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# Redefining the golden hour for severe head injury in an urban setting: The effect of prehospital arrival times on patient outcomes

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ABSTRACT

*Background:* In patients with severe head injuries, transportation to a trauma centre within the "golden hour" are important markers of trauma system effectiveness but evidence regarding impacts on patient outcomes is limited.
*Objective:* To determine the effect of patient arrival within the golden hour on patient outcomes.
*Methods:* A retrospective cohort of adult patients with severe head injuries (head AIS $\geq$ 3) arriving within 24 h of injury was identified using the trauma registry from 2000 to 2011. Survival analysis was used to determine the effect of patient arrival time on overall mortality. Study outcomes were in hospital mortality and survival to hospital discharge without requiring transfer for ongoing rehabilitation or nursing home care.
*Results:* There was a significant association with mortality with each incremental minute of patient arrival (HR 1.002, 95%CI 1.001–1.004, $p = 0.001$). There was however no survival benefit observed for patients arriving within 60 min of injury time (HR 0.77, 95%CI 0.50–1.18, $p = 0.22$) but an apparent benefit for those presenting within 2 h of injury time (HR 0.31, 95%CI 0.15–0.66, $p = 0.002$). Patient arrival within 60 min of injury time was associated with increased odds of survival to hospital discharge without requiring ongoing rehabilitation (OR 1.78, 95%CI 1.14–2.79, $p = 0.01$).
*Conclusion:* A survival benefit exists in patients arriving earlier to hospital after severe head injury but the benefit may extend beyond the golden hour. There was evidence of improved functional outcomes in patients arriving within 60 min of injury time.


## Introduction

Trauma systems are largely designed and implemented around the capability of providing timely access to definitive care. This is predicated on the principle that time is a critical factor in determining the outcome of an injured patient. One of the most well known principles in medicine is the "golden hour" of trauma, which specifies that patient outcomes are improved when patient transport to a designated trauma centre is completed within an hour of injury.[1]

Although it would seem intuitive that treating patients more rapidly results in reduced mortality and secondary injury, the evidence for the golden hour in general and timing of craniotomies for head injuries on patient outcomes is limited.[2–6] A recent large multicentre study in the US did not find any association between prehospital transport time and mortality in all trauma patients.[6] Some studies have even suggested that decreasing time to craniotomy is associated with increased patient mortality.[7,8] Such studies may be limited by length and selection biases associated with patients who survive to undergo delayed craniotomies. A Canadian trauma centre study of 149 patients with acute traumatic subdural haemorrhage found a trend to improved survival in patients transported within 1 h of injury.[9]

Confirmation of such findings in more a more general group of patients with severe head injuries, where timing is thought to be crucial, may have important implications for trauma system design and clinical approaches.[10] The objective of the present study was to determine the effect of prehospital time on patient outcomes in a group of urban trauma patients with severe head injuries.

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## Methods

The study was conducted at a Major Trauma Centre in New South Wales Australia treating around 3000 trauma admissions a year, of which 250 are defined as major trauma (injury severity score $> 15$). After institutional human research ethics approval, the hospital trauma registry was queried for all adult (age 15 years or older) major trauma admissions with severe head injury (head abbreviated injury score $\geq 3$) due to blunt trauma between January 2000 and June 2011. Exclusion criteria were patients transferred from other health facilities, injuries occurring more than 24 h prior to hospital presentation, patients who self presented or did not come by ambulance and patients with no vital signs on arrival. Patients with associated spinal injuries transferred to other spinal trauma hospitals for ongoing care were also excluded.

Demographic and injury characteristics were obtained, including the time of incident routinely recorded on ambulance sheets, triage time from emergency department records and time of any craniotomy from operation notes. Patients were classified as having an urgent craniotomy if one was performed within 24 h of injury time. The patient arrival time was defined as the number of minutes from recorded incident time to triage time. Patients who arrived to the emergency department within 60 min or less of injury time were classified "Early" whilst the patients arriving after 60 min were classified as "Delayed".

For the purpose of multivariable analyses vital signs were categorised into clinically relevant groups of Glasgow coma score (GCS 3–8, 9–13 and 14–15) and systolic blood pressure (SBP $< 90$ and $>90$ mmHg). Vital signs were obtained from the first recorded observations after arrival to the emergency department and GCS calculated regardless of intubation status on arrival (Best verbal response = 1 for intubated patients). Patients with large extradural, subdural or intracerebral haemorrhages (both anterior and posterior fossa) were defined by abbreviated injury score (AIS) codes as those with depth greater than 1 cm on initial CT scan. All head CT scans for trauma were reviewed and reported by a Radiologist and entered prospectively into the trauma data registry. Patient disposition (transfer to rehabilitation, other hospital or nursing home or discharge for follow up), from the hospital was also recorded.

