The Surge Capacity for People in Emergencies (SCOPE) study in Australasian hospitals

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ABSTRACT

Objectives: To measure physical assets in Australasian hospitals required for the management of mass casualties as a result of terrorism or natural disasters.

Design and setting: A cross-sectional survey of Australian and New Zealand hospitals.

Participants: All emergency department directors of Australasian College for Emergency Medicine (ACEM)-accredited hospitals, as well as private and non-ACEM accredited emergency departments staffed by ACEM Fellows in metropolitan Sydney.

Main outcome measures: Numbers of operating theatres, intensive care unit (ICU) beds and x-ray machines; state of preparedness using benchmarks defined by the Centers for Disease Control and Prevention in the United States.

Results: We found that 61%–82% of critically injured patients would not have immediate access to operative care, 34%–70% would have delayed access to an ICU bed, and 42% of the less critically injured would have delayed access to x-ray facilities.

Conclusions: Our study demonstrates that physical assets in Australasian public hospitals do not meet US hospital preparedness benchmarks for mass casualty incidents. We recommend national agreement on disaster preparedness benchmarks and periodic publication of hospital performance indicators to enhance disaster preparedness.

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Hospital surge capacity is defined as the ability to provide acute care to both critical and non-critical mass casualties simultaneously, and is a marker of the ability to deliver emergency care in a disaster situation. At present, there are no established standards of appropriate physical or human preparedness targets for Australasian hospitals.

Current epidemiological evidence indicates that 50%–80% of people acutely injured in a mass casualty disaster will arrive at the closest medical facilities generally within 90 minutes after the event.[1] International best-practice models for mass casualty care state that the number of available operating theatres and the ability to take simple x-rays are measures of the capacity to provide care for both critical and non-critical patients.[2] The number of intensive care unit (ICU) beds is also one of the physical indicators of a hospital's capacity to care for critically injured patients, although there is no internationally agreed benchmark for this.

In 2005, the Health Resources and Services Administration (HRSA), United States Department of Health and Human Services, set a benchmark for hospital surge capacity for all US states to establish a system providing for triage, treatment, and disposition of 500 combined adult and paediatric patients (suffering from acute illness or trauma requiring hospitalisation from biological, chemical, radiological or explosive terrorist incidents) per million population above the daily staffed bed capacity.[3,4] Subsequent guidance has proposed hazard-specific disaster preparedness targets of 50–500 patients per million population above the current daily bed capacity.[5]

The US Centers for Disease Control and Prevention (CDC) predicts that terrorist bombings using conventional weapons produce a casualty pattern of one-third of patients critically injured, dead or dying and two-thirds of patients requiring minimal intervention.[2] The CDC also estimates that, for patients exposed to blast injury or other penetrating trauma, an x-ray series to screen for fractures, foreign bodies, blast lung or other injuries will take around 10 minutes; therefore, each available machine could contribute to the radiological work-up of about six patients per hour.[2]

An early review of 202 terrorist bombings found a 13% death rate, and a 30% hospitalisation rate among survivors,[6] and a later review by the same author of indoor terrorist bombings[7] found that the death rate varied from 5% to 68% and the proportion of people critically injured varied from 7% to 22%. Another review by Arnold et al[8] of 44 mass casualty bombings revealed an overall death rate of 3%, suggesting that the overwhelming majority of those seriously injured would survive to require medical care. The study also found that the median value for hospital admission rates was 34%. All of these analyses are consistent with the CDC prediction of one-third of people critically injured.

Operating theatres, ICU beds, and x-ray machines represent a resource ceiling on treatment capacity in Australasian hospitals, and hence define the least distensible, if not rate-limiting, steps of the clinical care pathway for the management of mass casualties. Therefore, we aimed to survey the number of operating theatres, ICU beds and x-ray machines in hospitals in Australia and New Zealand, and to use US benchmarks and data on mass casualties to estimate the state of preparedness of Australasian hospitals for admission of mass casualties.

METHODS

Questionnaire

The survey was conceived by the Research Committee of the Australasian Trauma Society, and the study was approved by the Human Research Ethics Committee of the University of Sydney.

