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ORIGINAL ARTICLE

PREDICTED IMPACT ON VICTORIA'S AMBULANCE SERVICES OF A NEW MAJOR TRAUMA SYSTEM

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Background: In 1999, a new major trauma system was proposed for the state of Victoria, Australia. The guidelines for the new system were aimed at delivering major trauma cases to definitive trauma care in the least time possible. The aim of the present study was to analyse the potential effect of this system on Victoria's ambulance services.

Methods: The present study modelled the workload of major trauma cases in Victoria's ambulance service for one year pre- and post-introduction of the guidelines. Cases were analysed regarding whether their first hospital destination would change under the proposed guidelines, and, subsequently, whether they would require interhospital transport to a higher level trauma service. The impact on the ambulance services was modelled as annual changes in distances travelled due to predicted changes in hospital destinations.

Results: Analysis of the predicted changes indicated that, in general, Victoria's metropolitan and rural road ambulance crews would not be greatly affected. However, some metropolitan road crews may have to travel extra distances for up to 110 cases per year. The major impact was on air retrieval crews, where the annual number of interhospital transfers is predicted to increase from approximately 150 to 330.

Conclusions: The present study demonstrated that most of the impact of a new trauma system on Victoria's ambulance services could be readily absorbed into the current workload. However, it also highlighted areas affected disproportionately within the ambulance services; in particular, air retrieval. Such studies are important to enable the effective implementation of new trauma systems.

Key words: ambulances, delivery of health care, injuries, transportation of patients, wounds.

INTRODUCTION

In the past few decades, there has been a clear acceptance that the systematic organization of regional trauma services is an efficient way to improve trauma outcomes. This stems primarily from studies demonstrating that morbidity from major trauma can be further decreased through appropriate prevention mechanisms. Studies in Australia have suggested that between 30 and 40 per cent of trauma deaths are potentially preventable.[1,2]

A number of studies have subsequently demonstrated the health benefits of an integrated, tiered trauma system in which patients are delivered directly to definitive trauma care, rather than initially stabilized at the closest emergency medical facility prior to transfer to a specialist unit.[3,4] This form of trauma system has been recommended within Australia by bodies such as the New South Wales and South Australian Departments of Health,[5,6] and the Australian National Road Trauma Advisory Council (1993),[7] as well as internationally by the Surgical Colleges in the USA and the UK.[8,9] In 1998, following such reports, a committee established by the Victorian Government likewise concluded that the optimum balance between early resuscitation and definitive treatment was most likely to be achieved if cases were transported directly to 'the highest designated trauma service accessible in 30 minutes' (Fig. 1).[10] The committee recommended designation of three inner-city hospitals as Victoria's Major Trauma Services (MTS); two as adult trauma services and one as a paediatric trauma service. The remaining hospitals were designated, from most to least specialized, as Metropolitan Trauma Services (MeTS; secondary level) and Regional Trauma Services (RTS; secondary level), Urgent Care Services (UCS; primary level), and Primary Injury Services (PIS; primary level).[10]

Effective implementation of the proposed system is, in part, dependent on the capacity of ambulance services to adapt to any consequent changes in workload. Previously published work estimating the impact of similar trauma system implementations on ambulance services is limited. The introduction of an integrated trauma system in western Sydney was demonstrated to have had a negligible effect on the number and duration of ambulance dispatches.[11,12] However, in the western Sydney study no rural or air transport was investigated. In addition, any impact on a specific ambulance service would be highly dependent on the particular capacity and structure of the service, and the population and geography of the region it services. Therefore, the aim of the present study was to analyse the potential effect of the proposed MTS on Victoria's ambulance services. The effect was measured by analysing proposed changes in the number of major trauma patients transported using Victoria's ambulance services, plus any change in the distances and times travelled for such transports, due to hospital by-passes.

METHODS

Setting

This study is set within the state of Victoria, which has a population of approximately 4.5 million people, with 3 million located within metropolitan Melbourne. To service Victoria, there are two public ambulance services; the Metropolitan Ambulance

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Service (MAS, with one dispatch centre) and Rural Ambulance Victoria (RAV, with five dispatch centres). Two helicopters provide air retrievals for Victoria, one at a metropolitan location and one at a rural location. In addition, there are five fixed-wing aircraft, all located at a metropolitan airfield approximately 10 min by road from the proposed MTS.