The primary outcome was in-hospital mortality analysed as a time dependent outcome with respect to observed length of stay. The secondary outcome was survival to hospital discharge without requiring transfer for ongoing rehabilitation or nursing home care.

### *Patient management*

Patients were managed using standardised severe head injury algorithms based on adult trauma life support principles. Performance indicators that were routinely assessed as part of a rigorous quality assurance programme included prehospital scene time of 20 min or less, definitive airways management within 10 min of arrival, CT scanning within 1 h of arrival and urgent craniotomies within 4 h of injury time, based on current American College of Surgeon quality indicators.

### *Statistical analysis*

Univariate analyses were used to describe crude differences in baseline characteristics and outcomes in patients who did or did not meet arrival benchmarks (less than 60 min from injury time) and craniotomy time benchmarks (less than 4 h from injury time). Means were described using standard deviations (SD) and medians with interquartile range (IQR). Multivariable Cox proportional hazards models were used to adjust for a priori confounders such as age, GCS categories, injury severity scores (ISS), hypotension and need for craniotomy within 24 h of injury. All other covariates were entered into the model using stepwise selection algorithm with an entry criteria p value of 0.10. To investigate the effect of increasing patient arrival time, the same model was repeated using dummy variables for different patient arrival to injury times (30, 60, 90, 120 and 180 min) as well as arrival time on a continuous scale. A Kaplan–Meier estimator plot was used to compare survival functions and Schoenfields residuals were used to test the proportional hazards assumption. Analysis was performed on SAS 9.2 (SAS Institute, Cary NC, USA) and significance was defined as a two tailed $p$ value of less than 0.05.

## Results

Between 2000 and 2011, 1550 adult patients were identified with major trauma and severe head injury (AIS $\geq 3$) from the hospital trauma registry. Of these 1034 patients fulfilled inclusion criteria, being patients transferred directly from scene within 24 h of injury. A further 51 records were excluded due to missing values for incident date or time. Therefore 983 cases were available for analysis of patient arrival time.

Of the 983 cases with severe head injury, 192 patients (20%) arrived after 60 min and 40 patients (4%) arrived after 120 min. Males comprised 72% of the study population and the mean age was 51 years (SD 23 years). The most common mechanisms of injury were falls (50%), pedestrians (16%), assaults (12%) and motor vehicle incidents (11%). The mean patient arrival time was 60 min (SD 100 min) (median 43 min IQR 33–56) from injury. Airway intubation was required in 47% of cases. The median ISS was 21 (IQR 17–26) and 21% had a large subdural or extradural haemorrhage. One hundred and fifty-five patients (16%) had a craniotomy performed within 24 h of injury.

Overall in-hospital mortality was 15% with 61% of patients requiring intensive care admission. Survival to hospital discharge without requiring transfer for rehabilitation or nursing home care occurred in 202 (21%) patients. Table 1 compares baseline characteristics and outcomes in "early" and "delayed" patient arrival to the emergency department. Patients in the delayed group were older and associated with more falls as the mechanism of injury. Patients in the early group were associated with lower GCS scores and were more likely to require airway intubation.

Fig. 1 shows the Kaplan–Meier overall unadjusted survival curves for the two study groups. In patients arriving within 60 min unadjusted 30-day survival was higher (81%, 95%CI 78–85%) compared to those arriving after 60 min (74%, 95%CI 60–84%) but did not reach statistical significance (log rank $p = 0.61$).

Using multivariable Cox proportional hazards model across strata of GCS (GCS covariate did not meet the proportional hazards assumption), there was a rise in mortality with each incremental increase in patient arrival time in minutes (HR 1.002, 95%CI 1.001–1.004, $p = 0.001$). This was adjusted using a stepwise selection algorithm which included into the final model age, presence of hypotension, GCS categories, airway intubation, large intracranial haemorrhage and whether a craniotomy was performed or not. When divided into relevant time intervals using the same model, there was no apparent association between mortality and the early patient arrival group (arriving within 60 min of injury) compared to delayed arrival (HR 0.77 95%CI 0.50–1.18 $p = 0.22$) (see Tables 2a and 2b). There was no association between arrival within 30 min and mortality (HR 1.15, 95%CI 0.75–1.77, $p = 0.51$). There appeared to be a survival benefit for patients arriving within 90 min (HR 0.35, 95%CI, 0.18–0.65 $p = 0.001$) and 120 min of injury (HR 0.30, 95%CI 0.16–0.64, $p = 0.002$).

Using the same covariates above in a multivariable logistic regression model, the odds of survival to hospital discharge without requiring transfer for ongoing rehabilitation or nursing