The questionnaire was designed to collect data on hospital surge capacity measures — numbers of operating theatres, ICU beds, and x-ray machines (fixed and mobile). It was piloted in five major Sydney hospitals. In September 2004, the revised questionnaire was mailed to the 94 emergency department (ED) directors of all hospitals accredited by the Australasian College for Emergency Medicine (ACEM) in Australia and NZ. Within metropolitan Sydney, seven private and non-ACEM accredited hospitals (staffed by ACEM Fellows) with a 24-hour ED were also invited to participate.

After a response time of 4 weeks, all ED directors who had not responded received a phone-call reminder, followed by the questionnaire in an email. After a further 2 weeks, another reminder email was sent. Data collection ceased 3 months after the initial mail-out of the questionnaires.

1 Number of hospitals participating in the survey and response rates, by location

Location	Hospitals responding	Response rate
ACEM-accredited hospitals		
New South Wales	32/35	91%
Sydney	19/22	86%
Victoria	16/17	94%
Queensland	13/13	100%
Western Australia	7/7	100%
South Australia	5/5	100%
Tasmania	3/3	100%
Australian Capital Territory	2/2	100%
Northern Territory	2/2	100%
Australia	80/84	95%
New Zealand	8/10	80%
Australasia	88/94	94%
Private and non-ACEM accredited hospitals		
Sydney	7/7	100%

ACEM = Australasian College for Emergency Medicine. ◆

Analysis

Data from the returned questionnaires were collected in a database and all analyses were conducted using SPSS, version 12.0 (SPSS Inc, Chicago, Ill, USA).

We calculated the numbers of operating theatres, ICU beds and x-ray machines required according to the CDC predictor of numbers of mass casualties (one-third critical, two-thirds non-critical) and CDC benchmarks for hospital capacity,[1,2] and compared the figures to actual availability in all jurisdictions surveyed. As the interquartile range of hospital admissions from the review of mass casualty bombings was 14%–53%,[8] we selected the lower interquartile figure, as well as the CDC predictions, to estimate the state of hospital preparedness for admission of seriously injured patients. Thus, the need for hospital admission of these patients was estimated in a sensitivity analysis, applying a lower limit of 15% and an upper limit of 33%.

Population estimates for Australia and NZ were obtained from the Australian Bureau of Statistics and Statistics New Zealand, respectively, both at 30 June 2004, to calculate ratios per 100 000 population of operating theatres, ICU beds, and x-ray machines, as well as surge populations (500 patients per million population).[3,4]

RESULTS

Of the 101 hospitals invited to participate in the survey, 88 ACEM-accredited (94%) and all Sydney private and non-ACEM accredited hospitals completed the questionnaires (Box 1). The ACEM-accredited hospitals assessed a total of 3 282 835 patients in 2003. According to Australian government figures, 4.1 million Australians were treated in EDs in 2003–2004.[9] In this period, about 800 000 New Zealanders were treated in NZ EDs (Dr B Peddinti, Chair, NZ Faculty of ACEM, personal communication). Of the participating ACEM-accredited hospitals, 44% were classified as major referral hospitals, 30% as urban district hospitals, and 26% as regional or rural base hospitals.

The total numbers of operating theatres, ICU beds and x-ray machines by jurisdiction (Australian states and territories and NZ) are given in Box 2, together with the calculated ratios per 100 000 population:

- The number of operating theatres per 100 000 population is lowest for NZ and Western Australia and highest for the Northern Territory and the Australian Capital Territory.
- The number of ICU beds per 100 000 population is also lowest in WA and NZ and highest in the NT and Sydney.
- The number of x-ray machines per 100 000 population is lowest for NZ and highest for the NT.

Calculated numbers of critical care casualties for the two thresholds chosen (15% and 33%) and the proportion at risk of not having access to operating theatres and ICU beds in Australian and NZ hospitals are shown in Box 3. In a major disaster, the proportion of critically injured patients at risk of being denied immediate access to operating theatres ranged from 59% to 81% in Australia and from 70% to 87% in NZ. The proportion of critically injured patients estimated to be denied immediate access to ICU beds ranged from 31% to 69% in Australia and from 51% to 78% in NZ.

Mass casualty preparedness for non-critical care patients (66% threshold) indicated by access to x-ray machines differed substantially across jurisdictions (Box 4). The number of x-ray machines available was greater than predicted needs in the NT and matched estimated needs in Sydney and Tasmania. However, overall, there was a shortfall of available x-ray machines of 38% for Australia and 60% for NZ.

