The Impact of Climate Change on Healthcare Facility Infrastructure: A Preliminary Investigation of Mitigation and Adaptation Strategies

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Abstract

This paper proposes that increased attention be paid to mitigation and adaptation of healthcare facility infrastructure to cope with extreme weather events, particularly those generated by the impacts of climate change on Australia. Although the effects of climate change have been studied and potentially addressed through the development of mitigation strategies, little research has been undertaken in the area of safeguarding physical infrastructure by means of adaptive strategies, especially within the healthcare system. This paper argues that adaptive strategies for healthcare facilities are necessary to ensure continuity of service delivery to the population in catastrophic weather events such as heatwaves (and bushfires), floods, storm surges and cyclones. It argues that these are likely to be associated with a changing climate and adaptation strategies should include an allowance for an increase in the likelihood of these disasters occurring. Finally it proposes dissemination of the research findings through the Australasian Health Facility Guidelines (AHFG).

Introduction

With global climate change now evident, extreme weather events are increasing (1-3). While many current studies have focussed on assessing the extent of, and ways to mitigate, climate change, much less is known about the accompanying problems likely to be generated by extreme weather events impacting on essential physical infrastructure, such as healthcare facilities. The likelihood of extreme weather events is difficult to determine in terms of timing and severity, as in general the information available relates to probabilistic forecasting rather than absolute predictions. Nevertheless, the risks associated with extreme weather events cannot be neglected because when they occur, healthcare services will inevitably be subject to increased demands from the community, thus overburdening existing facilities and the healthcare system in general. Therefore, necessary precautions should be implemented to safeguard healthcare facility infrastructure to enable it to continue supporting the delivery of healthcare services in emergency situations.

In Australia, climate is projected to show an annual increase of between 0.4-2.0°C in average temperature above that prevailing in 1990 by the year 2030 – and 1-6°C by 2070 (3). To date, warm temperature extreme events have generally increased whereas numbers of extremely cool temperature events have decreased (2-5). Overall impacts are likely to be expressed in terms of:

- A greater number of heatwaves and fewer frosts. These may occur in greater concentrations e.g. two or more days rather than as isolated events
- More frequent El Nino Southern Oscillation (ENSO) events – resulting in a more pronounced cycle of prolonged drought followed by heavy rains
- Reduction in rainfall and associated reduction in water runoff in Southern and Eastern Australia
- More severe wind speed during cyclones, associated with storm surges progressively amplified by rising sea levels
- Increase in storms and days at high risk of bushfire

- Changes in ocean currents which may affect coastal waters in terms of temperature and nutrient levels.

The nature of extreme weather events and their health and facility impacts

The incidence of extreme weather events including heatwaves, floods, storms, and tropical cyclones is increasing, and in Australia, already the pattern of weather extremes in the recent years is growing (1, 2, 4). Such episodes put pressure on the healthcare system, both directly (to public health) in terms of increasing numbers of hospital admissions as well as indirectly in terms of the consequences arising from health facility infrastructure failures. Evidence from previous cases of extreme weather events, particularly those in Australia, are scattered and are often poorly documented. Nevertheless, they clearly indicate the difficulties and challenges faced by the healthcare system and facilities in responding to these events.

1. Heatwaves (and Bushfires)

'A heatwave is a complex phenomenon resulting from a certain combination of temperature, humidity, air movement and duration. …a heatwave is an extended period of very high summer temperatures with the potential to adversely affect communities' (6). The increased likelihood of higher average temperatures associated with climate change (2, 3) means that heatwaves may occur more often in Australia than at present and hence cause a greater number of people within the community to suffer from heat stress and its associated effects.

Health impacts: In Australia and other countries, heatwaves are responsible for more deaths than any other natural hazard but are mostly underrated because they are viewed as a 'passive' hazard in contrast to the more catastrophic hazards such as tropical cyclones or bushfires(6) (7). Official death tolls associated with heatwaves also tend to be greatly understated as death is often assumed to be the result of an existing ailment (6). Those at highest risk are the elderly, the very young, the chronically ill, the overweight and those dependent on drugs or alcohol (2, 3). While heatwaves do not always result in deaths, the

Sydney 2005 heatwaves were reported as the cause of a considerable increase in hospital admissions, placing pressures on the healthcare system (8). Such events require the employment of additional staff, increased demand for medical supplies plus greater need for equipment suitable for use with overweight and older people, in addition to potentially resulting in the overcrowding of healthcare facilities.

