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Review Article

PREPAREDNESS

Review of the requirements for effective mass casualty preparedness for trauma systems. A disaster waiting to happen?

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Summary

Mass casualty incidents (MCIs) are diverse, unpredictable, and increasing in frequency, but preparation is possible and necessary. The nature of MCIs requires a trauma response but also requires effective and tested disaster preparedness planning. From an international perspective, the aims of this narrative review are to describe the key components necessary for optimisation of trauma system preparedness for MCIs, whether trauma systems and centres meet these components and areas for improvement of trauma system response. Many of the principles necessary for response to MCIs are embedded in trauma system design and trauma centre function. These include robust communication networks, established triage systems, and capacity to secure centres from threats to safety and quality of care. However, evidence from the current literature indicates the need to strengthen trauma system preparedness for MCIs through greater trauma leader representation at all levels of disaster preparedness planning, enhanced training of staff and simulated disaster training, expanded surge capacity planning, improved staff management and support during the MCI and in the post-disaster recovery phase, clear provision for the treatment of paediatric patients in disaster plans, and diversified and pre-agreed systems for essential supplies and services continuity. Mass casualty preparedness is a complex, iterative process that requires an integrated, multidisciplinary, and tiered approach. Through effective preparedness planning, trauma systems should be well-placed to deliver an optimal response when faced with MCIs.

Keywords: disaster preparedness; mass casualty incidents; narrative review; trauma systems; trauma centres

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Editor's key points

- Mass casualty incidents (MCIs) are diverse and unpredictable but preparation is possible and essential. The nature of MCIs requires a trauma response, but this requires effective and tested disaster preparedness planning.
- This narrative review describes the key components necessary for optimisation of trauma system preparedness for MCIs using established WHO guidelines, and considers whether trauma systems and centres meet these components.

Mass casualty incidents (MCIs) are diverse and unpredictable but can be prepared for. Unlike pandemics, where case numbers are low initially and followed by an exponential increase, MCIs commence with a large surge in casualties in a short time frame. MCIs span multiple causes including natural disasters, transport collisions, terrorism, and armed conflicts, and their frequency will increase because of climate change.[1] In 2020, there were 389 natural disasters resulting in 15 080 deaths, 98.4 million people affected, and a global cost of US$171 billion.[2] MCIs are often devastating to communities and have profound mortality and long-term morbidity consequences.

Introduction of organised trauma systems has reduced mortality rates and improved functional outcomes for injured patients.[3–7] Trauma systems are designed to provide an integrated, multidisciplinary, and tiered response (including 24-h capabilities), encompassing the entire patient journey.[8] Learnings from armed conflicts were the precursor to modern trauma systems, embedding the principles necessary for MCI response.[9] Functional trauma systems are critical to regional MCI responses.

Previous authors have shown better MCI preparedness and outcomes where trauma systems are present.[10,11] However, there is wide variability in trauma system design[12]; most have been established to manage routine caseloads and case-mix, with contingency for minor variations. Healthcare and trauma systems, in general, have finite capabilities that can be quickly overwhelmed by MCIs, jeopardising the care of direct casualties of the event, and the health and welfare of the wider community through disruption of usual healthcare services,[11] as illustrated by the severe acute respiratory syndrome-coronavirus 2 (SARS-CoV-2) pandemic. Despite the importance of trauma systems in MCI response, national and multicentre studies describing disaster preparedness of trauma systems and centres are few.[11,13,14] Most publications document individual MCI responses, providing valuable insights into the strengths and weaknesses of local disaster response,[15–32] but limited evidence of uptake of disaster preparedness plans.

In this review, we describe the key components for optimisation of trauma system preparedness for MCIs, whether trauma systems and centres meet these components, and areas for improvement of trauma system response. Guided by the WHO toolkit and checklist,[33,34] the areas of leadership and governance, communication, education and training, safety and security, triage, surge capacity, continuity of essential services and supplies, post-disaster recovery, and the specific requirements for MCIs involving paediatric cases, are covered.

Leadership and governance

Mature leadership structures and governance create the foundation for optimal disaster preparedness.[34] Effective leadership is needed to prioritise disaster preparedness, ensure commitment of adequate resources, and implement relevant, evidence-informed policies, plans, and guidelines. In their survey of US trauma centres, Trunkey and colleagues[11] found that higher levels of funding for emergency preparedness were associated with improved preparedness, highlighting the importance of leadership through investment.

