



Global health, global surgery and mass casualties: II. Mass casualty centre resources, equipment and implementation

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ABSTRACT

Trauma/stroke centres optimise acute 24/7/365 surgical/critical care in high-income countries (HICs). Concepts from low-income and middle-income countries (LMICs) offer additional cost-effective healthcare strategies for limited-resource settings when combined with the trauma/stroke centre concept. Mass casualty centres (MCCs) integrate resources for both routine and emergency care—from prevention to acute care to rehabilitation. Integration of the various healthcare systems—governmental, non-governmental and military—is key to avoid both duplication and gaps. With input from LMIC and HIC personnel of various backgrounds—trauma and subspecialty surgery, nursing, information technology and telemedicine, and healthcare administration—creative solutions to the challenges of expanding care (both daily and disaster) are developed. MCCs are evolving initially in Chile and Pakistan. Technologies for cost-effective healthcare in LMICs include smartphone apps (enhance prehospital care) to electronic data collection and analysis (quality improvement) to telemedicine and drones/robots (support of remote regions and resource optimisation during both daily care and disasters) to resilient, mobile medical/surgical facilities (eg, battery-operated CT scanners). The co-ordination of personnel (within LMICs, and between LMICs and HICs) and the integration of cost-effective advanced technology are features of MCCs. Providing quality, cost-effective care 24/7/365 to the 5 billion who lack it presently makes MCCs an appealing means to achieve the healthcare-related United Nations Sustainable Development Goals for 2030.

INTRODUCTION

Progress toward the United Nations (UN) healthcare-related Sustainable Development Goals (SDGs) for 2030 requires addressing acute conditions (injury, complicated childbirth, acute abdomen) and non-communicable diseases (neoplasia, cardiovascular events, musculoskeletal disorders).¹ Progress towards those SDGs also requires

Summary box

- Low-income and middle-income country (LMIC) healthcare is frequently resource-poor (government sector), costly beyond the means of the populace (private sector) and fragmented (civilian vs military vs private sector).
- Cost-effective technologies (smartphones, digital data collection and analysis, cost-effective and resilient medical devices) can greatly enhance LMIC healthcare delivery.
- National Surgical, Obstetric and Anaesthesia Plans (NSOAPs) are providing a structure for LMICs to achieve the healthcare-related United Nations Sustainable Development Goals for 2030.
- Adapting the trauma/stroke centre model (from prevention to prehospital care to acute and critical care to rehabilitation) for an LMIC—together with collaboration between LMIC and HIC medical personnel—reduces morbidity and mortality during both daily and mass casualty disaster situations.
- A global Mass Casualty Centre network provides the co-ordination, integration and standardisation in healthcare delivery, personnel training, data collection and research that are essential to achieve both NSOAPs and United Nations Sustainable Development Goals for 2030.

addressing the morbidity/mortality resulting from the healthcare infrastructure failure and delayed response that accompany mass casualty disasters—whether natural (earthquakes, hurricanes, floods) or man-made (building collapse, transportation accidents, terrorist events). These issues are particularly prominent in low-income and middle-income countries (LMICs)—where the majority of the 5 billion people who lack basic surgical care reside.

Over half the deaths and roughly 40% of the disease burden in LMICs are the result of conditions treatable with prehospital and

emergency care.² In preparation for the 72nd World Health Assembly (Geneva May 2019), the WHO Director-General published a report affirming the importance of the emergency care system for global health (for both daily healthcare and mass casualty events)³:

The emergency care system... extends from care at the scene through transport and emergency unit care, and it ensures access to early operative and critical care when needed... Implementing community-based education and first-aid training, certification for prehospital providers and 24 hours availability of emergency unit services at first-level hospitals save lives and maximize the effectiveness of later interventions. Well-organized emergency care is therefore a key mechanism for achieving a range of SDG targets, including those on universal health coverage, road safety, maternal and child health, noncommunicable diseases, infectious diseases, disasters and violence... Besides meeting the everyday health needs of the population, a well-organized, prepared and resilient emergency care system has the capacity to maintain essential acute care delivery throughout a mass event... Everyday emergency care systems are an essential substrate for effective emergency response.³

Mass casualty centres (MCCs) address both acute healthcare conditions and healthcare infrastructure failure in disasters (and ‘routine’ power outages)⁴ by providing resilient and mobile 24/7/365 healthcare that is an integral part of the ongoing healthcare system. The rationale for MCCs—an extension of the trauma/stroke centre model established decades ago in high-income countries (HICs)—is presented in the companion article (Khan T, Quintana L, Aguilera S, *et al.* Global health, global surgery and mass casualties: I. Rationale for integrated mass casualty centres in *BMJ Global Health*).