In addition, when heatwaves occur, conditions that encourage severe bushfires are also likely to result. Apart from causing danger and possible injury to those fighting or fleeing them, bushfires may also cause a reduction in air quality through the prevalence of smoke and ash resulting in respiratory problems for those most vulnerable – the elderly, asthmatics and others.

Facility impacts*:* In the event of Sydney heatwaves in 2005 “one hospital has been swamped by people not needing medical treatment - simply looking to take advantage of its spacious air conditioned reception area” (9). The 7-day heatwave in Adelaide in February 1997 caused hospital computers to overheat and fail (6). Where there is increased use of fans and air-conditioners this may cause overheating in electricity supply cables and other electrical appliances, posing a risk of fire. Water shortages and water supply failures may also become a problem during prolonged heatwaves as demand for water may increase dramatically. Further adding to the complexity of the situation, transport systems may also suffer from problems and interruption due to possible heat-related expansion of railway lines and steel bridges, and other associated damage to roadways (6). Bushfires may similarly disrupt transport systems, seen as recently as early 2007 in Sydney. The closure of the F3 Freeway link and the rail links north of Sydney for at least two days in January caused significant disruption on a major national communication and transport route.

2. Floods

It is anticipated that over the next few decades, climate change will increase the risk of extreme floods occurring (10-12). Two types of floods are considered in this scenario: flash floods and riverine floods. Flash floods develop rapidly within

some minutes or hours, often caused by heavy rainfall that may turn a river bed into a raging torrent. This type of flood is difficult to predict, giving little warning to residents living in surrounding areas. Riverine floods build up more slowly, hence warnings are usually more reliable, allowing residents living in the vicinity the time to better protect themselves and their property (11).

Health impacts: The flooding of the river Elbe in 2002 in Saxony/Germany required immediate public health action in order to ensure a proper public hygiene response (11). Floods are significantly likely to result in degradation of human health and loss of life, high financial cost, not to mention the resulting trauma and associated human misery (10-12).

Facility impacts*:* Where healthcare facilities are flooded, electrical power outages may be unavoidable, so evacuation may be necessary for oxygen-dependent patients and manual medical recording may be needed (13). In the UK in June 2005, Warwick Hospital suffered “significant flooding” after several hours of torrential rain and thunder, forcing emergency patients to be evacuated by ambulance and helicopters to other facilities (14). It is also noted that flooding may create an access problems for physicians and other staff travelling to and from the hospital (13).

3. Storm surges

Storm surges are caused by the effect of wind in conjunction with a storm, plus temporal variations of atmospheric pressure, water temperature, and the difference in temperature between air and sea. These factors may result in greater thermal expansion of the body of water and more water vapour to be contained in the atmosphere (15, 16). Storm surges often accompany a tropical cyclone as it comes ashore and coastal flooding may extend along the coast for over 100 kilometres (11, 17). As the paths of cyclones are often erratic, it can be very difficult to predict the height of the sea tide during a storm surge (17).

Health impacts: As a result of the impact of Hurricane Katrina in the Southern USA in 2005, a number of hospitals were submerged in water, contaminated with sewage and chemicals. Approximately 93 hospitals were adversely impacted by

Hurricane Katrina, with19 hospitals being evacuated and another 18 being closed (18). Numerous deaths were attributed to transportation shortages, although evacuation measures were aided by helicopters, buses, and ambulances. In March 2006, Australia underwent a similar experience when severe Tropical Cyclone Larry crossed the tropical north Queensland coast near Innisfail. Although this was an event of much smaller scale than Hurricane Katrina, medical services were placed under pressure, requiring the diversion of other medical support (i.e. nurses and health officers) from other parts of Queensland (6, 19).

Facility impacts*:* Water pushing several kilometres inland where land is low lying may potentially knock down healthcare facilities and wash away roads (11, 17) (20). In March 2006, Cyclone Larry in north Queensland, the Innisfail Hospital was forced to close, thus requiring medical support from Townsville and Cairns Base Hospitals. Herberton hospital was without power until a generator was provided and leaking roofs resulted in emergency evacuation (6, 19).

4. Tsunamis

Tsunamis are giant tidal waves caused by volcanoes or earthquakes under the ocean often quite distant from the coast (11). Tsunami threat is uncertain, and in most areas the probability of occurrence is not known, but when it does occur is likely to have an extremely high impact (21). There is no research suggesting that the incidence of tsunami will alter as a result of climate change, yet the Asian tsunami experience highlights potential issues for communities including threats to healthcare physical infrastructure when the number of tsunamis increases as a natural variation to the status quo.