Data collection

The potential changes in workload for the MAS and RAV (as a consequence of the Ministerial review of trauma and emergency services in Victoria)[10] relate solely to changes in the transport of major trauma cases (see Fig. 1 for proposed transport criteria). We estimated these changes by modelling the workload of major trauma cases of the MAS and RAV for one year pre- and post-introduction of the guidelines. The present study is a

VITAL SIGNS (major trauma if any one of the following present)

	ADULT	CHILD (<16 years)
RESPIRATORY RATE	<10 OR > 30 / min	< 15 or > 40 / min
CYANOSIS	Present	Present
HYPOTENSION	< 90 mmHg	< (75 + age of child in years)
CONSCIOUS STATE	GCS < 13	GCS <15

OR

INJURIES (major trauma if any one of the following present)

ALL PENETRATING INJURIES: head/neck/chest/abdo/pelvis/axilla/groin
BLUNT INJURIES
• patients with a significant injury to a single region: head/neck/chest/abdo/axilla/groin
• patients with lesser injuries involving two or more of the above body regions
SPECIFIC INJURIES
• limb amputations/limb threatening injuries, suspected spinal injury, burns >20% (adults or children) or suspected respiratory tract, serious crush injury, major compound fracture, fracture to two or more of the following: femur/tibia/humerus, fractured pelvis

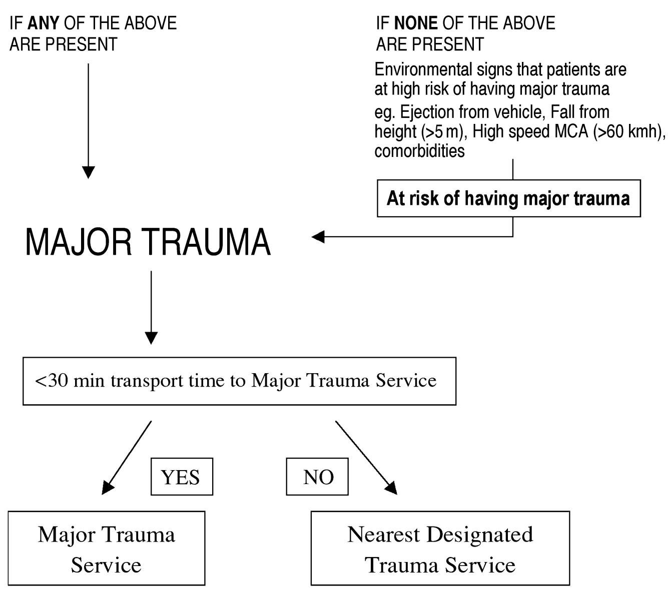

Fig. 1. Pre-hospital major trauma criteria as designated in the Report of the Ministerial Taskforce on Trauma and Emergency Services and the Department of Human Services Working Party on Emergency and Trauma Services.[10] GCS, Glasgow coma score.

detailed examination of Victorian major trauma cases presenting to hospitals within one financial year (July 1997 to June 1998, inclusive), the most recent financial year for which data was available.

We selected major trauma cases from the Victorian Admitted Episode Dataset (VAED), which includes all patient separations from public hospitals throughout Victoria. A number of variables were available for each separation, including up to 12 discharge diagnoses listed as International Classification of Disease (9th Revision; ICD-9)[13] codes. Information on the location and time of accident was collected from the ambulance patient-care records (PCR) within patient medical records at each hospital. Ethics approval for access to the VAED and patient medical records was obtained from the relevant committees of Monash University and all hospitals involved.

Cases were selected retrospectively if they had an ICD-9 injury code 800–839, 850–904, 925–929, 940–957, or 959 (where cases coded as 808 or 820 were only included if aged less than 65 years), an ICD/Injury Severity Score (ISS) score greater than 15, and a hospital separation date between July 1997 and June 1998, inclusive. Calculation of ISS was performed by the Victorian Department of Human Services using the ICDMAP-90 software (John Hopkins University and Tri-Analytics, MD, USA), resulting in an ICD/ISS score for each case. Some injuries were not assigned an ICD/ISS by the conversion program because non-specific ICD-9-CM codes are not assigned an Abbreviated Injury Scale score and are considered indeterminate. The prevalence of indeterminate ICD/ISS was approximately 4%, similar to other reports,[3] and such cases were excluded from our analyses. After initial case selection, the age distribution of cases was examined and it was found that the elderly (> 80 years) were over-represented compared to previous studies (21% compared to 3%).[14] As such, cases over the age of 80 were excluded from the analyses and the final caseload was adjusted to reflect a random 3% of cases of those aged over 80.

