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Global health, global surgery and mass casualties. I. Rationale for integrated mass casualty centres

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ABSTRACT

It has been well-documented recently that 5 billion people globally lack surgical care. Also well-documented is the need to improve mass casualty disaster response. Many of the United Nations (UN) Sustainable Development Goals (SDGs) for 2030—healthcare and economic milestones—require significant improvement in global surgical care, particularly in low-income and middle-income countries. Trauma/stroke centres evolved in high-income countries with evidence that 24/7/365 surgical and critical care markedly improved morbidity and mortality for trauma and stroke and for cardiovascular events, difficult childbirth, acute abdomen. Duplication of emergency services, especially civilian and military, often results in suboptimal, expensive care. By combining all healthcare resources within the ongoing healthcare system, more efficient care for both individual emergencies and mass casualty situations can be achieved. We describe progress in establishing mass casualty centres in Chile and Pakistan. In both locations, planning among the stakeholders (primarily civilian and military) indicates the feasibility of such integrated surgical and emergency care. We also review other programmes and initiatives to provide integrated mass casualty disaster response. Integrated mass casualty centres are a feasible means to improve both day-to-day surgical care and mass casualty disaster response. The humanitarian aspect of mass casualty disasters facilitates integration among stakeholders—from local healthcare systems to military resources to international healthcare organisations. The benefits of mass casualty centres—both healthcare and economic—can facilitate achieving the 2030 UN SDGs.

Summary box

- Globally, 5 billion people lack surgical care, resulting in one-third of all deaths, with lost gross domestic product (GDP) exceeding US$1 trillion by 2030.
- Disasters (both natural and man-made) typically result in 100 000 or more deaths per year, many of which could be avoided with improved emergency care.
- Trauma/stroke centres evolved in high-income countries (HICs) when it became clear that 24/7/365 healthcare resources greatly reduced morbidity and mortality from trauma and other emergency conditions.
- Integration both of civilian and military emergency healthcare resources, and of HIC and low-income and middle-income healthcare personnel, improves response, reduces duplication and expands cost-effective quality healthcare.
- Mass casualty centres combine the trauma/stroke centre model with integration of healthcare personnel, technology and equipment to improve both daily and mass casualty care.
- Mass casualty centres are a practical and cost-effective mechanism to achieve the healthcare-related United Nations Sustainable Development Goals for 2030.

INTRODUCTION

Although global healthcare advances to date have been primarily due to sanitation, mosquito nets, vaccines and antibiotics, expansion of surgical services in low-income and middle-income countries (LMICs) is presently a major need.[1–6] More deaths result from lack of surgery than from HIV/AIDS, tuberculosis or malaria by a factor of 10. The Lancet Commission on Global Surgery 2030 and other recent publications document the need for—and benefit from—addressing conditions that depend on surgery.[1–6] In addition to trauma, surgery is essential to reduce morbidity/mortality from non-communicable diseases (NCDs) and other conditions—ranging from cancer to childbirth (caesarean section, congenital malformations) to ageing (cardiovascular, neurologic, orthopaedic conditions).

If one questions the cost to improve global surgical resources, the data argue we cannot

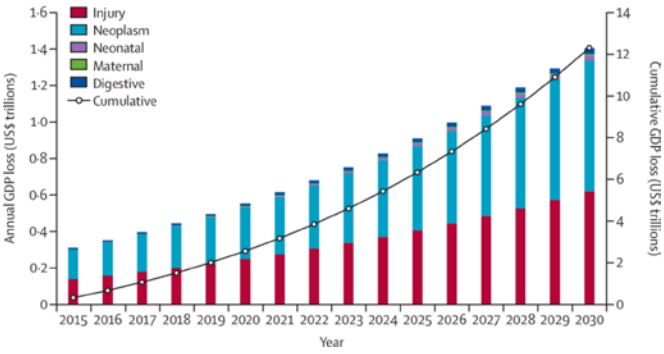

Figure 1 Annual and cumulative gross domestic product (GDP) lost in low-income and middle-income countries from five categories of surgical conditions. Data are based on WHO's Projecting the Economic Cost of Ill-Health (EPIC) model (2010 US$, purchasing power parity). Adapted from Meara *et al*.[5]

afford *not* to invest in such resources. The cumulative gross domestic product (GDP) lost in LMICs over the next 10 years if we do not address the morbidity/mortality of injuries and neoplasia in particular will be trillions of US dollars (figure 1).[7] The worldwide economic loss in 2010 alone due to surgical conditions is staggering: over US$11 trillion in mortality and over US$3 trillion in morbidity.[6] Annual economic losses from surgical conditions are greater in high-income countries (HICs) than in LMICs: 18% vs 13% equivalent percentage of GDP (figure 2).[6] In both HICs and LMICs, healthcare costs are the primary cause of bankruptcy and poverty, respectively.[6]