Established leadership frameworks must review disaster preparedness plans to address weaknesses in a timely fashion, ensure simulation drills are performed at regular intervals, and incorporate learnings from these simulations and others' responses to MCIs into preparedness plans.[18,35] Although frameworks, such as the WHO ones, are a useful starting point for leadership structures, they need to be tailored to suit specific trauma, healthcare, and wider disaster system environments. Individual locality plans are required to address threats that are most prevalent to their community and the intricacies of their geography and the community they serve.[14,34] Given the need for region-specific approaches, the focus here is on select examples and whether key components have been enacted or not.

Well-organised leadership and governance committees are crucial for creating a realistic and successful plan. For example, the Israeli Ministry of Health implemented a robust monitoring system that continually assesses the preparedness of its designated trauma centres and uses these evaluations to determine hospital accreditation status. Centres are formally assessed every 2 yr by independent evaluators using an objective measurement tool of parameters and indicators of disaster preparedness.[36] After assessment, missed benchmarks are re-evaluated 3 months later and resulting modifications must be reported to the centre's board and the Ministry of Health.[36] Using this state-run monitoring system, disaster preparedness of Israeli trauma centres has increased.[36] Similar efforts in larger nations have not been replicated. However, trauma centre verification by the American College of Surgeons and the Royal Australasian College of Surgeons includes questions about disaster preparedness. In addition, the US Health and Human Services Assistant Secretary for Preparedness and Response is piloting a Regional Disaster Health Response System as a framework for cooperation between government and non-government agencies for disaster response.[37]

Disaster preparedness leadership can be multi-tiered to reflect national, regional and local responses, and commonly requires dedicated, multidisciplinary disaster preparedness committees. Gabbe and colleagues[13] surveyed major (Level I) trauma centres in Australia, Canada, England, and New Zealand (NZ) to ascertain their level of preparedness for disasters; 84% (n=69) of eligible centres responded. Most (91%) centres had a dedicated disaster preparedness committee. The local trauma director was a member in only 61% of cases, and almost a third of respondents expressed concern about committee representativeness.[13] Notably, this was the second survey of Canadian centres within a decade. Although the

proportion of Canadian trauma centres with a disaster preparedness committee rose from 83% to 100%, trauma director representation had increased from half to 60%.[38,39] Coordination of committees at different levels of response is required, and the WHO recommends that committee members comprise senior managers from operational departments.[34] There is no explicit recommendation for trauma leadership representation. Given the importance of trauma systems in disaster response, this omission could be seen as an oversight. Representation from trauma leadership at each level of disaster planning could improve trauma system integration in the disaster plan and response.

Communication

Efficient, clear, and centralised communication during an MCI response is the 'glue' that ensures seamless enactment of the disaster plan and key aspects of response. Early establishment of pre-defined communication lines should be a priority of the immediate response to an MCI, both within and between organisations.[11,18,20] Construction of a triage communication network that incorporates information from each step in the pathway is crucial, from the first responders at the scene, to the Emergency Medical Services (EMS) transporting patients, to the triage officers at trauma centres.[20] Network integration allows for coordinated triage and reduced likelihood that trauma centres will be overwhelmed.[18,20]

Many advocate for a central communication and operations hub to improve triage decision-making and allow for rapid inter-hospital transfers, or early diversion of transports, in the event that the receiving hospital cannot provide definitive treatment.[20,40,41] Centralised communication should be an existing trauma system feature, as not all trauma-receiving hospitals will provide all services, and communication across the system is needed to best match the patient to the optimal hospital for treatment.[35]

In practice, many trauma systems rely on pre-hospital trauma triage guidelines to direct patient flow from the injury scene. Centralised communication may be limited to inter-hospital transfers of trauma patients, where communication between referral, retrieval, and receiving services is needed. Nevertheless, leverage from these existing communication networks would be critical in MCIs, as effective communication systems are difficult to establish at short notice with interim agreements.[42] Centralised command centres were used after Hurricanes Katrina and Rita,[40] and after the Boston Marathon explosions.[18] Pre-hospital 'commanders', who coordinate with receiving hospitals to establish real-time capacity updates, may improve triage to appropriate destinations. Electronic linkage of medical record systems that demonstrate real-time capacity has also been recommended as a way of improving central command effectiveness.[35]