All data was recorded in a Access database. A quality control assessment of 10% of cases with data entered from available patient care records was undertaken. Data entry accuracy for all fields was found to exceed 98%.

Cross validation of data

Data derived from this selection procedure was compared proportionally to data collected in the 1992/1993 Victorian Major Trauma Study,[14] which collected data prospectively on major trauma cases by visiting the emergency departments of all major hospitals throughout Victoria during the years 1991–1993. Major trauma cases were defined as those with an ISS greater than 15.

Geographical analyses

Each case transported by ambulance was examined individually in order to determine whether the destination or mode of transport would change under the proposed guidelines, in accordance with the triage criteria shown in Fig. 1.

All cases and hospitals were plotted on a map of Victoria using MapInfo software (MapInfo Professional version 5.5; MapInfo, NY, USA). Using the MapInfo 'MarketDrive' add-on software, each case was analysed for the time taken to reach a MTS, a MeTS or a RTS. Cases were designated at the highest level of trauma care available within 30 min. Once the pre-hospital cases had been designated, each was considered for interhospital transport, according to the same criteria. In the present study, it was assumed that after consultation between hospitals 80% of potential interhospital transport cases would be transported again. As the exact rate of interhospital transport cannot be known without prospective analysis, an additional analysis was performed assuming that 100% of major trauma cases would eventually be delivered to a MTS. In areas that were more remote and rural, air transports were considered for interhospital transport if cases were greater than 40 km from a MTS. Cases between 40 and 150/200 km were designated as helicopter transport, cases further than 150/200 km were designated as fixed-wing transport.

To calculate changes in distance or time travelled by road ambulance crews, the one-way travel time and distance, calculated using 'MarketDrive', was doubled to account for changes to and from a major trauma case destinated hospital. To calculate changes in time travelled by air retrieval crews due to a gain or loss of a major trauma case, the known one-way flying time, taken from ambulance PCR, was doubled and 10 min were added to account for loading and unloading of patients.

Assessment of the burden of changes in major trauma transport is also dependent on the level of over-triage carried out by ambulance officers in the field. Over-triage is the incorrect identification and triage of a patient as a major trauma patient, and triage decisions are encouraged to err on the side of over-triage in order to minimize under-triage.[8,15] The basic analyses in the present study assume that half of the final population triaged by the ambulance services as major trauma is not true major trauma, based on international recommendations.[8] Uncertainty analyses have also been performed, assuming that non-major trauma cases make up one-third or two-thirds of the triaged population, as these rates have also been observed in practice.[8,16] Over-triage applies only to the pre-hospital, not interhospital, transport of major trauma patients.

RESULTS

Current cases

Using the definition described here, it was found that there were 1358 major trauma cases admitted to hospital during the 1997–1998 financial year. Seventy-five more major trauma cases either died in the hospital emergency department or were dead on arrival. The distribution of cases with respect to age, gender and injury type was compared to a set of 1025 major trauma cases collected prospectively in a 1993 major trauma study in Victoria, and was found to be very similar (Table 1). As expected, the majority of cases occurred within the metropolitan Melbourne area (60–70%; Table 1; Fig. 2).

Table 1. Classification of major trauma cases within the study set, in comparison to the Victorian Major Trauma Study[14]

	1993 VMTS	1997/1998 study case set
Age > 54	22%	21%*
Proportion male	68%	73%
Injury cause		
% Motor car accidents	57%	57%
% Fall	22%	22%
Proportion rural	34%	30–39%†
Inter-hospital transfer	24%	27%

*This figure incorporates the adjustment of those aged over 80; 3% of the study population.

†The range of 9% is based on the number of air transports without identified pick up addresses because such transports are often from rural areas.

VMTS, Victorian Major Trauma Study.

Accuracy of case selection

In this study, case selection was performed retrospectively, as a proxy for identification of major trauma patients by ambulance officers in the field. We made assumptions regarding the degree of over-triage, and we assessed the proportion of selected cases that would have been triaged as major trauma given the triage criteria described in Fig. 1. A random 10 per cent of cases within the current study was analysed by Victorian ambulance officers regarding their likelihood of being transported as major trauma under the proposed guidelines. Using this method, the positive predictive value of the study selection criteria, in reference to this operational definition of major trauma, was 80%.

