The development of a web-based algorithm for the prediction of patient presentation rates at mass gatherings

Introduction

Large public events are often referred to as mass gatherings. Many large public gatherings, including fairs, sporting events and concerts are held in Australia. In the research literature mass gatherings are usually defined as events attended by more than 25,000 people (De Lorenzo 1997) though some authors include events attended by more than 1000 spectators. There is renewed interest in mass gathering medicine research because epidemiological data has not been used extensively to guide planners and providers in the first aid management of mass gatherings (De Lorenzo 1997) and, generally, research has focused on a single event or venue and has not provided data that can be transferred to other events and venues. Much of the existing data is descriptive and does not consider the influence of features of the crowd, venue, weather or event and their effect on patient presentation rates (Bowdish et al. 1992). As a result service providers tend to rely on historical precedents when making decisions about providing health care at these large events and there is limited understanding of the factors which might influence the number and type of patients presenting to health care services.

It is estimated that mass gatherings in Australia attract a combined spectator audience of approximately 14 million people each year. Several of these events generate a patient load of more tan 1 000 patients per day and health services at these events must be carefully planned and appropriately resourced to manage the number and type of patients expected.

This paper provides a summary and discusses the implications of research undertaken by St John Ambulance Australia and the University of South Australia that focused on the factors influencing rate and type of patient problem presenting to health care providers at major public events. The research developed regression models for the prediction of patient presentation rate (PPR) and transport to hospital rate (TTHR).

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Background to the research

The provision of emergency medical care and first aid for spectators and participants at large public events is a growing area of interest. This interest has been generated in part as a response to catastrophic events such as the Hillsborough stadium fire (April 1989) and recognition of the need for an effective and pre-planned response to emergencies of this kind. For providers of emergency patient care, however, the day-to-day provision of patient services at large public gatherings also requires careful planning. Larger public events present an array of difficulties and issues that must be considered if an effective response is to be provided to patients requiring emergency care. Planning for these events is complex and requires an understanding of typical patient presentation rates per thousand spectators (PPR) typical patient problems (associated with the event and audience) and other influences on the demand for services such as variation in the ambient temperature and humidity on the day of the event.

A number of issues associated with mass gatherings have been identified in the literature. There exists a high degree of variability in the medical and first aid provisions at such events (Saunders et al.1986; Franaszek 1986) and there is very limited information about services within Australia. General standards have been proposed (Emergency Management Australia 1999; Great Britain Health and Safety Commission 1993) but no uniform standards are accepted and widely used (Donagen 2000). The most commonly reported structure has the medical and first aid resources centred around fixed aid-stations, the number depending on the size and topography of the event. The planning required to support these services is extensive and time consuming. Hnatow and Gordon (1991) identified the following nine elements of health planning for mass gatherings: attendance (crowd size); personnel; medical triage and facilities; communications; transportation; medical records; public information and education; mutual aid; data collection. Additional elements identified in the literature have included public access, disaster planning and the operating environment (e.g. weather, terrain and duration).

Within Australia relatively few investigations have been undertaken in the area of mass gathering first aid (Flabouris and Bridgewater 1996; Fulde et al. 1992; Richards et al. 1984). The most useful of these has been the work of Flabouris and Bridgewater (1996) because it provided a beginning analysis of the relationship between the demand for first aid care and features of the operating environment such as the temperature and crowd size.

An important example of the effect of planned emergency patient care strategies at major events has been provided by a recent study of the impact of cardiac defibrillation on survival from cardiac arrest at the Melbourne Cricket Ground. In addition to providing support for the introduction of automatic defibrillators in public venues, this study emphasises the effect of establishing response arrangements that allow basic and advanced life support to access patients in a timely manner. The research, undertaken by St John Ambulance Australia, (Wassertheil 2000) indicates that a coordinated, planned and appropriately resourced emergency response can significantly reduce deaths from cardiac arrest at major public events. During the period of the research the incidence of cardiac arrest at the Melbourne Cricket Ground was 1:500,000 attendances. Of the 28 cardiac arrest patients in the sample, 24 (86%) left the venue alive and 20 (71%)

were discharged home from hospital. Twenty-one cases were managed with almost immediate cardiopulmonary resuscitation (CPR), early rapid response defibrillation and delayed Advanced Emergency Life Support. Of these, 19 (91%) were 'at scene' survivors and 15 (71%) survived to 'hospital discharge'. CPR was performed on 26 patients (92.9%) within two minutes from the time of collapse. The two cases where CPR was delayed occurred outside the venue in the car park.