A recent study analysing deaths from acute abdominal conditions and geographical access to surgery across India mapped the age-standardised death rates and high-mortality and low-mortality clusters.[8] Low-mortality clusters were more likely than high-mortality clusters to be closer to well-resourced district hospitals (ie, those with 24 hours surgery/critical care); this was not true for proximity to district hospitals with only basic resources.[8] The authors conclude:

> "Full access to well-resourced hospitals within 50 km by all of India's population could have avoided about 50 000 deaths from acute abdominal conditions, and probably more from other emergency surgical conditions."

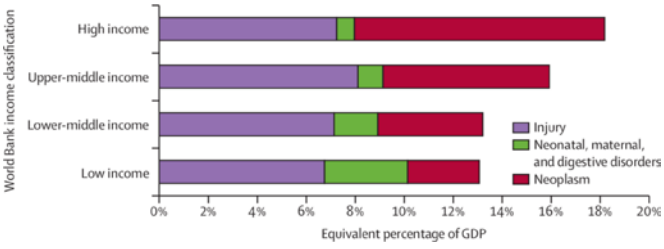

Figure 2 Annual economic welfare losses secondary to surgical disease, expressed as equivalent percentage of gross domestic product (GDP), by World Bank income classification, value of lost welfare approach. Adapted from Alkire *et al*.[6]

Similar geographic information system data—together with women's perceptions regarding quality of care available—have been used to argue for improved access to appropriate levels of emergency obstetric services in Mozambique.[9]

Given the cogent humanitarian and economic arguments for universal health coverage (UHC)—including both financial risk protection and universal access to essential surgical care—the question remains:

> "How do we implement surgical care for those - the majority of the world's population - who do not currently have it?"

We propose a practical option for expanding surgical care worldwide, particularly in LMICs. This option leverages the universal humanitarian response evoked by a disaster to benefit both mass casualty disaster response as well as day-to-day healthcare by providing 24/7/365 surgical services.

The morbidity/mortality, plus the social and economic consequences, of natural disasters have been well documented.[10] Immediately following the 2010 Haiti earthquake, 20 000 people died daily who could have survived had basic surgery been available.[11] Injuries such as soft-tissue wounds, long bone fractures, abdominal, brain and spine trauma are all amenable to emergency surgery. Natural disasters —both geological (earthquakes, volcanoes) and hydrometeorological (hurricanes, floods)—and man-made disasters (transportation/infrastructure failure, terrorism) can destroy the medical infrastructure, making the only option importation of outside healthcare resources. WHO recognised the benefit of local healthcare response for mass casualty disasters[12]:

> "…the most timely and cost effective response to trauma is the one mobilised by the affected country itself…"

Mass casualty disaster response currently requires days to weeks before healthcare personnel are on-site. Some countries such as Israel and Chile have emergency response ministries that can quickly devote military emergency medical resources to disasters affecting civilians. Most countries, however, depend on international organisations (United Nations (UN), WHO), and non-governmental organisations (NGOs, eg, International Committee of the Red Cross (ICRC), Médecins Sans Frontières (MSF)). None of these organisations can deploy to a mass casualty site on a moment's notice. Bureaucratic approvals and lack of on-call personnel make such a belated mass casualty disaster response of minimal benefit for acute care. As seen in Haiti, medical personnel arriving days to weeks after the event result in massive numbers of victims who die or suffer permanent injury unnecessarily.

Following the 2008 Wenchuan earthquake, over 68 000 people died and 374 000 people were injured.[13] The closest functioning hospital to the epicentre—the People's Hospital of Deyang City (1200 beds, with surgical subspecialty resources)—treated approximately 1900 patients over the 3 weeks following the earthquake.