Hospital use

It was found that pre-hospital transport cases were admitted predominantly to a proposed MTS (tertiary level), MeTS (secondary level) or RTS (secondary level). Only 13% of cases were initially

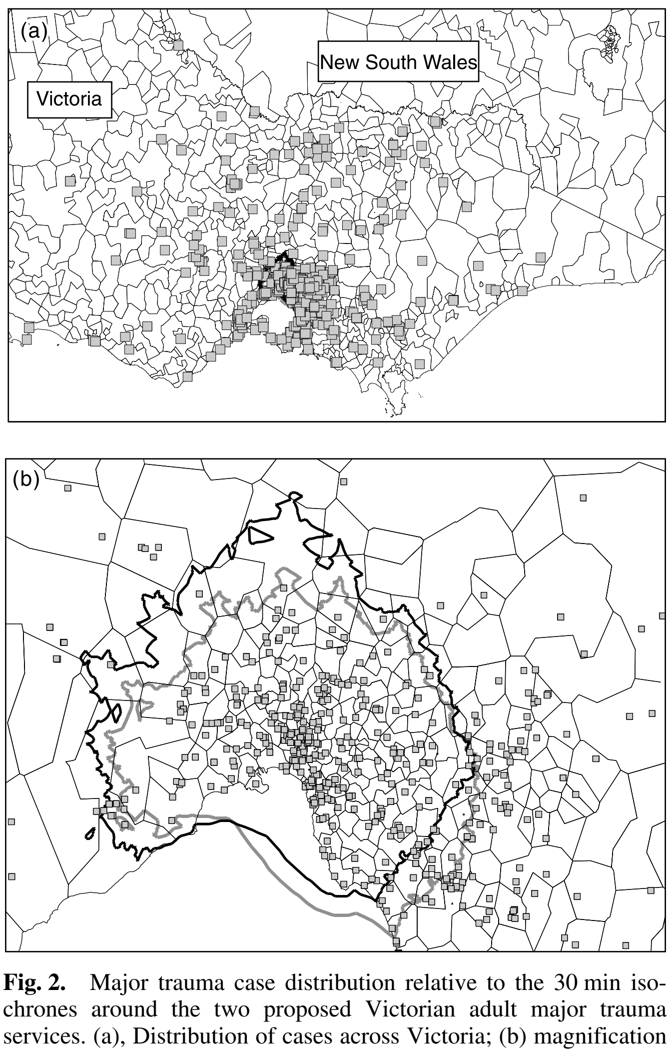

Fig. 2. Major trauma case distribution relative to the 30 min isochrones around the two proposed Victorian adult major trauma services. (a), Distribution of cases across Victoria; (b) magnification of metropolitan Melbourne. Lines indicate postcode boundaries.

admitted to a proposed PIS or UCS (primary level). Overall, approximately 50% of the major trauma cases in Victoria passed through one of the proposed MTS at some stage. However, as the guidelines recommend that almost all major trauma cases attend a MTS, it is expected that there will be an increase in the transport of major trauma cases to the MTS under the proposed guidelines.

Ambulance service use

As expected, the majority of cases were initially transported to hospital by ambulance (1162, or 86%), with only 9% of cases identified as transported by private means. These figures describe the observed numbers of major trauma transports with no adjustment for over-triage. Of those cases initially transported to hospital by ambulance, approximately 1057 (91%) were transported by road and 105 (9%) by air. Three hundred and sixty-one (27%) of all admitted major trauma cases were transported subsequently to a higher level hospital, with approximately 149 (40%) of these transports performed by air retrieval. In total, 125 road ambulance branches were involved in the transport of at least one major trauma case. For these branches, the annual number of major trauma cases transported ranged between 1–60 (median 5; mode 1).

Implications of proposed changes

Modelling of major trauma case transport by Victoria's ambulance services after introduction of the proposed major trauma system indicated that there would be changes to both the number of cases transported and the hospital destinations of these cases.

Table 2. Distribution of major trauma cases after first transport to a Victorian hospital

	MTS	MeTS or RTS	PIS or UCS
Current distribution	26%	61%	13%
Predicted distribution	52%	41%	7%

MTS, major trauma services; MeTS, metropolitan trauma services; RTS, regional trauma services; PIS, primary injury services; UCS, urgent care services.