This research shows that typical survival rates for life threatening illness can be significantly improved where a planned response is available; in this case the survival rate from cardiac arrest was an extraordinary 85.7%.

Emergency patient care response where large crowds gather relies on a multi-level response capacity. Given the size of both venues and crowds it is usual to rely on first aid trained personnel to provide first line basic life support for spectators. The presence of a large cohort of first aid trained personnel will reduce the time lapse between collapse of the patient and the provision of initial care significantly.

The second line response requires more highly trained first aid personnel able to provide elements of advanced life support (such as cardiac defibrillation) and finally, timely response and transport by ambulance services. Often medical, nursing and ambulance personnel will be in attendance as part of the first aid service at the event.

Each of these layers of the patient care service can operate effectively where good planning and coordination are present. The provision of an effective response requires a number of things: an effective communication system; appropriate placement and response times from first aid teams; adequate support from other public safety agencies (for example police) and adequate human and material resources to meet the demand for patient care. Each of these resource elements relies on good information about probable patient presentations (i.e. type and number of patients expected at the event).

Research findings

The research reported here arose from concern about the lack of epidemiological data suitable for the prediction of patient numbers and types across different public events and venues. Over a period of 12 months 201 mass gatherings (attended by more than 25,000 people) were surveyed throughout Australia. The survey was undertaken by St John Ambulance Australia personnel and the researchers, and collected data on the incidence and type of patient presenting for treatment and the environmental factors that may influence these presentations. Environmental factors included, weather, crowd size, mobility of the crowd, access to first aid, and type of event. A standard reporting format and definition of event geography was employed to overcome the event specific nature of many previous surveys.

The total number of spectators attending events in the research sample was 12,046,436. The total number of patients was 11,956 and of these 330 required subsequent transport to hospital for further treatment (see *Table 1*). The patient presentation rate per thousand spectators (PPR) was, on average, 0.992 compared with between 0.5 and 2.0 for mass gatherings reported in the literature. The highest PPR for a single event in the sample (26.85) was recorded for an outdoor rock festival held during the summer months, and the lowest rate (0.0) at a motor vehicle rally. The transportation rate (TTHR -transport to hospital per thousand in attendance) for all events was 0.027. TTHR's previously reported in the literature ranged between 0.01 and 0.55. Ambulances were in attendance at 63.2% of the mass gatherings in the sample; they were not in attendance at 28.4% of the events, and it was not known if ambulances were in attendance at 8.4% of the events.

Events in the research sample were defined as 'focused' or 'extended' and 'bounded' or 'unbounded'. This classification of events in terms of their geographical characteristics was a strategy to assist in the comparison of data across similar venue types. Events that were held in a clearly defined venue/location were described as 'focused'.

Events that were not focused on a single location, such as marathons and parades, were described as 'extended'. An event contained within a boundary, often fenced, was described as 'bounded'. Events that were not contained in this way were described as 'unbounded'. The most common event categories in the sample were bounded/focused and unbounded/extended. Patient presentation and transportation rates between these two categories differed significantly.

Bounded/focused events had a PPR of 1.26 and patients were transported to hospital at a rate of 0.03/1000. Typically, events included in this category were stadium-based sporting events including various football codes, concerts and fairs. Unbounded/extended events had a PPR of 0.26 and a TTHR of 0.02. These events were typically parades, fun runs and other races.

There are several features of the event categories that may account for the difference in PPR between bounded/focused events and unbounded/extended events. The most significant may be the availability of first aid and other patient care services at bounded/focused events. Patient care is more readily accessible and there may be less 'leakage' of patients to surrounding health care agencies at fenced events. This conclusion is however speculative, and further research will be required to evaluate the difference in risk of injury and illness between these two categories.

The research data demonstrates the effect of the event type on patient presentation rates. Events where the audience is predominantly seated and not

Patient category	Patient number	Percent of total patients	Transported number	Percent of total trans
cardiac (non arrest)	77	0.64	46	13.94
cardiac arrest	6	0.05	6	1.82
respiratory (non asthma)	88	0.74	12	3.64
asthma	353	2.95	18	5.45
heat related illness	126	1.05	9	2.73
laceration	763	6.38	15	4.55
fracture	121	1.01	54	16.36
drug/alcohol related	126	1.05	38	11.52
minor Injury	3084	25.79	18	5.45
minor problem	6460	54.03	9	2.73
other	752	6.29	105	31.82
Totals	11956	100	330	100

Table 1: The relative number of patient presentations in each category.

mobile generally demonstrate a significantly lower presentation rate. Typically these are large stadium events. At shows and fairs spectators tend to be more mobile and this seems to be associated with a higher incidence of injury.