Notably, in any MCI response, contingency plans must be in place if traditional modes of communication are compromised.[11,43,44] Standard communication networks can be compromised through physical devastation to infrastructure, overloading of existing systems in a time of crisis, and government shutdown of systems in response to an ongoing threat.[43,45,46] Some have resorted to the use of 'runners' – individuals designated to convey information between areas of the hospital – whereas Wi-Fi-based communications were used after the Arena bombing in Manchester when mobile phone communications failed.[47] Given their vulnerability, the need for pre-planned communication strategies that do not depend on mobile and other telephone phone networks is key. Two-way radio, Wi-Fi communication apps, pagers, and satellite phones have been suggested as viable alternatives, whereas provision for 'runners' should also be included as a back-up.

Trunkey and colleagues[11] reported high levels of communication preparedness of US trauma centres; more than 90% reported robust communication strategies that included the presence of non-traditional communication methods. Despite reported high levels of communication preparedness, more recent evidence from drills[48] and real-life incidents[24,49] in the USA suggest that further improvement is warranted. After the Boston Marathon bombings, law enforcement made the decision to shut down cellular phone towers, and hospital staff resorted to landline and pager use.[24] In 2020, a multi-national survey of trauma centres found that 84% reported reliable and sustainable back-up communication options (largely two-way radio and web-based communication) but only 22% had satellite phones.[13] These figures further support the need for improvement on this critical aspect of disaster response. In addition, disaster preparedness plans will need to adapt to the new, and discontinuation of older (e.g. pager networks), technologies.

Education, training, and simulation

Trauma system preparedness for MCIs requires that staff undergo stringent, regular training programmes that ensure competency.[37] Basic emergency management and advanced trauma care skills provide good baseline knowledge for an MCI response.[35] However, training in the management of injuries that may be rarely encountered in usual practice in the civilian context, or encountered commonly but in low volumes (e.g. blast injuries), is needed. Education and training may also include identification of specialists in these injuries, and established means of engagement in a relevant MCI. The engagement of military surgeons in the Manchester Arena bombing provides an example of this approach.[47] Some governments have funded centres to support training, education and response to disasters (e.g. Australia's National Critical Care and Trauma Response Centre [NCCTRC]). Targeted training ensures that, in the event of an MCI, there are personnel with foundational training who can respond immediately. Only 74% of Australian, Canadian, English, and NZ trauma centres surveyed reported the availability of training for staff to prepare for an MCI.[13]

Furthermore, up-to-date records of trained staff are needed in an MCI so that trauma centres can quickly mobilise trained staff into appropriate roles. Gabbe and colleagues[13] found that less than half of major trauma centres surveyed had a database of trained personnel to call upon in an emergency; this was just 15% for Canadian centres.[39] Placing the onus on individual centres to maintain these records is challenging as junior medical staff rotate regularly, and local records may not reflect current staffing allocations. A regional or national approach to training record keeping may better enable rapid mobilisation of trained staff in an MCI.

In addition to staff training programmes, staff should have the opportunity to regularly practise these skills in a simulation environment.[18,47,50] Tabletop drills and simulation games are commonly used,[13,51] are inexpensive, allow for many personnel to complete a drill more frequently, and may be

preferred in low resource settings.[51,52] Repeated paper-based mini-drills have been shown to increase participant knowledge of institutional disaster policy and procedures, potentially improving preparedness for MCIs.[53] Nevertheless, tabletop simulations cannot fully replace real-world multicentre, multi-organisational drills.[48,54]

Large-scale drills commonly include multiple trauma centres, regional hospitals, law enforcement, defence force, and emergency services, and provide a unique opportunity to stress and evaluate existing protocols.[48,54] Real-world exercises can address different scenarios, enabling adaptation to regional or system needs and threats. Real-world exercises can stress a system's resources sufficiently to test disaster response, but require multi-agency collaboration, which can be challenging to organise, and expensive to conduct.[55,56] Previous studies found that real-world exercises identified logistical and knowledge gaps not detected through tabletop exercises, justifying investment in these simulations.[57]

