.

The last few decades have seen a rise in awareness of mass casualty events and an appreciation of the need to prepare for them. Early research efforts concentrated on mass gatherings, where overcrowding and crowd control were the focus.²¹ Events such as the Hillsborough football stadium disaster in the UK highlighted the importance of crowd safety and the danger posed by stampedes. In addition, it became evident that large scale gatherings required on-site medical personnel.^{22,23} However, it was not until the tragic loss of life during the attacks in New York on 11 September 2001 that disaster planning was seen as an essential part of urban planning.²⁴ The last decade has seen a steady rise in terror-related mass casualty events, and in the last few years an acute increase, with a wave of violence sweeping across Europe and the United States.²⁵ It is for this reason that this review focuses on lessons learned over the last 5 years.

The areas of specific focus for this analysis, based on historical data,²⁵ were logistics (including system processes, communication and security), initial haemorrhage control when indicated, public education and research, and finally overall quality of the analysis undertaken.

The 5 year range of this review gave enough time for research and analysis to disseminate from one event to another. Two

further mass casualty events were considered for inclusion; the Grenfell Tower block fire on 14 July 2017 and the mass shooting in Las Vegas on 1 October 2017.^{26,27} There is no doubt that there are many lessons to be learned from both of these devastating incidents, but on preliminary review there was not enough research material available in the literature to conduct a complete analysis. In addition, enquiries and investigations into both events are still ongoing.^{27,28}

Limitations

The nature of mass casualty events and the research assessing the medical response means that there are several limitations to this review. Initially, a decision was made to narrow the scope of the review both in terms of event type and date. The focus was on events occurring in the last 5 years in order to analyse the latest lessons learned following the surge in mass casualty events in the western world. The results included in the literature review also vary in their research rigour and analysis. As discussed in the quality analysis below, the nature of mass casualty events means there is a paucity of high level evidence surrounding the topic. As of yet, a standardised prospective method of data collection for such events does not exist.

The articles included in the search were in the English language only as it was not feasible to include and translate other published material. A fully comprehensive analysis of all mass casualty event responses would necessitate review of internationally published accounts in any language, as well as those taking place in different environments.

Finally, most of the academic research in this field is centred on environments with adequate infrastructure and existing emergency medical services, and with varying levels of mass casualty preparedness.

Results

Eight articles were included for analysis following the literature review. They include two systematic reviews, one literature review and five retrospective analyses. Three of the papers reviewed international mass casualty events and the rest focussed on individual countries; two from the USA and one each from China, Lebanon and France.

Tables 1 and 2 summarise the details of each paper, as well as the lessons learned from each. Table 1 describes all the papers included and a breakdown of the event and study type as well as mortality and morbidity figures, where available. Table 2 gives an overview of the papers and the lessons learned following analysis of the mass casualty events.

Discussion

As expected, there were common themes across all eight events reported, with the vast majority highlighting security, communication, training and planning as problematic during these events. In order to address these, it is important to understand why they occurred.

Paper	Country	Event	Study Type	Level	Mortality	Morbidity
Zhang <i>et al.</i> , 2017 (29)	China	Chemical explosion	Retrospective analysis	V	165	>1000
Sayed <i>et al.</i> , 2017 (33)	Lebanon	Bombing	Retrospective analysis	V	n/a*	n/a*
Turner <i>et al.</i> , 2016 (34)	International	Shootings	Systematic review	II	578	1071
Hirsch <i>et al.</i> , 2015 (30)	France	Multiple	Retrospective analysis	V	130	352
King <i>et al.</i> , 2015 (36)	USA	Bombing	Retrospective analysis	V	3	281
Gates <i>et al.</i> , 2014 (31)	USA	Bombing	Retrospective analysis	V	3	281
Turris <i>et al.</i> , 2014 (35)	International	All MCE**	Literature review	III	n/a*	n/a*
Timbie <i>et al.</i> , 2013 (37)	International	All MCE**	Systematic review	II	n/a*	n/a*

*n/a = data not available, **MCE = Mass casualty events,

Table 1: Research articles and breakdown of event, study type, level of evidence and mortality/morbidity figures

Paper	Lessons	Common Themes
Zhang <i>et al.</i> , 2017 (29)	Triage failures On scene security Lack of protective equipment for first responders Failure of decontamination Public awareness increased	Security Communication Training Planning
Sayed <i>et al.</i> , 2017 (33)	Clear definition of roles Security and hospital lockdown Communication failures Debriefing	Security Communication Training Planning
Turner <i>et al.</i> , 2016 (34)	Security Haemorrhage control Triage system Disaster planning and rapid extraction Communication failures	Security Training Haemorrhage control Planning
Hirsch <i>et al.</i> , 2015 (30)	Overwhelming surge capacity Co-operation	Planning Communication
King <i>et al.</i> , 2015 (36)	Lack of translation of lessons for military haemorrhage control Training and provisioning issues	Training Haemorrhage control Planning
Gates <i>et al.</i> , 2014 (31)	Co-operative effort Tourniquet use	Planning Haemorrhage control
Turris <i>et al.</i> , 2014 (35)	Lack of systematic reviews of MCE ** injury patterns not well described Failure of crowd control Weather conditions Centralised database for mass casualty events needed	Planning Security Data collection
Timbie <i>et al.</i> , 2013 (37)	Need for better evidence Difficulty in conducting research into MCE** Need for preparedness simulation	Planning Training Data Collection

*n/a = data not available, **MCE = Mass casualty events

Table 2: Research articles and data regarding lessons learned from each event.