Progress towards universal health coverage requires addressing both the full continuum of care and the breadth of resources necessary to provide that care. The MCC concept incorporates prevention, prehospital care, acute and critical care, and rehabilitation. The breadth of resources includes the personnel (physicians, dentists, nurses, allied health professionals, administrators, biomedical support staff, information technologists) and the equipment (from self-contained mobile operating rooms and critical care units to data collection and analysis platforms to telemedicine resources to robots and drones) required to impact healthcare significantly. The UN Office for Disaster Risk Reduction (DRR) has

published a guide for implementing the Sendai Framework for DRR, including a checklist that in essence describes the MCC concept.⁵

This article presents aspects of the personnel and equipment of the MCC concept, and requirements for implementation. Progress on the initial MCC models in Peshawar (Pakistan) and Iquique (Chile) is described. Although not exhaustive, sufficient detail is presented to demonstrate that MCCs are a practical and cost-effective strategy towards the healthcare-related SDGs for 2030.

PERSONNEL AND TRAINING

Half of the global healthcare workforce consists of nurses and midwives (hereafter considered jointly as ‘nurses’), and they are involved in 90% of contacts between patients and health professionals.⁶

Nurses

Nurses are crucial to expanding high-quality healthcare across the continuum from prevention to follow-up care.³ They are ubiquitous in all aspects of healthcare—from prevention and patient education to acute hospital care to rehabilitation and home care to palliative and hospice care. Nurses provide direct care and are also the mainstay of patient education—roles from teacher to treatment provider to social worker⁷:

... nurses have especially crucial roles to play in health promotion and health literacy... nurses are uniquely placed to act as effective practitioners, health coaches, spokespersons, and knowledge suppliers for patients and families throughout their life course.⁷

Nurses are critical to disaster response teams, such as the WHO Emergency Medical Team (WHO EMT), the Australian Medical Assistance Team (AUSMAT) and the Disaster Medical Assistance Teams (DMATs) of the National Disaster Medical System in the USA.^{8–11} DMATs nurses provide care for state and local healthcare systems during a disaster; staff both fixed and temporary medical sites, are self-sufficient for at least 72 hours and can provide support for up to 2 weeks.¹¹

Training for mass casualty disasters

The programmes noted above—WHO EMT and AUSMAT (introduced in the companion article)—are examples of detailed programmes to train healthcare professionals for mass casualty disasters. WHO EMT has a 54-page publication “Minimum Technical Standards and Recommendations for Rehabilitation for Emergency Medical Teams”¹²; AUSMAT and its partner National Critical Care and Trauma Research Centre in Darwin include firefighters among their personnel, and courses such as “Emergency Management of Severe Burns” in their training programmes.⁸ A broad range of personnel is involved in mass casualty response.

Twinning or dyads

Twinning (or dyads) is one technique for ongoing training between HIC and LMIC healthcare personnel.^{13–16} The

Table 1 Estimated deaths from cyclones/typhoons in South and Southeast Asia

Name	Country	Date	Maximum wind speed (km/h)	Estimated deaths
Nargis	Myanmar	Apr 2008	215	~140 000
Phailin	India	Oct 2013	260	<50
Haiyan	Philippines	Nov 2013	315	~7000

(references)^{23 48–50}



(reference 31)

Figure 1 Map of Albania telemedicine programme.

Foundation for International Education of Neurological Surgery pairs an LMIC healthcare training institution with an HIC institution.¹⁵ European and North American programmes have twinned with programmes in Africa, Central and South America, and Southeast Asia, among other regions. The Operation Giving Back programme of the American College of Surgeons has partnered 13 general surgery training programmes in the USA with Hawassa University in Ethiopia, sharing faculty and in-training personnel to improve the number and quality of general surgeons throughout sub-Saharan Africa.^{16 17} Twinning between HIC and LMIC training institutions increases efficiency and encourages global training standards. MCCs can serve as additional sites for HIC-LMIC

twinning interaction, resulting in improved quantity and quality of healthcare personnel globally.