Regular conduct and review of disaster drills and MCI exercises are important for gathering evidence about what does and does not work, and for informing improved procedures.[34,56,57] The definition of 'regular' and the required timing of exercises varies by jurisdiction. No clear consensus exists.[53,57–59] Jurisdictional resourcing and capabilities will likely dictate the choice and timing of disaster preparedness exercises. The Australian AUSTRAUMAPLAN includes no directive about the timing or type of exercises.[58] In contrast, the National Health Service England Emergency Preparedness, Resilience, and Response Framework sets minimum requirements of communications testing every 6 months, tabletop exercises annually, and live and command exercises at least once every 3 yr.[60] Trunkey and colleagues[11] reported that 97% of US trauma centres had conducted tabletop drills or simulation exercises, and 81% had activated their preparedness plan in response to a real event. Conversely, 58% of trauma centres in Australia, Canada, England, and NZ had activated their disaster plan (32% in the past 2 yr); 79% reported conducting a practice drill for an MCI and 48% had completed a multi-agency real-world exercise in the past 2 yr.[13]

Regardless of methodological choice, recommendations outlined as a result of training exercises should be acted upon in a timely way and then tested to ensure that improvements have been effective.[18,53] Skryabina and colleagues[57] found that deficiencies in emergency plans, procedures, resources, and communications identified through simulation exercises were often not integrated into an updated emergency plan. Gabbe and colleagues[13] reported that most (50/52) centres in Australia, Canada, England, and NZ that had undertaken a practice drill had reported the findings, and 80% of the time, the findings were incorporated in the revised disaster plan.

Safety and security

Outside of armed conflicts, trauma centres are not often the direct target of man-made MCIs.[61–63] Where they are, the effect on not only those directly, but also those who subsequently need health services can be profound.[62,63] The ability for a healthcare centre to 'lock down' whether because of a direct threat, or to reduce the number of unnecessary people disrupting clinical activities (e.g. influx of concerned relatives and media),[64] is crucial in ensuring high quality care.[11] As would occur on a ship in response to nuclear or biological hazards,[65] the ability to lock down specific areas is necessary to contain the spread of contamination.[11,66] Departmental-level lockdown can also be used to ensure the safety of staff and other patients in the circumstance where individuals become violent or pose other threats to safety. Maintaining the safety and security of each trauma centre, and possessing the ability to lock down if required, ensures that receiving hospitals can continue to manage the victims of MCIs, and patients already under their care, as efficiently as possible.

Concerns for patient and staff safety were identified as key themes in a qualitative study of the experiences of staff in MCIs in the US.[67] Most trauma centres would have the ability to lock down a facility if required,[13] and this has been confirmed in nationwide and multi-national surveys of trauma centres where 97% of US, and 89% of major trauma centres in Australia, Canada, England, and NZ reported established procedures for lockdown.[11,13]

Triage

The central doctrine of trauma systems focuses on ensuring that every patient arrives at the most appropriate centre in the shortest time possible.[8] Advanced trauma systems have effective triage processes that support this doctrine, which can be leveraged in MCIs. MCIs test trauma system triage processes that are otherwise designed to manage much smaller volumes of critically injured patients.[35] Gabbe and colleagues[13] reported high rates of triage preparedness for MCIs, with 97% of centres in Australia, Canada, England, and NZ having a mass casualty triage protocol that followed internationally accepted principles and guidelines. In large-scale natural disasters such as hurricanes[19,68] and earthquakes,[69] trauma centres in the area of the disaster can be compromised, necessitating transport of a large number of victims to nearby jurisdictions.[11] These types of MCIs demonstrate the importance of both region-wide and multi-region resource management systems.

In general, the mass casualty triage response is completed at two key time points: (1) at the scene when EMS must determine which patients need urgent transfer to hospital; and (2) on hospital arrival, where assessment of haemodynamic status and the need for life-saving treatment in the context of emergency, critical care, and surgical treatment capacity is undertaken.[70,71] Triaging patients in the immediate aftermath of an MCI can be difficult. EMS may be operating in an unsafe environment, and with limited access to reliable information.[72] There is a need to consider the situation as a whole whilst still providing critical medical care to severely injured patients. These EMS largely rely on guidelines and triage tools such as the Modified Physiological Triage Tool when determining the urgency of a patient transfer.[73,74] Of the more than 20 different triage systems for MCIs, there is no clear consensus that any one system is superior to others, although regional or jurisdictional consistency is beneficial for outcomes.[75]