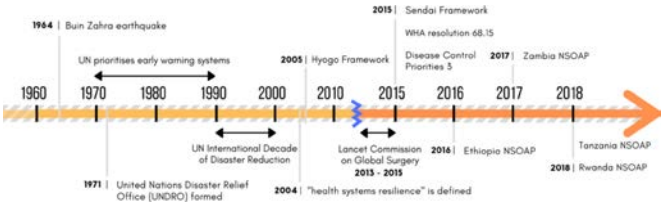

Figure 3 Timeline of key events in disaster management and global surgery policy since 1960. NSOAP, National Surgical, Obstetric and Anaesthesia Plan; UN, United Nations; WHA, World Health Assembly. Adapted from Pyda *et al*.[14]

It is estimated that the disability-adjusted life years (DALYs) loss totalled >10 000. The cost of DALYs lost (US$36.1 million) was reduced by US$15.2 million (42%) because of the surgical interventions.

Using the National Surgical, Obstetric and Anaesthesia Plan model, the 24/7/365 resources required for both emergency medical/surgical conditions and resilient mass casualty disaster response can be provided in LMICs. The parallel nature of key events in global surgery and disaster management since 1960 is illustrated in figure 3.[14]

Mass casualty disasters evoke a universal humanitarian response: government organisations and NGOs (both within country and across countries)—often at odds for economic, cultural or political reasons—unite for mutual aid in a disaster. The humanitarian response to disasters can catalyse change to benefit global health (and global economics) far beyond the welfare of the disaster victims themselves.

A network of mass casualty centres (MCCs) is a mechanism to achieve the UN healthcare-related Sustainable Development Goals (SDGs) for 2030.

MASS CASUALTY CENTRES

Trauma/stroke centres evolved decades ago in HICs with evidence that having personnel available 24/7/365 improved morbidity/mortality from trauma and strokes.[15–18] Leaving emergency care to the whims of the clock and the calendar—immediate care during weekday working hours (when personnel were in hospital), but care delayed for hours or longer on nights, weekends or holidays (when personnel were not in hospital or 'on call')—resulted in unacceptable morbidity/mortality during 'non-business' hours.

The wider value of a trauma centre system has been appreciated[19]:

> "A trauma system encompasses the entire spectrum of services that a country or region has in place: prehospital care, initial emergency care, definitive hospital care (care provided after initial resuscitation to definitively treat injuries), and long-term rehabilitation of injured survivors. It also encompasses the information systems needed to monitor and ensure quality of care along this spectrum."

The argument for providing immediate care to mass casualty victims is the same as for providing immediate care to a single victim:

> "Why should a person be penalised for being a mass casualty rather than an individual casualty – merely because the number of victims overwhelms the emergency response system, or the disaster itself (by earthquake, flooding, or bombing) has incapacitated the healthcare infrastructure?"

In many countries, the only medical resources—if any—ready to respond to mass casualty situations are in the military. Military emergency medical resources are 'at the ready' but rarely used. Yet military emergency response personnel require frequent training exercises to maintain readiness—not a cost-effective utilisation of precious healthcare resources when those exercises could include (as with civilian emergency response personnel) daily responses to care for actual victims.

Individual trauma/stroke centres—much less systems—are virtually non-existent in LMICs, contributing to global healthcare inequality. We propose MCCs that are not separate facilities, but rather are fully integrated (like trauma/stroke centres) into the ongoing healthcare system. The trauma surgeon is a general surgeon when not performing emergency procedures; the stroke neurologist is a staff neurologist when not attending to a stroke victim. Similarly, a trauma operating room is used for surgery during non-trauma periods—augmenting the overall healthcare resources. For the region served, the MCC (1) augments the healthcare resources 24/7/365, (2) provides care otherwise unavailable during mass casualties or periods when the existing healthcare infrastructure is incapacitated (power outage, earthquake, terrorism) and (3) improves prevention programmes, prehospital transport, rehabilitation, medical education, training and certification and research.

Some of the characteristics of MCCs are as follows:

- Location in an underserved area. Natural disasters disproportionately affect LMICs or specific regions (eg, the Pacific 'Rim of Fire').[4] Both natural and man-made disasters disproportionally affect LMICs because of substandard infrastructure and/or prevalence of terrorist events. Since an MCC augments the healthcare resources at all times, the benefit will be greatest where that need is greatest.
- Location where there is a sustained political will for improving healthcare; governmental/societal continuity is essential, as is local support (medical administration, military).
- Location that allows ready mobilisation to sites where mass casualty disasters are common.
- Capability to mobilise promptly to a disaster site (transport by ambulance or helicopter of portable operating rooms, generators, personnel) 24/7/365—ideally in <12 hours. If the disaster is near the MCC, the response would be in minutes rather than hours.