INFORMATION TECHNOLOGY

Data collection and analysis

Only when accurate data are available on (1) the patient's condition prior to care, (2) the care delivered, (3) the resources used and (4) the long-term outcomes can one begin continuous quality improvement.¹⁸ Large healthcare systems that have created sophisticated healthcare data collection and analysis programmes include the National Health Service in the UK and the Kaiser Healthcare System in the USA. The varying resources



B. Left – Portable CT-equipped operating room. Right – Mobile CT-equipped clinic. (references 32 & 33)

Figure 2 (A) Reconstruction—battery-equipped CT scanners. (B) Mobile CT-equipped facilities.

and needs at different MCCs around the world require a nimble and adaptable system—one where data collected at various MCCs can be compared. Diverse locations of MCCs permits cost-effective and quality-effective techniques arising at one MCC to be exported to other MCCs. Learning effective healthcare solutions from LMICs has been published by author NC.^{19 20}

One example of comprehensive data collection and analysis is the electronic health ('e-health') system established at Westchester Medical Center, New York Medical College, near New York City, USA.²¹ By providing rich operational data (eg, through timestamps), data collected at every step of the patient's involvement in the healthcare system allow identification of bottlenecks, gaps and redundancies—and options for improvement of outcomes. Such data lead to conservation of limited healthcare resources, for example, identification of patients who can be safely treated in an intermediate rather than a critical care unit (CCU).²¹ A recent commentary addresses the need for affordable critical care in LMICs.²²

Telemedicine

Telemedicine benefits for healthcare include

- Extension of healthcare both geographically (through consultations to remote clinics) and temporally (through staffing during nights and other times of reduced specialist resources).
- Immediate dissemination of information during both disasters and routine care.

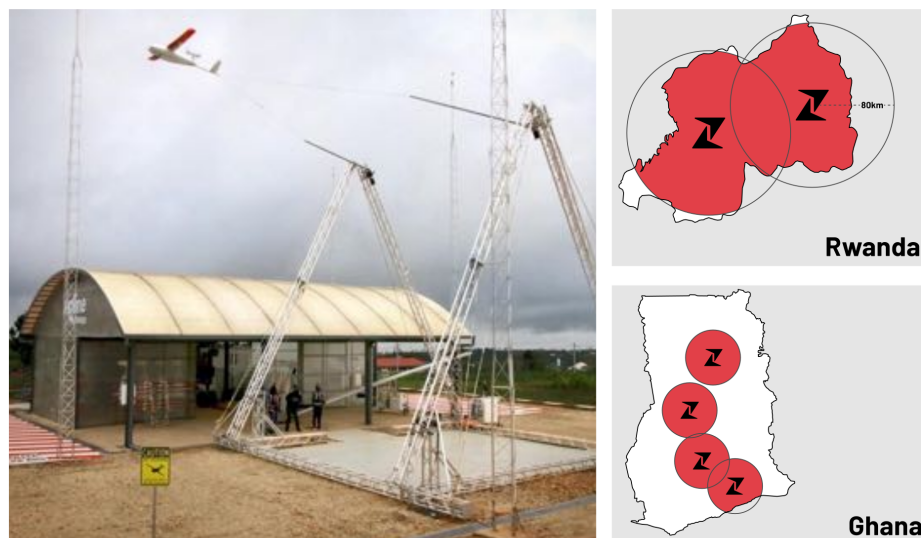
- Augmentation of resources (eg, experts as virtual surgical assistant for complex surgeries).

In disasters with a warning—such as hydrometeorological events (cyclones/hurricanes/typhoons and tsunamis)—a basic but resilient telemedicine system can be life-saving. One significant factor for the modest loss of life from Cyclone Phailin was the 31 telemedicine stations in the Indian state of Odisha: communication allowed the co-ordinated, timely evacuation of 1.3 million people to 600 storm shelters (table 1).²³

State-of-the-art data collection and analysis goes hand-in-hand with telemedicine, including CCU settings. The value of tele-CCU programmes has been documented.^{24 25} Another telemedicine application for enhancing 24/7/365 resource availability is teleultrasound.²⁶ Ultrasound is an imaging modality more widely available in LMICs than more costly modalities, for example, CT and MRI. Teleintensivists can supervise healthcare personnel (including nurses)—who may have only modest ultrasound training—to perform basic ultrasound examinations.²⁶

Telemedicine has been integrated into programmes for mass casualty disaster response: for example, since 2013, the North Atlantic Treaty Organization, under the Science for Peace and Security Programme, has been developing a Multinational Telemedicine System for disaster response.²⁷

Country-wide telemedicine programmes have been developed by the founder of the International Virtual



Left – drone launch centre in western Rwanda. Right – map of Zipline centres in Rwanda and Ghana. (reference 39)

Figure 3 Zipline drone delivery of medical resources in Africa.

e-Hospital (author RL). Both emergency and non-emergency care in Albania, Cabo Verde, Kosovo, the Philippines and Vietnam have benefited. A teleconsultation service to optimise neurotrauma care in Albania—where the only neurosurgical resources are in the capital, Tirana—has been implemented (figure 1).²⁸ From 2014 to 2018, 590 patients had teleconsultations for neurotrauma—with a median response time of 20 min. Two-thirds of the patients could be managed at the local centre, avoiding costly transfer of many patients by ambulance or helicopter to the National Trauma Centre in Tirana.²⁸