The expected attendance at an event is a relatively strong predictor of the number of patients who may require treatment (Bowdish et al. 1992), although the PPR may reduce slightly in larger crowds. Crowd size, in the research sample, ranged between 25,000 and 600,000.

The prevailing weather conditions during an event have been cited as an important influence on the number and type of casualties presenting for treatment (Bowdish et al. 1992). Temperature and humidity are positively correlated to PPR though this effect is complex and relative humidity has the most consistent effect on the number of patient presentations. There is a positive linear relationship between relative humidity and PPR in most circumstances.

At temperatures in excess of 30 degrees celsius, in Australia, crowd awareness and behaviour appear to have reduced the effect of ambient temperature on the PPR. These results highlight the complex interrelationship between factors that influence the number and type of patient presentations with other variables such as the availability of alcohol and the mobility and activity of the crowd having an effect. Nonetheless there is cause for increased preparedness at events where high humidity (and temperature) is expected.

Further research utilising measurements of wind chill and heat index may provide a better understanding of the influence of weather because these parameters combine ambient temperature and relative humidity.

It is likely that an increase in the number and visibility of personnel at a venue results in a slight increase in the PPR because spectators are more likely to seek assistance for minor complaints that might not be treated if first aid personnel were not so readily available. Events included in the research were attended by St John personnel and the usual qualification profile for an event included first-aiders (basic first aid 45.3%) (advanced first aid 43.5%), nurses (7.2%), ambulance officers (2.7%) and medical officers (1.3%). The research identified a positive relationship between the number of health care personnel at an event and the recorded patient presentation rate. The average number of health care personnel on duty at events in the sample was 0.60/1000 in attendance.

Patient presentations were recorded using illness and injury categories that reflect those commonly used in the mass gathering literature. *Table 1* lists the relative number of presentations in each category.

Minor injuries (cuts, abrasions, sprains) and minor problems (headache, sunburn, blisters) account for 80% of patient presentations.

Asthma is the most prevalent of the potentially life threatening medical emergencies. The category 'other' includes several patient problems that are of concern though the incidence of each of these conditions is low. The most prevalent problems in the 'other' category are (752 patients in all) burns (13.4%), nausea (12.9%), epilepsy/fitting (8.7%), syncope (6.7%) and eye injury (6.2%).

The most prevalent form of injury requiring prompt management is laceration.

The dominance of minor injury and minor problems in the data underscores the importance of first aid personnel at mass gathering events. A large cohort of first aid trained personnel will provide a visible and accessible point of contact for patients requiring minor treatment. More severe conditions may then be referred on to medical, ambulance and nursing staff.

Predicting patient presentation rates

There is considerable support in the literature for the view that patient presentations at mass gatherings are influenced by several factors; thus simple analyses of mass gathering data that establish correlation between, for example, crowd size and PPR do not provide a sufficiently sophisticated tool for predicting patient presentations. The research reported here has focused on the development of predictive models that can be applied across different venues and types of event.

Regression analysis was used to develop models that predict within reasonable statistical limits the PPR and TTHR for mass gatherings. These models are complex but underpin an internet-based algorithm that appears simple and has been made available for use by event organisers, emergency services and health care providers to assist in planning for mass gatherings.

The model for prediction of PPR accounts for 64 percent of the variance in the research data and the TTHR model accounts for 31 percent of the variance in the data at the 95 percent level of confidence.

Models for the prediction of PPR and TTHR

Because there are several factors influencing the number and type of patients presenting at mass gatherings the models developed incorporate several of the environmental factors that are considered to be significant influences on PPR and TTHR.

Using the data three regression models were obtained. Univariate analysis and two-way plots were used to identify outliers and possible linear relationships with the dependent variables (total number of patient presentations), (total number transported to hospital), and (predicted number of patient presentations).

Single variable regression models were run to test the ability of each variable to account for the variance in the dependent variable and then a backward stepwise regression procedure was used to identify the best model for each. The first model predicts the number of patient presentations at a mass gathering (*figure 2*). Using the same modeling procedures outlined in *figure 2*, two models were identified for predicting the number of patients transported to hospital. One of these models has been incorporated into the web-based algorithm and can be used when the predicted number of presentations is known (based on the PPR model above). In the interest of brevity the model is not presented here though details can be accessed through the web-site.