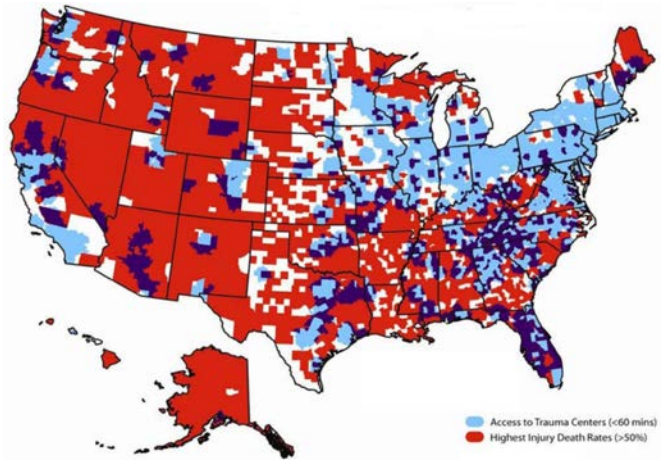

Figure 4 Lack of access to an appropriate level of trauma care is associated with higher trauma patient mortality. Source: map provided by Charles Branas PhD, Professor of Epidemiology, University of Pennsylvania, 2016. Adapted from Berwick *et al*.[26]

- Initial staffing, where feasible, by both local (LMIC) and HIC healthcare personnel, including medical professional societies and NGOs, for example, ICRC and MSF. Local personnel gain exposure to up-to-date techniques; HIC personnel benefit from exposure to cost-effective and resource-effective solutions that local personnel can provide. The 'twinning' concept of pairing LMIC and HIC academic medical centres has been successful in LMICs.[20–22]
- MCCs are fully integrated into the ongoing healthcare system—from prevention through acute care to rehabilitation, from medical education and training to certification and licensure. Worldwide standardisation of care is one benefit of a global MCC network.
- Medical research (both clinical and basic science): MCCs provide a global research network for data on differences in conditions worldwide—and thus insights into more effective treatments.
- Incorporation of the latest technological advances—from data acquisition and analysis to telemedicine to drones and robots—that also augment healthcare resources in the MCC region during non-disaster times. Technological and personnel resources for MCCs are described in the companion article (Aguilera S, Quintana L, Khan T, *et al*. Global health, global surgery, and mass casualties: II. Mass casualty centre resources, equipment, and implementation. Submitted to *BMJ Global Health* 2019.).

INITIAL MCC MODELS: CHILE AND PAKISTAN

The two initial MCC models are Iquique (northern Chile) and Peshawar (northwest Pakistan). Reasons for these sites include the following:

- Local need for mass casualty disaster response resources. The Iquique region has frequent earthquakes and tsunamis. Although Chile has dedicated resources to disaster response—having both military resources readily available for emergencies and a ministry for emergency response (Oficina Nacional de Emergencia del Ministerio del Interior y Seguridad Publica (ONEMI))[23]—these agencies are not seamlessly integrated into the local healthcare delivery system. However, the interaction among these organisations makes the MCC concept more readily implemented in Chile than elsewhere. In Peshawar, both natural and man-made disasters are common occurrences. The development of healthcare in Peshawar over the past decade is remarkable, and interaction between the Pakistani military and civilian healthcare is considerable.
- Geography. Both Iquique and Peshawar are medical hubs for regions with significant geographic challenges for healthcare. In Northern Chile, emergency care can be 1000 km away; Pakistan's Khyber Pakhtunkhwa (population over 40 million) is challenged by extremely mountainous terrain and an underdeveloped transportation network.
- Local support. The longstanding dedication of authors SA and LQ in Chile, and TK in Pakistan, has been essential for the MCC project.

PROJECTS SIMILAR TO MCCS

The US National Trauma Care System (NTCS)

Concern in the USA regarding mass casualty disasters in the 1980s led to the National Disaster Medical System.[24] A proposal to unite civilian and military emergency medical services was made in 1991[25]:

> "…we recommend an organisation with one central command at the federal level, unencumbered by bureaucratic delays, that maximises use of our greatest resource, the local EMS systems' trauma centres."