EQUIPMENT

Resilient mobile imaging and surgery

Although ‘resilient’ is usually considered the ability to withstand catastrophic insults (such as earthquakes or storms), in many LMICs emergency care is frequently disrupted by events like electrical power outages. The association between power outages and a pregnant woman delivering in a healthcare institution versus at home was investigated for Maharashtra, India.⁴ With the average number of power outages—8.5 per month—the odds of delivering at home rather than in a healthcare facility increased 18%; that is, each additional power outage resulted in 2% greater chance of a delivery at home.⁴

In LMICs, electrical power outages disrupt emergency surgery and critical care equipment (eg, ventilators) and likely also deter the populace from using those healthcare facilities:

We speculate... that power outages directly affect women’s decisions to seek care: a woman may decide to stay at home if there is an outage but without any knowledge of how long the power outage may last.⁴

Battery-powered CT scanners—both head and body versions—can address both power outages at fixed facilities (hospitals) and mobile imaging needs at remote sites (figure 2).²⁹ Mobile, self-sufficient, surgical field hospitals, equipped with such a battery-powered CT scanner, have also been developed (figure 2).^{29 30} A ground ambulance can be retrofitted with a head CT scanner (cost US\$175 000) for US\$10 000 or less. Such mobile CT ambulances have enhanced trauma/stroke care in HICs—from Berlin to Cleveland.

The Lancet Commission on Global Surgery 2030 estimated that lost gross domestic product in LMICs due to injury and neoplasia will exceed US\$1 trillion per year by 2030, neoplasia costs exceeding injury.³¹ Body CT-equipped vehicles—mobile imaging clinics—have been developed for lung cancer screening (figure 2).²⁹ Imagine a mobile diagnostic vehicle (CT, ultrasound, laboratory) making daily trips to different regions of a country to perform dozens of diagnostic studies per day; those individuals with findings indicating additional evaluation or treatment (eg, MRI scan, surgery) could have timely follow-up at a (perhaps distant) tertiary facility.

Robots and drones

Robots and drones (unmanned aerial vehicles) for disaster response are being developed by academic institutions, commercial entities, governmental institutions and militaries worldwide.³² The Center for Robot-Assisted Search and Rescue, headed by Professor Robin Murphy at Texas A&M University, has extensive experience with drones and robots for emergencies.³³ ‘Smart’ drones—equipped with sophisticated sensors such as thermal imaging and laser-induced distance and ranging—can identify the living buried under rubble. Robots can improve both land and water rescue (eg, identification and retrieval of flood or building collapse victims). Combining such



(reference 47)

Figure 4 Seizario smartphone app for immediate geographical localisation and emergency response notification.

drones and robots with a dispatcher wearing virtual reality goggles allows optimal triage of disaster response resources through constant updates of disaster scenes.

Drones can provide prompt delivery of medical resources, from vaccines and antibiotics to blood and laboratory tests to devices such as defibrillators.^{34 35} Zipline uses battery-powered drones to deliver blood products, vaccines, and so on, across Rwanda and Ghana (figure 3).³⁶ The benefit (time savings) of defibrillators transported by drone to a cardiac arrest victim has been documented.^{37–40}

IMPLEMENTATION

Prevention

Community education programmes such as ThinkFirst and Pense Bem stress the negative consequences of risky behaviour. ThinkFirst, begun in the USA (1986) to educate school-age children, now has approximately 130 chapters across the USA and 40 international chapters from Algeria to Taiwan.⁴¹ Pense Bem (“Think Well”)—begun in Brazil (1995) and modelled after ThinkFirst—has been integrated into the Brazilian school system and now reaches approximately 20% of all school-age children in Brazil.⁴² In Peshawar, author TK began a community education injury prevention programme over 20 years ago; Peshawar’s ThinkFirst programme received the ThinkFirst 2019 International Chapter of the Year Award.

Such injury prevention programmes—from risky behaviour of pre-teens to dangerous driving habits to domestic and other violence—are an integral part of the MCC project.

Transport from injury scene to definitive care

Methods used in HICs—ambulances with trained EMTs (and helicopters where feasible)—are integral to MCCs. Training follows the examples of the WHO EMT Initiative and AUSMAT.^{8 9} In Peshawar, a ground ambulance service with trained EMTs was begun in May 2017.

MCCs in LMICs can introduce novel techniques to improve prehospital care, two of which are presented below.