MCIs are generally considered to result in three 'waves' of patients arriving at hospitals.[70,76] The first wave differs most from the normal trauma patient scenario and largely comprises patients who can mobilise themselves to the nearest healthcare centre. These 'walking wounded' are rarely triaged as high priority, but by virtue of their mobility, overwhelm the nearest hospital to the incident.[70] The second wave comprises patients in critical condition, who have been triaged by EMS to require immediate treatment and transport, followed by critical care and urgent surgery. The third wave involves patients,

largely with lower acuity, who are triaged and treated at the scene in a safe area.[70] Triaging strategies and protocols must incorporate common patient flow patterns to ensure appropriate resource allocation.

Seventy-six percent of major trauma centres in Australia, Canada, England, and NZ had a contingency site for receipt and triage of mass casualties. Tracking systems for casualties were present in 75% of centres.[13] Ninety-three percent of US trauma centres reported an identified triage area for MCIs.[14]

Friemert and colleagues[70] suggested a two-phase secondary triage process that involves an initial external receiving area for first categorisation of patients, before in-hospital triage (second phase). This first point of hospital triage ensures the safety of the trauma centre, and acts as a gateway enabling the triage officer within the hospital to deal only with patients with potentially life-threatening injuries.[70] In MCIs that involve a significant number of blunt and penetrating trauma cases, the availability of operating theatres is paramount. Continuous re-triaging of patients is necessary to ensure those requiring life-saving emergency surgery are prioritised over less urgent cases.[77]

Several authors have suggested that the in-hospital triage process should involve a senior trauma surgeon working on the floor of the emergency department.[47,50,70,77] This 'surgeon commander' would be appointed within each centre's emergency plan as a roaming manager and triage officer whose sole responsibility could be to organise the theatre space and triage appropriately[47,77]; 75% of US trauma centres reported they had an identified triage officer.[14] The rationale for this extends from the military experience informing trauma system design and disaster preparedness, and the anticipated needs of patients. In the early stages of a disaster response, patients transferred to theatre will require life-saving interventions; the presence of an experienced trauma clinician whose role is to be in constant contact with the surgeons in the operating theatres (but not operate themselves) has been hypothesised to improve patient flow into theatre and prioritisation of critical patients.[47,70] Overall, whether this is a surgeon or other specialty will vary according to local models of trauma care training and delivery, and this role will likely be performed in conjunction with a senior emergency or trauma care nurse with experience in triage and trauma systems. Once patients are past the surgical and critical care phase, a trauma specialist to coordinate the needs of patients through the remainder of their care, including discharge planning and rehabilitation, has been recommended.[47]

Surge capacity

Despite the perpetual state of preparedness of trauma centres and systems, an understanding of hospital resources necessary for an MCI response is necessary to ensure even distribution of patients and the optimal delivery of care under the circumstances. Communications and command centres require real-time knowledge of the status of key departments in each trauma centre involved, in order to pre-empt and prevent bottlenecks in patient flow.[11]

'Surge capacity' is used to describe the ability of a centre to rapidly increase resource availability (supplies, equipment, personnel, and space) in response to higher than normal patient load,[78] and represents a function of equipment, staffing, and space.[79] Bed capacity alone is insufficient for calculating surge capacity; the rate of arrival of casualties must be considered. Overall, there is little consensus on targeted increases of available resources. In part, this is because resource demand will be highly dependent on contextual factors including the nature of the MCI, casualty types, and specialties required. Figures of 5–35% above normal levels have been considered achievable,[78] whereas computer simulation exercises have suggested that trauma centres adopting disaster plan procedures could accommodate the arrival of four to five critically ill patients per hour without compromising quality of care.[80]

The proportion of patients requiring urgent surgical and critical care, and common bottlenecks, will vary based on the type of MCI. Innovative thinking and planning are needed to maximise surge capacity.[79] Strategies to increase surge capacity include converting non-clinical areas (e.g. lecture theatres, car parks) into treatment spaces,[78] discharging patients with appropriate functional status via reverse triage (i.e. identifying patients where early discharge would have low risk of complications),[75,78,81] cancelling future elective procedures,[24,78] and accessing additional equipment from storage and neighbouring healthcare facilities.[81] The capacity to operationalise surge plans requires that relevant staff can be contacted and are available to respond. Furthermore, tiered and staggered systems should be used to minimise staff fatigue. These requirements reinforce the need for an up-to-date staff list that details relevant capabilities.[71,78,81] More than 70% of US trauma centres reported the capability to stagger staff for 3–4 days.[22]