It was found that 797 (69%) of pre-hospital major trauma cases transported by ambulance would not change their destination hospital under the proposed guidelines. Of the 365 cases that would change their destination hospital, 94% would be transported directly to a MTS (tertiary level), with the rest being transported to a secondary level trauma service (Table 2). The total burden of any change in destination hospital needs to incorporate the impact of potential over-triage. Assuming that half of the final population triaged by the ambulance services is not true major trauma, this corresponds to changes in pre-hospital ambulance transport of 730 major trauma cases, of which 703 would be transported by the MAS. These changes would affect 46 MAS and 7 RAV road ambulance branches. It was found that the road ambulance branches affected by the changes would most commonly have to travel an increased distance twice within a year (Table 3). In the 730 cases predicted to change destination hospital, the median extra distance travelled to and from a new destination hospital was 34 km for the MAS and 60 km for RAV (Table 3).

Once the first destination hospital had been allocated, it was possible to analyse interhospital transfers. It was expected that some ambulance branches would have to travel more, due to more onward transfer from proposed primary and secondary level hospitals, whilst others would have to travel less due to initial hospital by-pass. Although some trauma systems recommend all major trauma cases to go to a MTS, the Victorian guidelines suggest that, after consultation between hospitals, a proportion of major trauma cases will not be transported again. We have estimated the rate of interhospital transport at 80%. From this analysis, it was found that there would be an extra 137 interhospital transfers (a 38% increase) per year in Victoria under the proposed guidelines. The majority of these increases would be carried out by air retrieval, which would be responsible for 65% of the 497 predicted interhospital transports. For those road ambulances affected by the guidelines, the most common change for both the MAS and RAV would be to lose one interhospital transfer case per year (Table 3). The predicted decrease in interhospital transports by RAV is mainly due to the fact that the air ambulance would be the primary transport method for the excess interhospital transfers from these regions. Uncertainty analysis, assuming 100% interhospital transport of potential cases, did not significantly alter road ambulance transport numbers, but did lead to an additional 80 air transports annually.

Table 3. Summary of change in major trauma transport for each road ambulance branch over 1 year (excluding those with no change) for the MAS and RAV

	No. pre-hospital transports with changed destination hospital*		Average change in distance (km) travelled per altered pre-hospital case†		Change in no. inter-hospital major trauma cases‡		Average distance (km) travelled per inter-hospital case added or lost§	
	MAS	RAV	MAS	RAV	MAS	RAV	MAS	RAV
Minimum	2	2	5	10	−14	−10	14	60
Maximum	93	9	65	60	+21	−1	180	239
Median	9	2	34	60	−1	−1	40	120
Mode	2	2	14	60	−2	−1	40	60

*Figures are adjusted from the raw data and assume that half the triaged population is non-major trauma.

†Change in distance travelled is calculated as double the distance between the current destination hospital and the proposed destination hospital, due to extra travel there and back.

‡Figures are adjusted from the raw data and assume a rate of interhospital transport of 80%.

§Change in distance travelled is calculated as double the distance between the two hospitals.

MAS, Metropolitan Ambulance Service, RAV, Rural Ambulance Victoria.

Although most road ambulance crews will be affected minimally by the proposed guidelines, two types of ambulance transports will be significantly affected. First, the road crews located at the outer perimeter of inner Melbourne, which are near the 30 min boundary for the MTS, will have to take most major trauma cases to the MTS, rather than to their local hospitals. In addition, their interhospital transfer burden will increase due to their proximity to many of the secondary trauma services, which will be a first stop for a proportion of major trauma cases. Almost all of the 14 ambulance road crews with an increased distance to travel in more than 20 cases per year are located along this boundary and all are MAS crews. These crews have a median of 29 and a maximum of 110 cases with increased distance per year.

As the exact degree of over-triage of pre-hospital transport is not known, variations of the main analyses were performed, assuming that non-major trauma patients made up one-third or two-thirds of the triaged population. Such a variation had a significant effect on road ambulance branches with an initially large number of major trauma cases with altered destination hospitals. With an over-triage rate of two-thirds, such crews may experience between 29 and 156 altered hospital destinations per year. In comparison, with an over-triage rate of one-third, these crews experience between 17 and 86 altered hospital destinations per year.

The second significant increase in burden due to the proposed trauma system can be seen in air transport. It was assumed that the number of pre-hospital transports performed by air crews would remain the same; however, this may under-estimate the increased air load. It was found that interhospital air retrievals, both fixed-wing and helicopter combined, would increase from approximately 150 to approximately 330 cases (120% increase) per year. It was found that most of this increase would be experienced by the helicopters, with an increase of 129 cases per year. The times taken for these journeys range between 30 and 160 min. Fixed-wing aircraft would experience an increase of 22 cases per year, with travelling times between 70 and 325 min. An extra 32 cases per year would be transported by either helicopter or fixed-wing aircraft, with travelling times between 70 and 170 min.