To decrease the high maternal mortality ratio of 583 per 100 000 population in western Kenya, a mobile phone-based, 24/7 Uber-like transport system was developed to improve the number of antenatal and postnatal care visits and reduce the time to health facility for delivery.⁴³ Personalised and interactive text messages and the transport system improved the odds of receiving at least four antenatal and four postnatal care visits fourfold to fivefold. Another benefit was enhanced community involvement: local transport vendors (largely Uber-like motorcycle operators) became aware of the benefit of prompt and continuing maternal and neonatal care.

Seizario is a smartphone app for persons with epilepsy (figure 4).⁴⁴ The app immediately notifies others (family, healthcare personnel) that the patient is having a convulsive seizure (detected by the accelerometer) and provides the victim’s location (through the global positioning system—GPS). Such an app can be expanded to detect persons involved in various injuries, from falls by the elderly to road traffic accidents to gun violence. Using the accelerometer and GPS smartphone capabilities, the location of the injured victim(s) can be immediately transmitted to emergency personnel. By having taxi, mini-bus and school-bus drivers, ambulance personnel and others have a smartphone with this app at all times when ‘on the job’—and encouraging others at high risk to do so as well (the elderly, law enforcement personnel, those working in dangerous construction sites)—the time from injury to treatment can be markedly reduced, and thus outcomes significantly improved.

Acute care

Optimisation of acute care in LMIC settings is a topic worthy of book-length documentation. One aspect of MCCs is the integration of telemedicine into ongoing



Stakeholders Conference

November 15-16, 2018 Islamabad, Pakistan

- **Sensitized key stakeholders** (provincial, government, private, associations, professional bodies, children focus)
- Promoted the need for **Situational Analysis** for concrete data
- Decision to pass **Consensus Statement** and to work on **NVSC2025 document**
- Formation of the **steering committee** to provide strategic direction



(courtesy of author HS)

Figure 5 Pakistan's national health vision 2025 programme.

24/7/365 care from CCU teleintensivists to remote clinics, as discussed above.

Rehabilitation

By developing minimum technical standards and recommendations for rehabilitation, WHO has acknowledged the importance of rehabilitation for disaster response.¹² In Peshawar, rehabilitation has been an integral part of healthcare: cost-effective rehabilitation is a goal of the MCC project.

MCC PROGRESS

Progress: Iquique

In Chile, communication with and support from the Chilean Ministry of Health for the MCC concept was established by author LQ. Author SA held an initial conference regarding an MCC in Iquique in 2018—bringing together the local health authorities, the Chilean military (Chilean Air Force Base in Iquique) and the Chilean Emergency Response Ministry (ONEMI). Follow-up meetings were arranged with (1) the Chilean Ministry of Health (April 2019) and (2) the Naval Hospital Director (October 2019).

Progress: Peshawar

Over the past decade in Peshawar, author TK has opened two hospitals, a medical school (100 students per year), a nursing school (50 students per year) and allied health professions programmes. Author TK thus has had long-standing interactions with local, provincial and national Pakistani health authorities. A community-based trauma prevention programme (now including ThinkFirst) has evolved over the past two decades. A ground ambulance service began in May 2017. The Pakistani Military Commander in Peshawar has expressed support for integration of civilian and military medical resources for the MCC in Peshawar in a series of meetings, most recently in November 2019. Several coauthors are facilitating MCC participation in Pakistan's National Health Vision 2025 programme, which includes a National Surgical, Obstetric and Anaesthesia Plan and a National Vision for Surgical Care (NVSC) (figure 5).

CONCLUSION

Recent publications on the need to expand surgical resources in LMICs to meet the UN SDGs for 2030 raise the question of implementation.^{31 45–47} MCCs offer the benefits of trauma/stroke centres for both mass casualty response and ongoing day-to-day healthcare in the region

served. MCCs incorporate innovations—technical and personnel—from both LMICs and HICs. From smartphones to telemedicine, MCCs in LMICs take advantage of new technologies, potentially without the burden of legacy healthcare infrastructure. Standardisation of advanced data collection and analysis across MCCs—both clinical and research—produces the ‘big data’ necessary for evidence-based global healthcare. Twinning MCCs in LMICs with medical centres in HICs creates two-way interactions in patient care, research and healthcare education. Over time, this permits standardisation of treatment, training and licensure across national boundaries.

In summary, MCCs address the goals set by the WHO Director-General for emergency and trauma care as well as the criteria of the checklist for implementation of the Sendai Framework for Disaster Risk Reduction.

With only a decade remaining to reach the 2030 SDGs, feasible and concrete programmes are needed to advance global healthcare. MCCs are a practical way to achieve the healthcare-related SDGs for 2030.

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