National and multi-national surveys of trauma centres have identified deficits in surge capacity planning. Fifty-four percent of trauma centres in Australia, Canada, England, and NZ had a surge capacity system that mostly involved tracking total bed numbers, critical care, and emergency capacity.[13] Few centres considered monitoring of staff availability and patient movements.[13] Trunkey and colleagues[11] found that 55% of US trauma centres had protocols in place to ensure that critical staff could be quickly cross-credentialed from nearby centres. Lewis and colleagues,[14] in their study of US trauma centres, reported that 83% of centres had protocols to call on additional staff and 41% had plans in place to provide emergency training.

Provisions and guidelines for increasing surge capacity should be clearly outlined in each centre's disaster preparedness plan.[33] The ability to surge in response to an MCI will differ depending on the pre-existing bed occupancy rate,[40] and surge capacity must be continuously monitored. Clear understanding of a centre's capacity at all stages of care is crucial in reducing mortality and morbidity. Open communication of capacity and requirements with the command centre will ensure appropriate allocation of staff and minimise the potential for overwhelming individual centres.

Continuity of essential services and supplies

A key advantage of using trauma systems and centres for response to an MCI is their perpetual state of readiness.[11] Trauma centres normally operate close to capacity, with an average capability of 3 days of essential supplies.[11] When an MCI occurs, there is need to manage the MCI casualties while continuing to care for existing patients until arrangements for transfer or discharge can be made. This requires an uninterrupted supply of staff, essential services, equipment, supplies, and pharmaceuticals.[11] In MCIs, supply can be compromised because of the high volume of casualties and the need for essential services outstripping usual supply lines. Previous natural disasters have highlighted the vulnerability of supply lines for essential resources and profound delays in restocking.[82,83] The inability to meet demand will compromise the

response and potentially impact on care.[81] As such, predetermined network mutual aid agreements and the capacity for national coordination are important in minimising disruption and improving disaster response.

In the immediate aftermath of an MCI, it is essential that access to water, food, power, and oxygen are secured and that backup arrangements are in place should the primary supply fail.[11] In addition, it is important to ensure that the centre has a large enough stockpile of medical supplies to cater for patients and staff for at least 72 h. Seventy-five percent of trauma centres in Australia, Canada, England, and NZ reported having stock to sustain maximum operations for 72 h[13]; only 42% of US trauma centres reported this capability.[22] Notably, Gabbe and colleagues[13] found that 28% of trauma centres in Australia, Canada, England, and NZ had arrangements for continued resupply for 3 or more days, representing a clear point of vulnerability in an MCI response. Most recently, the SARS-CoV-2 pandemic has exposed the vulnerability of medical supply lines, highlighting the importance of contingency plans and diversified supply lines in disaster situations.[84]

Contingency agreements with suppliers, and inventory monitoring and tracking, are necessary to enable efficient management of resources. In addition, trauma centres will need a designated area to receive and assess the suitability and safety of donated goods. Although most (89%) US trauma centres reported the capacity to track expenditure on essential supplies during an MCI, only 27% had a mechanism for receiving donated goods.[11] This finding was mirrored in the multi-national survey by Gabbe and colleagues,[13] who found that 11% of trauma centres had an established mechanism for accepting donated goods in an MCI.

Maintaining an updated database of staff information, qualifications, and their level of training assists the hospitals not only in the initial surge, but also to ensure adequate staffing for the following days.[13,85] It is also advantageous if centres have contingency plans to accommodate and aid staff to organise their personal affairs, including any necessary support for their families.[11] Only 20–40% of US trauma centres reported this capability.[11] Disaster plans inclusive of contingencies specific to staff care needs would support continuity of care for disaster responses extending beyond a few days.[11]

Post-disaster recovery

Planning for the post-disaster phase is needed to mitigate a disaster's long-term impact on trauma centre and systems operation.[33,86] The WHO recommends a post-action report to hospital administration, emergency managers, and appropriate stakeholders that includes an incident summary, a response assessment, and an expenses report.[33] Eighty-one percent of major trauma centres in Australia, Canada, England, and NZ included the need for a post-action report in their centres' disaster plans.[13] Without a post-action plan, the potential to integrate learnings from a real-world disaster response into updated disaster preparedness plans could be lost.