The algorithm

The mass gathering algorithm for the prediction of PPR and TTHR, developed as an outcome of this research, can be accessed in the mass gathering section of the Emergency Management Research Page at: www.unisa.edu.au/nur/ESRIG/emr.htm. The algorithm can also be accessed from the St John Ambulance homepages at: www.stjohn.org.au

Conclusions

This paper reports on research into the influence of environmental factors (including crowd size, temperature, humidity and venue type) on the number of patients and the patient problems presenting to first aid services at large public events in Australia. Regression models were developed to predict patient presentation rates and transportation to hospital rates at future mass gatherings and these models have provided the basis

Model to predict the number of patient presentations at a mass gathering

The estimation equation is as follows:

Y = b0+ b1 C1 + b2 C2 + b3 C3 + b4 C4 + b5 C5 + b6 C6 + b7 C7 + b8 C8 + b9 C9
Where Y = the predicted number of presentations and:

b0 = -78.184699	b5 = -20.390940	b0 = INTERCEPT	C5 = SPORT
b1 = -31.488567	b6 = -0.616134	C1 = SEATS	C6 = HUMID
b2 = 84.556898	b7 = -0.000456	C2 = BOUNDED	C7 = ATTEND
b3 = 42.370240	b8 = 0.000016246	C3 = INDOOR	C8 = ATTHUMID
b4 = 81.319501	b9 = 20.067439	C4 = OUTDOOR	C9 = DAY_NGHT

The model is used in the following way:

- the value of SEATS is 1 when the event has a non-mobile population (i.e. attendees are seated), and zero when the population is mobile.
- the value of BOUNDED is 1 when the event is fenced/bound and zero when the event is unbound.
- the value of INDOOR is 1 when the event is indoors and zero when the event is outdoors.
- the value of OUTDOOR is 1 when the event is outdoors and zero when the event is indoors.
  events which are *both* indoor and outdoor record a 1 for INDOOR *and* a 1 for OUTDOOR.
- the value of SPORT is 1 for all sporting events and zero for all non-sporting events.
- HUMID is the level of humidity expected for the day of the event.
- ATTEND is the number of persons expected to attend the event that day.
- ATTHUMID is the result of multiplying expected humidity by expected attendance.
- the value of DAY_NGHT is 1 for events which are both day and night and zero for events which are only day or only night.

An example of the calculation is provided below:

For a seated, bounded, outdoor, day only, sporting event to be held on a 25 degree day with a humidity of 50% and an expected attendance of 40,000, the predicted number of presentations would be calculated as follows:

Y = -78.184699 + -31.488567*SEATS + 84.556898*BOUNDED + 42.370240*INDOOR + 81.319501*OUTDOOR + -20.390940*SPORT + -0.616134*HUMID + -0.000456*ATTEND + 0.000016246*ATTHUMID + 20.067439*DAY_NGHT

Y = -78.184699 + -31.488567*1 + 84.556898*1 + 42.370240*0 + 81.319501*1 + -20.390940*1 + -0.616134*50 + -0.000456*40000 + 0.000016246*(40000*50) + 20.067439*0

Y = -78.184699 -31.488567 + 84.556898 + 0 + 81.319501 -20.390940 -30.8067 -18.24 + 32.492 + 0

Y = 19.25 presentations

Figure 2: Model to predict the number of patient presentations at a mass gathering.

for an algorithm designed to assist emergency management agencies and venues in the prediction of PPR and TTHR.

Further work is being undertaken to replicate the project across a broader range of event types and environmental variables. This work will have two important outcomes. It will serve to strengthen the reliability of each model and expand the size of the research database. This later outcome will allow work to be undertaken on the prediction of patient illness and injury profiles for individual events.

The current models are limited to the prediction of overall patient presentation rates and the relationship between variables such as heat stress and cardiac presentations cannot be identified at present.

The models developed in this research provide a means to quantify the level of resource required to meet health care needs during large public gatherings. Mass gathering events generate health care resource demands at the event itself, and for ambulance and hospital authorities in the provision of transport and hospital resources suited to the scale of the event. For example, hospitals need to reserve sufficient emergency beds to manage the predicted influx of patients from an event in their vicinity. In the past, agencies have adopted a philosophy designed to ensure that more than adequate resources are available and this provides a form of insurance and reduces the likelihood that health care agencies will be overwhelmed. The models developed here provide an opportunity, in a resource deficient system, for resourcing to be related more closely to actual (predicted) need.

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