DISCUSSION

This is the first comprehensive Australasian study to accurately assess the physical facilities available in hospitals to receive and treat the victims of a mass casualty disaster according to established international benchmarks.

Based on the above modelling, our study suggests that resources for critically injured patients in an Australasian mass casualty

2 Numbers of operating theatres, intensive care unit (ICU) beds, and x-ray machines in Australasian hospitals and ratios per 100 000 population, by location

		Operating theatres		ICU beds		X-ray machines	
Location	Population	No.	Ratio	No.	Ratio	No.	Ratio
New South Wales	6 731 295	213	3.16	422	6.27	249	3.70
Sydney*	3 808 139	184	4.83	351	9.22	202	5.30
Victoria	4 972 779	122	2.45	223	4.48	145	2.92
Queensland	3 882 037	145	3.74	150	3.86	99	2.55
Western Australia	1 982 204	46	2.32	72	3.63	71	3.58
South Australia	1 534 250	49	3.19	104	6.78	68	4.43
Tasmania	482 128	23	4.77	32	6.64	25	5.19
Australian Capital Territory	324 021	16	4.94	15	4.63	9	2.78
Northern Territory	199 913	10	5.00	26	13.01	19	9.50
Australia	20 108 627	624	3.10	1044	5.19	685	3.41
New Zealand	4 093 383	91	2.22	149	3.64	91	2.22
Australasia	24 202 010	715	2.95	1193	4.93	776	3.21

* Includes private hospitals and hospitals not accredited by the Australasian College for Emergency Medicine (ACEM) with emergency departments staffed by ACEM Fellows. ◆

3 Hospital indicators of mass casualty preparedness — critical care resource requirements

Location	Surge population*	Critical care casualties† 15% threshold	Critical care casualties† 33% threshold	Percentage of critical care casualties at risk of: Operating theatre non-availability‡ 15% threshold	Operating theatre non-availability‡ 33% threshold	ICU bed non-availability‡ 15% threshold	ICU bed non-availability‡ 33% threshold
New South Wales	3 366	505	1 111	58%	81%	16%	62%
Sydney§	1 904	286	628	36%	71%	[19%]¶	44%
Victoria	2 486	373	820	67%	85%	40%	73%
Queensland	1 941	291	641	50%	77%	49%	77%
Western Australia	991	149	327	69%	86%	52%	78%
South Australia	767	115	253	57%	81%	11%	59%
Tasmania	241	36	80	36%	71%	12%	60%
Australian Capital Territory	162	24	54	33%	70%	37%	72%
Northern Territory	100	15	33	33%	70%	[42%]¶	21%
Australia	10 054	1 508	3 318	59%	81%	31%	69%
New Zealand	2 047	307	676	70%	87%	51%	78%
Australasia	12 101	1 815	3 993	61%	82%	34%	70%

* Surge population = catchment population (see Box 2) × 500 patients per million population. † No. of critical care casualties = surge population × 15% or 33%. ‡ Percentage of critical care casualties at risk of operating theatre or ICU bed non-availability = [(no. of critical care casualties – no. of operating theatres/ICU beds [see Box 2]) / no. of critical care casualties] × 100. § Includes private hospitals and hospitals not accredited by the Australasian College for Emergency Medicine (ACEM) with emergency departments staffed by ACEM Fellows. ¶ No. of ICU beds exceeded no. of critical care casualties. Percentage of ICU beds available = [no. of ICU beds – no. of critical care casualties / no. of ICU beds] × 100. ◆

situation do not meet US benchmarks. In the event of a major disaster, the model predicts that 61%–82% of critically injured patients may not have immediate access to operating theatres and 34%–70% may not have immediate access to ICU beds.

The best-case scenario for ICU bed availability would be in Sydney where critically injured patients would occupy all but 19% of the total ICU beds — in the unlikely event that they were not already occupied.

Applying the HRSA benchmark of 500 injured per million population[4] specifically to the Sydney metropolitan area predicts a preparedness target of 1900 acutely ill or injured patients from a chemical, biological or radiological (CBR) incident or an explosive incident. This figure is equivalent to 2.3% of the 83 500 seating capacity for a sporting venue such as the Telstra Stadium, Sydney.