In 2016, a similar proposal (NTCS) evolved from data showing that trauma deaths were much higher if the injury occurred far from a trauma centre (figure 4).[26] Since trauma accounts for nearly one-half of all deaths among those under age 46 (cost approaching US$1 trillion yearly), the economic incentives to reduce trauma morbidity/mortality are huge.

The NTCS programme parallels the MCC project on a US national, rather than global, basis.

Australian Medical Assistance Teams and Response Centre

Australian Medical Assistance Teams (AUSMAT) personnel—from physicians to firefighters—are trained to respond to disasters both national and international.[27] An integral part of AUSMAT is the National Critical Care and Trauma Response Centre (NCCTRC). NCCTRC is an essential link in the Australian Trauma Registry and regularly deploys teams to mass casualty disasters throughout the Asia-Pacific region.

WHO Emergency Medical Teams initiative

WHO has established an international training and certification programme for healthcare professionals worldwide who wish to provide emergency care for

disasters—from earthquakes to Ebola outbreaks.[28] The mission and composition of EMTs are similar to those of MCCs:

> "The mission of the EMT initiative is to enhance preparedness and promote the rapid deployment and efficient coordination of Emergency Medical Teams adhering to minimum standards in order to reduce the loss of life, alleviate suffering, and prevent long-term disability as a result of disasters, outbreaks and/or other emergencies…"[29]

> "(EMTs) come from governments, charities (NGOs), militaries and international organisations such as the International Red Cross/Red Crescent movement. They work to comply with the classification and minimum standards set by WHO and its partners, and come trained and self-sufficient so as not to burden the national system."[28]

The WHO EMT initiative has developed minimum standards of training and equipment for aspects of emergency medical response rarely addressed in detail, for example, rehabilitation.[30]

The healthcare benefit from improvement in day-to-day care is much greater than from improvement only in disaster care. The MCC project will meet WHO EMT certification requirements. As an implementation project, MCCs will extend the training and certification benefits of the WHO EMT initiative.

The Israeli Trauma/Mass Casualty Management System and Israeli Defense Forces Field Hospital (IDF-FH)

Integration of civilian and military emergency response is perhaps most developed in Israel, a country on constant high alert for mass casualty events.[31 32] This includes injury prevention, prehospital care, acute care and posthospital care and rehabilitation.[31] The IDF-FH was the first foreign medical team (FMT) to be awarded FMT type 3 designation (the highest level of emergency care) in 2016 by WHO.[12 32]

JUSTIFICATION FOR MASS CASUALTY CENTRE NETWORK

We propose expanding the trauma/stroke centre concept for emergency care to a network of MCCs that would combine the following to provide mobile and resilient healthcare for both daily and mass casualty situations:

- civilian and military healthcare resources;
- public, private, NGO and international agency (UN, WHO) healthcare resources;
- LMIC and HIC healthcare resources.

The MCC concept was initially proposed in an earlier publication.[33]

Man-made disasters are common worldwide: sociopathic individuals and terrorists possess the means to inflict mass casualties. The effects on families (and societies) are equally devastating whether the mass casualty is natural or man-made. An immediate medical response is essential to reduce the long-term consequences of both natural and man-made disasters.

Benefits of a network of MCCs include:

- 24/7/365 emergency care for the region around the MCC.
- Expansion of trauma/stroke centre services—blood bank, radiology, critical care, pathology—to conditions beyond acute trauma: difficult (eg, caesarean) childbirth, neonatal disorders (prematurity, birth trauma, spinal bifida, hydrocephalus), cardiovascular events, acute abdomen, infections, neoplasia.
- Implementation: (1) prevention programmes (injury avoidance, diet and lifestyle optimisation, personal well-being) to reduce the burden of acute conditions and chronic disorders (eg, NCDs); (2) prehospital care (ground—and where feasible—air ambulance); (3) rehabilitation/follow-up programmes.
- Cost savings: integration of military and civilian resources—reduced duplication plus military day-to-day emergency response reduces training missions merely to 'stay current'.
- Daily association of LMIC and HIC healthcare personnel affords educational and camaraderie benefits in both directions: technical refinements flow from HIC to LMIC personnel; cost-effective solutions flow from LMIC to HIC personnel.
- Worldwide MCCs provide improved/standardised medical education and training.
- Worldwide MCCs provide a global research platform for disorders far beyond trauma/stroke—including NCDs and emergency conditions.