Health impacts: The South Asian tsunami in 2004 was one of the largest flooding disasters in recent history, causing about 280,000 fatalities in eight countries from Asia to Africa (22). Post-traumatic stress disorders and problems of hygiene and infectious diseases were also noted, which caused many fatalities including a large number of suicides (22).

Facility impacts*:* During the 2004 tsunami in Indonesia, one main referral hospital, 4 district hospitals, and 41 out of 240 clinics were destroyed (23). In the Maldives, where most healthcare facilities escaped major structural damage, some facilities such as Mulee hospital lost all their medical records and equipment. Access difficulties were also noted, which further hindered the provision of health services following the disaster.

Early identification of healthcare responses to extreme weather events

These different perspectives have led to various responses to address and minimise the risks of heatwaves, bushfires, floods, storm surges, and tsunamis. There are various available measures that can reduce morbidity and mortality following natural disasters in order that the number of casualties and losses are minimised (22). Some possible responses are summarised in Table 1.

Our preliminary investigations of the current literature indicate that there are immediate as well as long-term responses appropriate for extreme weather events including heatwaves, bushfires and floods, storm surges, and tsunamis; these will be elaborated in the subsequent section of this paper. *'Immediate' responses* refer to the need for timely action in responding to a disaster situation in order to mitigate further losses and adverse effects. *'Long-term' responses* are more strategically focused on minimising the impacts of future disasters on the community.

POSSIBLE INFRASTRUCTURAL RESPONSES TO EXTREME WEATHER EVENTS	
Immediate	• Increased public awareness • Warning procedures for the community especially those at highest risk • Thermal control – airconditioning, close blinds, windows, etc (for heatwaves/bushfires) • Environmental control (to filter out smoke and dust, etc) • Emergency fire fighting response • Evacuation of those in immediate danger to safer facilities, surge hospitals, etc.
Long-term	<u>Urban planning</u> • Regulations – such as the Australian Standards, Building Codes, Health Facility Guidelines, Engineering Services guidelines – to ensure appropriate ventilation, air quality, thermal condition • Urban Design (eg land use, green spaces, water bodies) • Environmental management of high risk areas adjacent to urban areas or health facilities • Improved communication networks among urban planners • Redundancy built into road and transport networks to avoid isolation of facilities and emergency services • Availability of safe and environmentally controlled gathering spaces for the community to seek relief e.g. shopping centres, public libraries, etc, and to avoid unnecessary burdens being placed on health care facilities by those not in need of healthcare interventions. <u>Health System Responses</u> • Coordinated disaster responses – emergency services – ambulance, fire, police, etc that work with facilities to ensure healthcare delivery is uninterrupted • Relief plan: surge hospitals, counselling, etc <u>Facility Management</u> • Site selection and utilisation • Facility design, detailing, and construction • Maintenance of equipment, e.g. airconditioning and facility fabric such as roofs and downpipes, so that structural failure is avoided in a disaster situation • Backup and spare capacity for building services e.g. electricity, water, ensuring uninterrupted supply

Table 1: Summary of possible infrastructure responses for managing the risks associated with extreme weather events that could impact on healthcare facilities

1. Heatwaves

In the United Kingdom, as an *immediate (and operational) response* to heatwaves, primary care trusts are required to ensure that protective measures such as proper ventilation, fans, and a fridge are available for use by their vulnerable patients whether in their own homes or in residential care (24). Carers in aged care residential facilities should initiate the shading of buildings (i.e. drawing curtains, etc), check if windows are able to be opened, ensure staff members know the rooms that are the easiest to keep cool and review the distribution of residents accordingly. They must check that the air conditioning system works properly, and ensure enough thermometers are placed to measure room temperatures as needed (24).

In terms of *long-term responses*, it is necessary to control the outdoor thermal environment and external microclimates through the relationships between pockets of sun and shade, the varying degree of protection afforded by these, and the potential exposure to wind (25). Careful planning is needed to determine the appropriate mix of surrounding land uses, including the need for green spaces, and water bodies (2). In terms of infrastructure responses, it is necessary to consider the location and sizes of windows, extent of overhanging eaves, shading, building heights, etc (2).