Among the predicted 1900 acute victims in a Sydney terrorist attack, the CDC[2] estimate of critical disease burden suggests that about 630 patients (33%) will be dead, dying or critically injured, whereas using data from the review of mass casualty bombings,[8] there would be a more modest 286 (15%) of the potential 1900 victims requiring urgent surgery or intensive care.

Study limitations

While our survey represents the majority of ACEM-accredited hospitals in Australasia, it does not exhaustively identify all health care facilities, such as private hospitals and other health facilities, theoretically available to provide care for mass casualty patients. However, we did include a number of non-ACEM accredited and private hospitals in Sydney, which showed levels of preparedness similar to those of the ACEM-accred-

4 Hospital indicators of mass casualty preparedness — non-critical care resource requirements

Location	Surge population*	Non-critical care casualties (66% threshold)†	X-ray throughput per hour‡ (non-critical care casualties)	Non-critical care casualties (%) at risk of x-ray non-availability§
New South Wales	3 366	2 222	1 494	33%
Sydney¶	1 904	1 257	1 212	4%
Victoria	2 486	1 641	870	47%
Queensland	1 941	1 281	594	54%
Western Australia	991	654	426	35%
South Australia	767	506	408	19%
Tasmania	241	159	150	6%
Australian Capital Territory	162	107	54	50%
Northern Territory	100	66	114	[42%]**
Australia	10 054	6 636	4 110	38%
New Zealand	2 047	1 351	546	60%
Australasia	12 101	7 987	4 656	42%

* Surge population = catchment population (see Box 2) × 500 patients per million population. † No. of non-critical care casualties = surge population × 66%. ‡ X-ray throughput per hour (non-critical care casualties) = no. of x-ray machines (see Box 2) × 6. § Percentage of non-critical care casualties at risk of x-ray non-availability = [no. of non-critical care casualties – x-ray throughput per hour / no. of non-critical care casualties] × 100. ¶ Includes private hospitals and hospitals not accredited by the Australasian College for Emergency Medicine (ACEM) with emergency departments staffed by ACEM Fellows. ** X-ray throughput per hour (non-critical care casualties) exceeded no. of non-critical care casualties. Percentage of x-ray throughput capacity available = [x-ray throughput per hour – no. of non-critical care casualties / x-ray throughput per hour] × 100. ◆

5 Strategies for increasing hospital surge capacity*

- Discharge patients early
- Establish a discharge holding area
- Convert outpatient procedure beds into inpatient beds
- Use hallways and create alternative treatment areas
- Develop partnerships with other local hospitals to create treatment capacity
- Use non-heath care facilities (eg, schools)
- Use automated surveillance and tracking systems
- Link information from physicians, clinics, and hospitals to the public health system and first responders
- Implement communication systems to allow rapid dissemination of information to key players

* Source: adapted from the Agency for Healthcare Research and Quality.[3] ◆

ited departments in states other than New South Wales. Moreover, the extent to which these private and non-ACEM accredited hospitals would be willing and staffed to render trauma care was not explicitly surveyed and remains speculative. The mere presence of physical assets does not equate with adequate trauma care, as care of these complex patients is an interdisciplinary specialty and requires experience and training. However, even when data from metropolitan Sydney private and non-ACEM accredited hospitals are pooled with ACEM-accredited hospitals, there are marked deficiencies in physical resources needed for mass casualty care.

The numbers of operating theatres and x-ray machines were easily counted, but the number of available ICU beds and ventilators may be open to interpretation. We believe responders' counts may include interpretative error, yet we have no evidence to suggest consistent over- or under-reporting bias. We estimated, as a result of the survey, that Australia and NZ have 1193 ICU beds. However, an inquiry to the database for the 2004–05 financial year of the Australian and New Zealand Intensive Care Society Research Centre for Critical Care Resources revealed a total of 1227 ventilator beds in the public and private sectors for Australia and NZ (unpublished data).

The hospital non-responder rate for the survey was 20% for NZ and 5% for Australia, but, based on the magnitude of the resource gaps uncovered by benchmark comparisons, it would be unlikely that resource contributions from non-responders would eliminate such gaps.

How do our findings compare with current data?

