The role of biomedical engineering in disaster management in resource-limited settings

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Introduction

The costs of natural disasters, such as earthquakes and floods, and of wars and other man-made catastrophes go beyond the immediate loss of life, property, infrastructure and livelihood. The public health crisis that unfolds over ensuing weeks and months leaves much deeper, permanent scars in the form of reduced quality of life and disrupted national economies.[1] These effects are compounded in resource-limited settings, where catastrophes result in population displacement and undermine health facilities' capacity to provide care, since fully-established disaster management programmes are often lacking.[2]

Large-scale disasters that displace populations and strain the existing health-care infrastructure, such as the 2004 Indian Ocean tsunami and the 2010 earthquake in Haiti, have two well-defined stages: the crisis during the event, and the slower, more devastating catastrophe that puts the lives of millions of people at risk. Local government response is often focused on the former, with little attention to the latter. Crisis management in remote settings is particularly complicated. In this perspective piece we argue in favour of improved management of large-scale disasters through investment in biomedical engineering.

Typical disaster situation

Public health needs after a disaster progress through different phases. They include: (i) immediate rescue efforts, during which trauma care, food, clean water, sanitation and shelter are provided; (ii) infrastructural efforts to rebuild houses, schools and hospitals; and (iii) victim rehabilitation efforts consisting of long-term health and livelihood interventions. Disasters often contribute to cycles of poverty and poor health that take years, sometimes decades, to break.

Post-disaster relief activities typically focus on providing food, water and shelter and on general measures to safeguard the public welfare. This is illustrated by the "safe hospitals" campaign, launched by the World Health Organization (WHO) to ensure the structural integrity and functionality of hospitals after a disaster.[3] Although attending to immediate needs is clearly essential, relief efforts must also try to mitigate the long-term effects of a disaster. However, the time, resources and expertise needed to carry out these extended efforts are seldom available. After a disaster, spikes in malnutrition and communicable diseases often occur among displaced populations owing to food shortages and lack of good sanitation, clean water and adequate housing. Studies in Africa, Asia and Latin America have documented post-flood increases in diseases borne by vectors or spread by the faecal–oral route, such as cholera, non-specific diarrhoea, poliomyelitis, rotavirus infection and typhoid.[2,4-6]

Quantifying needs

While health facilities are expected to have access to electricity, water, waste disposal and communications, such services may be significantly compromised after a catastrophe. Hurricane Katrina is a case in point.[7,8] Post-disaster trauma care capacity needs to be enhanced through reinforcement of personnel and equipment.

Large-scale disasters put a significant strain on available resources. Local health facilities are often understaffed and overworked in the aftermath of a disaster and demand for personnel and material resources increases exponentially. Consequently, people who would not normally provide critical care may be required to do so. This implies a need for medical equipment and devices that are easy to use and require little training.

Humanitarian and development communities invest billions of dollars each year in relief and recovery efforts. However, disaster response is not consistently funded. Publicity or lack thereof is one of many factors that notoriously control the influx of relief aid.[7] Also, donors tend to allocate their money to specific causes and types of disasters. Further, the bulk of the funding starts flowing in only after a disaster has occurred. As a result, relief organizations have fewer resources to spend on disaster preparedness activities.

Given the ad hoc nature of disaster relief, available resources should be used efficiently to avoid the previously termed "ambulances to nowhere" situation. Efforts to improve a nation's emergency preparedness, institutional capacity and time to recovery after a disaster all pay off in the long run.

Role of biomedical engineering

Biomedical engineering plays an essential role in effective health care delivery and is employed by multi-disciplinary clinical and research teams in developing strategies for the diagnosis and management of many medical conditions. Further, biomedical engineering has demonstrated remarkable capacity to revamp health systems in resource-limited environments through improvements in diagnosis and treatment. For instance, a cell phone-based light microscope has exhibited potential for clinically identifying malaria and tuberculosis through the use of fluorescence with light-emitting diode (LED) excitation.[9]

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Unfortunately, middle- and low-income countries have few biomedical engineering departments conducting active research because of lack of technical capacity and resources. As a result, hospital equipment is often broken or misused. Maintenance of equipment often relies on expensive international expertise and local capacity to develop innovative engineering solutions is noticeably absent.

The rapid onset of catastrophes and their devastating effects work synergistically to increase morbidity and mortality in affected areas. In resource-limited settings, confirmatory laboratory tests are rarely available. For this reason, in these settings current WHO guidelines recommend basing diagnosis on observation alone. Point-of-care devices for diagnosis and triage that are robust, affordable and easy to use with minimal training could be used to rapidly and accurately diagnose diseases such as malaria, cholera and typhoid fever, help health-care providers to make appropriate decisions, and improve patient outcomes. For instance, proper management of diarrhoeal diseases using simple measures such as oral rehydration therapy and zinc can reduce case-fatality rates to less than 1%, as demonstrated in post-disaster cholera epidemics.[1]

The suddenness of disasters strains local health facilities by hugely increasing patient load. Following a disaster, hospitals become expanded critical care units needing heightened maintenance of equipment. Access to technicians adept in servicing equipment cannot be taken for granted in developing countries.

Integrated policy for sustainable solutions

Historically, disaster response planning has not competed effectively with other needs. Preparedness programmes in communities that have never experienced a disaster seldom go beyond disaster response planning as mandated by national guidelines. Recent studies indicate an association between anthropogenic climate change and recent extreme weather events.[10] As an extrapolation, the predicted increase in “natural” disasters in the future demonstrates a greater need for improved disaster prevention and response strategies. Responsibility for disaster relief and recovery is shared by various local, national and international institutions. An approach that incorporates biomedical engineering components at the national and international levels could improve crisis management programmes in resource-limited settings. Ministries of health, education and technology need to combine resources and expertise to strategize disaster management. Biomedical engineers need to be included on the planning committee for disaster preparedness and response activities. While the creation of independent biomedical engineering departments may not be economically feasible where resources are scarce, existing engineering faculties and organizations can be incentivized to develop solutions that are innovative, robust and contextually appropriate. Such solutions could include, for example, the use of solar power to charge devices normally requiring electricity. Development agencies could include rapid diagnostic kits as part of the aid package to health workers in the field.

In developing countries, health service equipment also needs maintenance, both in rural and urban areas. To this end, local engineering expertise in monitoring and servicing equipment needs to be regularly strengthened and leveraged to ensure that health facilities can serve the community daily and during unforeseen catastrophes. Biomedical engineers and technicians trained to monitor and maintain equipment in high demand should be included in disaster response teams to ensure that diagnostic and therapeutic equipment as well as local human resources are ready for service.

Conclusion

Solutions to problems in resource-limited settings require innovative engineering and interdisciplinary technical skills to keep costs low and improve response times. Sustainable solutions require local ownership and participation and can create a new job market. Integrating biomedical technical skills with existing institutional expertise has the potential to strengthen national disaster management. In the long run, greater investment in biomedical engineering will allow for the self-sustaining and efficient operation of health services in times of peace and crisis. ■

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