Staff debriefing and counselling, and employee assistance programmes (EAPs) are recommended in the post-disaster phase. Timely debriefing of staff experiences can contribute to post-action plans and improve future disaster responses.[67] Furthermore, a growing body of evidence describes the physical and mental health toll of healthcare workers who respond to MCIs.[28,87] In their multi-national survey, Gabbe and colleagues reported that 75% of participating trauma centres had a plan for debriefing staff, and there were marked differences between countries with regard to access to EAPs; 88% of Australasian centres, but only 54% of Canadian centres and 36% of centres in England, had EAPs. In addition, injuries sustained in MCIs often result in prolonged treatment requirements and mental health needs of patients.[28] Learnings from hospital responses to the SARS-CoV-2 pandemic could drive improved emotional and psychological support initiatives in MCI responses.[88]

Trauma centre preparedness for MCIs involving children and adolescents

Trauma and MCIs involve all age groups. Paediatric patients represent specific and unique challenges, including different patterns of injury and recovery, and the need for age-appropriate treatment and equipment that may not be readily available in all centres.[89–91] Mature trauma systems have integrated paediatric-specific guidelines, and designated paediatric trauma centres, with an attributable survival benefit for children and adolescents.[90,92]

Despite paediatric patients featuring significantly in MCIs,[47,93,94] most research has investigated the disaster preparedness of trauma centres in the adult setting. Paediatric patients have been considered at increased risk of adverse outcomes because of their anatomy and physiology.[93] In an MCI, the low number of specialised paediatric trauma centres, combined with the challenges of patient triage in a disaster, may contribute to poorer outcomes in this group.

Assessing and improving preparedness to receive severely injured paediatric patients in an MCI has been highlighted in numerous government and institutional reports,[93,95] yet many trauma centres report a lack of provision for the treatment of paediatric patients in their disaster plans and insufficient training of their employees to equip them to respond to an MCI with severely injured children.[96–98] Evidence regarding the availability of specialist paediatric staff in the event of an MCI is limited. Mortamet and colleagues[99] reported that a high proportion of French trauma centres had paediatric surgeons and anaesthetists on-call. However, details regarding the number and level of training of these paediatric specialists were limited, potentially jeopardising the true paediatric surgical capacity for MCI response.[99]

Child-specific psychosocial factors must also be considered in in any MCI response involving paediatric casualties.[100,101] Children are at increased risk of post-traumatic stress disorder after an MCI,[101] and this should be reflected in system-wide disaster preparedness plans.[93,102] Children may be overwhelmed by a disaster, unable to follow evacuation instructions, and even afraid of emergency services, highlighting the importance of keeping children and parents together where possible.[93] Early reunification of children and their families has been demonstrated to positively impact on survival, reduced healthcare costs, and reduction of systemic bed block.[103] Co-location of adult and paediatric trauma centres has been highlighted as a positive with this challenge in mind.[47] Co-location of hospital facilities in the aftermath of the 2017 Manchester bombings allowed for parents and children to be treated in the same ward at the Royal Manchester Children's Hospital, reducing child and parent anxiety.[47]

Conclusions

Mass casualty preparedness is a complex, iterative process that requires an integrated, multidisciplinary, and tiered

approach. The nature and unpredictability of MCIs require a trauma system response, highlighting the importance of established and effective disaster preparedness planning. Overall, for trauma systems to provide an optimal response to MCIs, strong representation from trauma leaders at all levels of disaster preparedness planning will be needed.

Authors' contributions

Conception and design of the manuscript: all authors:
Acquisition of manuscripts for inclusion: BJG, WV, AM
Drafting of the manuscript: BJG, WV
Critical revision of the manuscript for important intellectual content and approval of the final version to be published: all authors.
All authors agree to be accountable for the work, ensuring that questions related to the accuracy and integrity of any part of the work are appropriately investigated and resolved.

Declarations of interest

The authors have no conflicts of interest to declare.

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