System failures

By definition, mass casualty events overwhelm the medical resources available. Systems must be in place which ensure that patients can be secured, triaged and transported to definitive medical care. Problems were highlighted following an explosion involving hazardous chemicals at the port of Tianjin, China in 2015, where it was quickly understood that current measures were not capable of dealing with the number and severity of injuries. The emergency medical services who first arrived on the scene triaged according to whether patients were 'walking or not'. Those deemed to have minor injuries were then sent to the hospital outpatient department, while those critically injured were sent to the emergency departments. It was noted that the emergency departments at each of the 10 receiving hospitals quickly became overloaded due to a combination of over- and under-triage by pre-hospital teams, who were themselves overwhelmed by the number of casualties on the scene.²⁹

This was also noted by Hirsh *et al.* who surmised that, had it not been for the network of public hospitals in Paris who quickly responded by pooling their surgeons and opening redundant operating theatres across the network, the number of critically injured would have rapidly surpassed their surge capacity.³⁰

Gates *et al.* reported failures in the patient identification systems due to the volume of patients arriving at each hospital.³¹ This has also been reported in other papers in mass casualty event planning: a suggested method of circumventing this would be to assign geographical names or colours, in addition to hospital numbers, to unidentified trauma patients.^{31,32}

Communication

Tied in with systems failures, several of the papers noted that communication was suboptimal during the response. In 2013, a car bomb exploded less than two kilometres from the American University of Beirut Medical Centre (AUBMC) in Beirut, Lebanon. Although it is one of the largest medical

facilities in the country, with established mass casualty event plans in place, Sayed *et al.* reported that internal communication systems quickly became overwhelmed. Of particular note, the internal hospital paging system and cellular phones lines hindered staff communication, so that medical personnel resorted to using WhatsApp and other online messaging applications.³³ Furthermore, in their analysis of 17 separate mass casualty events, Turner *et al.* noted that 13 of the 17 events experienced communication failures, ranging from life-threatening inter-agency miscommunications to errors in patient transport and delivery to definitive care.³⁴

Security

One of the priorities in such events is rapid scene control to enable emergency medical personnel to evacuate the injured. Following the explosion at Tianjin, lack of on-scene security may have contributed to the deaths of over 100 fire-fighters as well as many first responders who rushed to the scene prior to a security cordon being set-up.²⁹ Hospitals dealing with the injured also need to take preventative security measures, both in terms of crowd control but also due to the risk of the hospital itself coming under attack.³³ In their analysis of 290 mass casualty events across the world, Turriss *et al.* highlight common reports of failures in crowd control resulting in stampedes.³⁵

Haemorrhage control

In their analysis, Turner *et al.* reiterate that haemorrhage is the leading preventable cause of trauma-related death in mass casualty events; it is estimated to be responsible for 30-40% of fatalities. This analysis notes that the principles of damage control and the prioritisation of catastrophic haemorrhage control should be translated from military to civilian practice.³⁴ In Boston, King *et al.* found that all of the tourniquets used on patients in the pre-hospital setting were improvised, including those applied by emergency medical services.³⁶

- Greater international academic collaboration is needed to produce a standardised, systematic and well validated method of mass casualty event analysis.
- There is a need for a centralised mass casualty event database to guide future responses.
- Regional networks of hospitals and greater interagency collaboration is vital to successful emergency response.
- Increased funding is needed to provide adequate surplus emergency resources, training, back-up communication and computer systems.
- Further research into lessons learned from the military needs to be carried out and implemented.
- Long term studies on the impact of these events focusing on psychological burden and economic impact on healthcare systems need to be conducted.

Box 1: Recommendations.

Research and public education

In one of the few comprehensive systematic reviews on the topic, Timbie *et al.* conclude that there is a paucity of research into preparedness for mass casualty events and recommend further work on establishing a research infrastructure to provide guidance to policymakers.³⁷ This is echoed by Turriss *et al.*, who recommend that a central database be created for all mass casualty events. This would include a standardised reporting format which would provide vital information for future response planning and preparedness.³⁵ Public awareness and education campaigns were also highlighted by Zhang *et al.* who suggest that a model similar to the public preparedness drills from Japan should be adopted to help augment and enhance response in the future.²⁹

Quality analysis

The articles were assessed according to the levels of evidence guidelines from the Oxford Centre for Evidence Based Medicine.³⁸ Due to the difficulty in conducting high level research in this area, there was a lack of high level evidence papers looking at the broader response to mass casualty events.

Timbie *et al.* published a comprehensive systematic review organised around four broad areas; managing demand for less urgent medical services, maximising existing resources, augmenting these resources and implementing crisis strategies. This conceptual framework was based on the guidelines from the Institute of Medicine Committee on Guidance for Establishing Standards of Care for Use in Disaster Situations on adaptive strategies for surge conditions from MCE.^{37,39}

Conclusion

Determining correlations in responses between mass casualty events is difficult. The varied nature of these events, different levels of preparedness and existing environmental conditions all add to the unpredictability of the response. It is clear from the research that lessons can be learned through in-depth analysis of each response. Although there is an abundance of papers describing individual responses, it is apparent that the need for more robust research into mass casualty events is needed. The events of the last five years have demonstrated that there is still a need for a reliable, standardised and validated mass casualty response system. Recommendations for future work in this area are described in Box 1.

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