Annual changes for the road ambulance service as a whole can also be calculated, with the predicted changes as a consequence of the proposed guidelines summarized as follows: for pre-hospital transport, introduction of the proposed guidelines would alter the destination hospital for 730 cases (MAS 703, RAV 26), constituting 419 extra hours of travel time (MAS 398, RAV 21) and covering 23 100 extra kilometres (MAS 21,800, RAV 1300). For interhospital transport of major trauma cases, road ambulances are expected to transfer 40 fewer cases (MAS +17, RAV −57), constituting 62 fewer hours of travel time (MAS +46, RAV −108) and covering 5600 fewer kilometres (MAS +2800, RAV −8400).

DISCUSSION

The present study demonstrates that, with the implementation of the proposed tiered major trauma system within Victoria, approximately 50% of Victoria's major trauma cases will be initially transported to a MTS (tertiary) within a 30 min transport time. This would be expected to have significant implications for major trauma outcomes, based on previous international studies.[3,4]

Investigation of the implications of the introduction of this system on Victoria's ambulance services indicated that, in general, Victoria's road ambulance crews would not be greatly affected, primarily due to the low incidence of major trauma compared to their annual workload of cases. These findings are similar to the introduction of a regionalized trauma service in western Sydney.[12] However, we also found that attention needs to be paid to those MAS road crews located at the boundary of permissible transport to a MTS. Such crews can have a significantly increased workload (up to 110 altered cases per year) due to an increase in the distance travelled for both pre- and interhospital transport of major trauma cases.

In addition, the present study has demonstrated that adherence to the proposed guidelines would have major implications for Victoria's air retrieval services. Combined helicopter and fixed-wing retrievals would be expected to transport an extra 180 time-critical cases per year, with travel times of up to 325 min per journey. If the demand exceeds the capacity of current air retrieval, a significant impact on rural road ambulances would also be observed. In the present study we did not examine any staffing implications for this increased retrieval workload. Clearly, there would be major resource issues needing to be examined, depending on the staffing model and transport platform chosen.

The present study has a number of methodological limitations, the primary one being errors in case capture. Such errors originate from a number of sources, including the use of a retrospective definition of major trauma to answer an operational question, the use of ICD/ISS scoring within this retrospective definition, and missing data within the VAED. The use of a retrospective definition was necessary for a number of reasons, the primary reason being the need to complete the analysis prior to the introduction of the proposed system. As it is not possible to retrieve cases from the ambulance databases based on clinical signs, case selection based on the proposed operational definition of major trauma (the triage guidelines) is only possible using a prospective study. While analysis of the cases by ambulance personnel indicated a positive predictive value for our selection of 80%, we were not able to analyse the sensitivity of our case capture in a similar way. Original validation of computerized ISS coding from ICD-9 codes demonstrated approximately 75% agreement with grouped, manually coded scores.[17] Consequently, it is possible that we have slightly over- or under-estimated the precise burden of the proposed system, but we expect the observed trends to remain robust. Due to these uncertainties of prediction and the significant impact that variation of over-triage rates had on the study outcomes, we strongly recommend a prospective study to monitor further the impact of the proposed system, once it has been implemented.

Sources of missing data included missing hospital patient identification (numbers), admission hospitals and accident site addresses. In the majority of cases (> 95%) other variables enabled imputation of relevant geographical variables. We have assumed that any errors within the case set are likely to be random with respect to the geographical distribution of our cases, which is the primary variable of interest in this study. While it is not ever possible to produce an exact model of reality, we have demonstrated that our case set compares well to a previous, prospectively collected Victorian major trauma case set.

The present study models the impact of a significant increase in the number of major trauma cases reaching proposed MTS following the introduction of a new major trauma system in Victoria. This highlights the increase in ambulance service resources that will be necessary to accommodate such a change. As expected, the major change will be for air ambulances, and road ambulance branches located near the 30 min perimeter of the proposed MTS. The changes in ambulance workloads described must be catered for, both financially and strategically, if the new major trauma system in Victoria is to be of maximum benefit. As changes are implemented, it will be important to monitor the actual system in comparison with the predictions of this model.

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