2. Floods, storm surges, and tsunamis

A range of similar responses are applicable to floods, storm surges, and tsunamis. In terms of an *immediate response*, it is important for people living in coastal areas to determine the location and extent of surge-prone areas, including assessing the need for evacuation to higher ground and how best to get there (17). Local councils and Emergency Services should also provide advice on detailed evacuation plans for their local areas (17). The risk profile of a community should also be identified using scenarios and loss studies. This will also provide the basis for educating the public regarding their risk exposure, thus

building support and engagement in mitigation programs, and in response and evacuation planning (21, 26).

In the event of a disaster, “surge hospitals” can be used “to treat a surge in the number of patients needing care, contained triage, treatment, and sometimes even surgical capabilities”, which can be extended over time if permanent facilities are severely damaged (20, iv). Different types of surge hospitals utilised to date in the USA have included: shuttered hospitals (or closed wards), facilities of opportunity, mobile medical facilities, and portable facilities (“hospital in a box”). As one part of the relief effort for Hurricane Katrina, a 35-bed mobile hospital was used treat several patients (27). It has been noted that the successful use of such facilities requires thorough planning around the areas of staffing, equipment, financial cost, and operational management perspectives during emergencies (20).

The identified *long-term response*, particularly for tsunamis and flash floods, includes careful urban planning to avoid new development in tsunami run-up areas to minimise future tsunami (or flood) losses (21). Other infrastructural planning includes efforts to design and construct new buildings to minimise damage, protect existing development through redevelopment, retrofit, and land reuse plans and projects, and taking special precautions in locating and designing infrastructures and critical facilities such as hospitals (26). Similarly for floods, in the USA the Federal Emergency Management Agency (FEMA) initiated a hospital flood protection project as it believes that “flood mitigation saves money” (28). The project involves enhancements to the existing earthen beam system, construction of a perimeter floodwall system with flood doors and floodgates, pumping and drainage improvements and protection of critical electrical and mechanical systems on the basement level (28). Other measures may also involve creating new and higher entry levels into the hospital and other facility work, such as ensuring that electrical wiring is above the flood-protection level. In Texas Children’s Hospital, this has involved the installation of submarine-like flood doors that are placed strategically throughout the hospital,

able to handle up to 230,000 pounds of water pressure (29). In other places such as New Zealand, Christchurch hospital initiated the construction of flood banks surrounding the area on the riverside (30).

Conclusion

It has been widely acknowledged that the effects of climate change will increasingly place pressures on the healthcare system in countries including Australia (4). However, currently, there seems to be a lack of studies focused on adapting healthcare facilities, and indeed healthcare systems overall, to climate change in order to safeguard them against the likely increased impact of extreme weather events. It appears that where extreme weather events are considered, they are subsumed under the disaster management and emergency planning umbrella, which does not extend to advice or clear and systematic strategies for safeguarding of healthcare facility infrastructure. Focusing on pre-disaster planning, this study investigates within the climate adaptation framework a possible range of responses for ensuring that healthcare buildings will be able to minimise and cope with the inevitable impacts of extreme weather events. A key outcome of this study would be key strategies to safeguard health facilities that involve measurement of the “adaptive capacity” to ensure successful implementation of the identified strategies from the perspectives of the healthcare system, social and community issues, economic factors including costs, technological solutions and advances, as well as the political climate. This includes the identification of potential consequences of neglecting the recommended strategies. A future practical outcome is to incorporate of such strategies into the Australasian Health Facility Guidelines and current health facility maintenance practices.