Assessment of disaster management principles by emergency medicine and other specialty societies dates from 1995.[10] Difficulties in undertaking such assessments have led to international calls for continued development of standardised tools.[11] By the early 1990s, international disasters prompted the World Health Organization and other similar technical bodies to promulgate best-practice disaster management guidelines for hospitals.[12-15] In Australasia, a strategic plan for disaster medicine was published in 2003, with recommendations to develop standards on supply, equipment and nomenclature relating to disasters.[16] Concerns relating to both preparedness for, and management of, terrorism in Australasia are now appearing in the medical literature,[17-19] with trauma centre specialists[19] and health bureaucrats[20] expressing different views on mass casualty preparedness.

The recent occurrence of significant mass casualty events (in Bali, London, and Madrid) has focused attention on Australasian preparedness for such events. This has prompted local professional bodies to express public concern about our lack of disaster preparedness. The Royal Australasian College of Surgeons Trauma Committee has stated that:

> Successful medical responses to terrorist activities are critically dependent on well established Integrated Trauma Systems which do not currently exist in Australia at a quality level . . .
>
> If there are massive casualties, our hospitals would be easily overwhelmed and swamped.[21]

Descriptions of the medical response to the first Bali bombing[22] revealed that 66 critically injured patients arriving over 21 hours represented a tremendous challenge for the entire Australian health care system. Subsequently, the Department of Parliamentary Services reported:

> Without wishing to detract from the admirable effort by the Australian Defence Force (ADF) and various medical authorities across Australia in successfully evacuating and treating surviving victims of the Bali bombing . . . all respondents who commented on the issue agreed that the Bali bombing was not a significant or real test of Australia's ability to deal with a mass casualty incident . . .[23]

Implications for policy and practice

We have shown that there is a relative lack of appropriate physical resources in Australasian hospitals when compared with US benchmarks and there is a need for greater resource allocation.

Factors such as inpatient access block, overburdened operating theatres and ICUs, as well as medical and nursing shortages, are well known limitations for the Australasian hospital system. In a system which is already operating at close to full capacity, these factors would further limit the ability to mount a significant surge capacity for a sudden influx of large numbers of critically injured patients. We believe that the cumulative effect of all the present limitations of the hospital system would magnify existing resource gaps.

Strategies have been developed to address health facility surge capacity in acute disaster management (Box 5).[24] Surge capacity is a multidimensional concept that can be divided into a number of performance indicators. These include the ability to receive, stabilise, provide definitive surgery, and transfer patients for ongoing care. In Australia, there has been some progress made by the National Burn Response Plan Working Party, which has developed the AUSBURNPLAN.[25] This group has stated that, in a terrorist event, there would be 10%–15% of the total surviving casualties with severe burn injuries, in addition to the other injuries associated with explosions and other acts of terrorism. They also predicted that more than 20 severe burn patients and/or more than 100 severe trauma patients would overwhelm the capacity of any one state or territory and would require transfer interstate for further treatment. Each state is expected to ". . . maintain a register of burn assets, including ventilators, available beds and staff resources". However, there is no onus on the states or territories to provide the extra capability.

Various government bodies have attempted to test the health system response capability at both a state and national level in Australia.[20] The exercise "Supreme Truth" was held at the Royal Adelaide Hospital in 2003 and evaluated a major public hospital response to a mass casualty incident involving a CBR incident. Although the outcomes from this exercise were considered to be

improvements to the South Australian Major Incident Plan, there were other views that were less optimistic, including a report to the Federal Parliament which stated that:

> The exercise quickly revealed that health authorities were unable to deal with the incident, with the hospital admitting that their CBR response plan "fell over within the first 15 minutes".[23]

Concepts and benchmarks in surge capacity continue to evolve. By 2006, a Science of Surge conference in the US, sponsored by *Academic Emergency Medicine* and the National Center for the Study of Preparedness and Catastrophic Event Response, differentiated between daily and extraordinary surge requirements and made further calls for setting of benchmarks to trigger surge actions.[26,27]

It is crucial for disaster preparedness that planners understand critical bottlenecks in surge capacity. National coordination will be necessary to establish agreed hospital benchmarks and performance indicators in disaster preparedness. We believe that annual publication of these health-facility data on a national scale will foster transparency and enhance good governance in Australasian disaster preparedness.

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COMPETING INTERESTS

None identified.

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