The essential nature of healthcare for improving poverty worldwide has been acknowledged by prominent international organisations such as the World Bank and WHO.[34 35]

In 2015, the UN created the SDGs for 2030.[36] Improved global healthcare (SDG 3: Ensure healthy lives…) is essential for attainment of other SDGs, including SDG 1 (End poverty…), SDG 4 (Ensure inclusive and equitable quality education…), SDG 8 (Sustain per capita economic growth…), SDG 9 (Develop quality, reliable, sustainable and resilient infrastructure…), SDG 10 (Reduce inequality within and among countries…), among others. Recent publications have documented progress in the economic needs for improved healthcare and indicators of UHC.[37–39]

The SDGs are laudable, but a major question remains:

> "How can we realise the healthcare-related SDGs?"

Achieving the SDGs requires system-wide action, not merely piecemeal reform.[40] Improved health systems would save over 8 million lives and US$6 trillion in economic losses yearly in LMICs.[40] In figure 5, treatment for four of the six conditions responsible for the most deaths involve surgery—cardiovascular disease, neonatal death, road injuries and cancer.[41] Additionally, trauma/stroke centres come with the metrics for ensuring the quality that is essential to realise the SDGs.[40]

Recent publications note the benefits of combining military and civilian healthcare resources, particularly in LMICs[42–44]:

> "The notion that military forces are unsurpassed in specific capabilities related to disaster response is almost universally accepted… Militaries are often far better equipped to

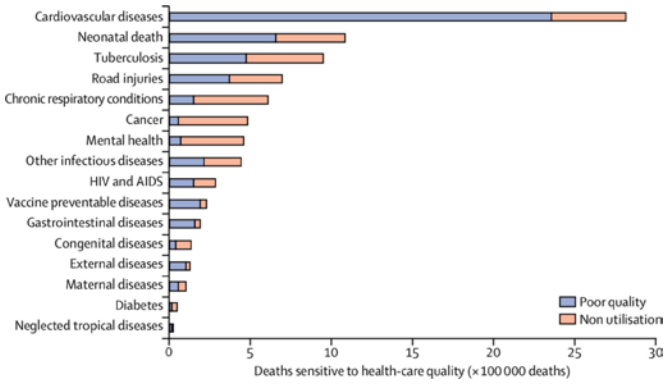

Figure 5 Deaths from Sustainable Development Goal conditions due to poor quality care and non-utilisation in 137 low-income and middle-income countries. External factor deaths are those due to poisonings and adverse medical events. Other infectious diseases deaths are those due to diarrhoeal diseases, intestinal infections, malaria and upper and lower respiratory infections. Adapted from Kruk *et al*.[41]

mobilise rapidly and provide transport, lift, and engineering capacities at a larger scale than other actors. Notably, militaries often have such exceptional capabilities because they typically have much larger budgets and more staff than civilian disaster response agencies."

In Iquique, military confrontations are uncommon, natural disasters are common and integration of military and civilian capabilities for mass casualty disaster response benefits from Chile's ONEMI. In Peshawar, terrorist events leading to military intervention are relatively common, as are natural disasters, but the interaction between military and civilian healthcare systems is advancing rapidly.

MCCs capitalise on military emergency medical resources currently underused in many countries to augment the healthcare system without additional economic burden, a true 'win-win' situation.

CONCLUSION

The MCC concept unites existing resources within country, between countries and across LMIC and HIC healthcare systems. Conceptualisation and implementation both come from the combined input of LMIC and HIC healthcare personnel. MCCs address the continuum of healthcare: (1) from prevention to acute and emergency treatment to intensive care to rehabilitation and (2) geographic access (ground and air ambulance) and resilience (self-contained facilities that function despite power outage or disasters). Thanks to economies of scale, reduction in resource duplication, technological advances (electronic records, telemedicine, robots/drones, as presented in the companion article) and globalisation of medical care, education and research—the MCC concept is an efficient and diplomatic means to achieve improved healthcare worldwide.

The MCC concept is a step towards realising the universal economic and quality of life goals that the SDGs for 2030 embody.

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