References

1. Klein RJT, Maciver DC. Adaptation to Climate Variablity and Change: Methodological Issues. Mitigation and Adaptation Strategies for Global Change. 1999;4:189-98.
2. Koppe C, Kovats S, Jendritzky G, Menne B. Heat-waves: risks and responses: World Health Organization; 2004.
3. Preston BL, Jones RN. Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions: CSIRO; 2005.
4. Australian Greenhouse Office. Climate Change Risk and Vulnerability: Promoting an efficient adaptation response in Australia. Canberra: Department of the Environment and Heritage; 2005 March.
5. Collins DA, Della-Marta PM, Plummer N, Trewin BC. Trends in annual frequencies of extreme temperature events in Australia Australian meteorological magazine. 2000;49(4):277-92.
6. Emergency Management Australia. Manual 4: Australian Emergency Management Terms Thesaurus. Australian Emergency Manuals Series 1998 19 January 2007 [cited 2007 27 January]; Available from: http://www.ema.gov.au/agd/ema/emaInternet.nsf/Page/RWP2E6DD4ACF65D443CCA257156007ACEA0
7. Bureau of Meteorology. Heatwaves. 2006 [cited 2006 29 August]; Available from: http://www.bom.gov.au/weather/wa/sevwx/perth/heatwaves.shtml
8. Robotham J. Hospitals in Sydney swamped as heatwave kicks in. Sydney Morning Herald. 2005 30 December 2005.
9. Mercer P. Australia swelters in heatwave. BBC News. 2001 27 January 2001.
10. Schreider SY, Smith D, Jakeman A. Climate change impacts on urban flooding. Climatic Change. 2000;47:91-115.
11. Meusel D, Menne B, Kirch W, Bertollini R, The Bratislava Collaborating Group. Public health responses to extreme weather and climate events—a brief summary of the WHO meeting on this topic in Bratislava on 9–10 February 2004. Journal of Public Health 2004;12(6):371 - 81.
12. Kundzewicz ZW. Non-structural Flood Protection and Sustainability. Water International. 2002;27(1):3-13.
13. Cocanour CS, Allen SJ, Mazabob J, Sparks JW, Fischer CP, Romans J, et al. Lessons Learned from the Evacuation of an Urban Teaching Hospital. Arch Surg. 2002;137:1141.
14. BBC News. Heavy rain causes hospital flood. 2005 25 June 2005 [cited 2006 5 September]; Available from: http://news.bbc.co.uk/1/hi/england/coventry_warwickshire/4622393.stm
15. Gönnert G. Maximum Storm Surge Curve Due to Global Warming for the European North Sea Region During the 20th–21st Century. Natural Hazards. 2004;32(2):211 - 8.
16. Danard M, Dube S, Gönnert G, Munroe A, Murty T, Chittibabu P, et al. Storm Surges from Extra-Tropical Cyclones. Natural Hazards. 2004;32:177-90.

17. Commonwealth of Australia. Storm Surges Preparedness and Safety. 2006 [cited 2006 25 July]; Available from: http://www.bom.gov.au/info/cyclone/storm_surge/storm_surge.shtml
18. Planning 2.0. Hurricane Katrina Update - Hospital Status. 2005 [cited 2006 5 September]; Available from: http://www.planning2.com/NewOrleansHospitalsKatrina.htm
19. Queensland Government. Tropical Cyclone Larry Report 1430Hrs. 2006 [cited 2006 29 August]; Available from: http://www.disaster.qld.gov.au/news/view.asp?id=1274
20. Joint Commission on Accreditation of Healthcare Organizations. Surge Hospitals: Providing Safe Care in Emergencies. USA; 2006.
21. Eisner R. Planning for Tsunami: Reducing future losses through mitigation. Natural Hazards. 2005;35:155-62.
22. Morgan O, Ahern M, Cairncross S. Revisiting the Tsunami: Health Consequences of Flooding. PLoS Medicine. 2005 June 01, 2005;2(6):e184.
23. International Centre for Migration and Health. The Public Health Consequences of the Tsunami: Impact on displaced people. Switzerland: International Centre for Migration and Health; 2005 April 2005.
24. NHS. Heatwave Plan for England: Protecting health and reducing harm from extreme heat and heatwaves: NHS; 2006.
25. World Health Organization. Heat-waves: risks and responses: World Health Organization; 2004.
26. National Tsunami Hazards Mitigation Program. Desigining for Tsunamis: Seven Principles for Planning and Designing for Tsunami Hazards. CA; 2001.
27. Harvard School of Public Health. Hurricane Katrina: Program Coordinator Joshua Frances serves as EMT in Miss. Harvard Public Health Now 2005 [cited 2006 5 September]; Available from: http://www.hsph.harvard.edu/now/sep16/frances.html
28. FEMA. Coastal Construction Manual: FEMA Publication; 2002.
29. Texas Children Hospital. Flood Protection System Earns Kudos. Texas Medical Center News 2003 [cited 2006 5 September]; Available from: http://www.tmc.edu/tmcnews/05_01_03/page_10.html
30. Canterbury HDB. Flood protection at Christchurch Hospital. Milestones 2002 [cited 2006 5 September]; Available from: http://www.cdhb.govt.nz/communications/milestones/milestones9.pdf#search=%22hospital%20flood%22