Diurnal variation in mortality in older nocturnal fallers

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Abstract

Background: the prevalence of older trauma patients is rising in Westernised populations. Age has an independent adverse effect on survival from injury. Factors contributing to this increased mortality are incompletely understood.

Objective: to examine the independent effects of age, time and mechanism of injury on survival from trauma at 30 days.

Received 9 September 2010; accepted in revised form 1 June 2011

Age and Ageing 2012; 41: 29–35
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Conclusions: age over 65 years has an independent detrimental affect on survival from trauma. A distinct diurnal variation in mortality was exclusive to older fallers.

Keywords: older, fall, mortality, elderly, trauma

Introduction

The older population is increasing and is predicted to represent approximately 25% of the population in Westernised societies by 2030 [1]. This is reflected in an increased prevalence of older trauma patients (>65 year age group) presenting to Emergency Departments [2]. Older trauma patients represent an important clinical subgroup, with several studies demonstrating a significantly higher morbidity, mortality and poorer long-term functional outcomes in this group compared with their younger counterparts [2, 3]. A higher prevalence of pre-morbid conditions (PMCs) and age-related physiological changes are important contributing factors to these adverse outcomes [4, 5]. Altered physiological responses associated with ageing may also contribute to an initial ‘under triage’ of the older trauma patient on arrival to an emergency setting, resulting in critical delays in treatment [6, 7]. Our understanding, however, of the critical factors determining the substantially worse outcomes from trauma with advancing age remains incomplete [2].

Falls are the most common cause of injury and associated morbidity and mortality in older adults, accounting for over 50% of injuries. This contrasts with trauma in younger patients, in whom road traffic collisions (RTC) are more common. Thirty-five per cent of community-dwelling older people fall at least once a year [8]. Approximately 25% of falls in this age group results in significant injury, incurring high costs in health and social care expenditure [1]. Falls in older people can be a reflection of underlying cardiovascular abnormalities and altered biorhythms, which in turn may contribute to a limited physiological reserve in the context of acute injury [9–11]. Furthermore, there is a strong overlap between falls and syncope in older people. Amnesia for loss of consciousness complicates up to 60% of cases of syncope resulting from carotid sinus syndrome (CSS) and 20% of syncopal episodes resulting from orthostatic hypotension [12]. In the absence of a witness account of the event, it can be difficult to differentiate between these two conditions. At least 20% of cardiovascular syncope in the older population presents as unexplained falls [13]. Blood pressure behaviour is abnormal in patients with CSS, with altered nocturnal blood pressures and a high prevalence of orthostatic hypotension [14]. Altered cardiovascular homeostasis could be reflected in an increased mortality following injury. We were interested in exploring possible associations between mortality differences in older compared with younger trauma victims. The aim of this study, therefore, was to examine the independent effects of time of injury, age and mechanism of injury on survival following trauma, using the UK Trauma Audit and Research Network database.

Methods

Patients

We studied patients injured as a result of blunt trauma, between 1 January 1989 and 1 January 2007, who were treated by participating hospitals of the Trauma Audit and Research Network (TARN), University of Manchester. TARN was established in 1989 to inform the UK Major Trauma Outcome Study that was based on the model of the US Major Trauma Outcome Study [15–17]. Over 60% of trauma-receiving hospitals in England, Wales and Northern Ireland submit their trauma data to TARN. The inclusion criteria to the TARN database are: injured patients of any age who sustain injury resulting in immediate admission to hospital for over 72 h; admission to an intensive or high dependency care unit; inter-hospital transfer for specialist trauma care or death occurring in hospital within 93 days of injury (irrespective of the cause). Data on age, gender, pre-injury health status, the time and location of the injury, pre-hospital interventions, the mechanism of injury, Glasgow Coma Scale (GCS) and vital signs on admission are all collected. Patients over the age of 65 years with an isolated fracture of the femoral neck or pubic rami and patients with single uncomplicated limb injuries are prospectively excluded. Patients submitted to TARN but
transferred to non-participating hospitals were also excluded from this analysis, as final outcomes were unknown.

Patient identifiers are removed prior to data transfer to the TARN coordinating centre. Details of every injury are recorded and defined according to the abbreviated injury scale (AIS) dictionary. From these data, the injury severity score (ISS), a measure of overall severity of anatomical injury, was calculated [18]. Analysis of the consistency of scoring has shown an inter-code reliability of 97% [19]. ‘Time of arrival’ to hospital was chosen for this study as the most objective time point to reflect the time of injury across all age groups. Outcome was based on 30-day mortality.

**Statistical analysis**

To evaluate possible age-related influences on outcome, age was categorised into: age <65years, ≥65years; hour of arrival into: 08:00–15:59, 16:00–23:59, 00:00–07:59; significant injury in body regions as: AIS >3 (moderate severity), in each of head, chest, abdomen, spine and limbs; mode of injury as: fall <2 m, fall ≥2 m, RTC or ‘other’ (mechanism). A factor to account for year of injury, pre-1995 and post-1994, was included in our model, as previous work identified improved survival by year from 1989 to 1994, after which it reached a plateau and no further improvement by year was observed [17].

Univariate analysis of mortality rates by age (as categorical <65 years, ≥65 years), mechanism of injury, ISS (mild 1–8; moderate 9–15; severe 16+) and hour of arrival was initially evaluated. Multivariate logistic regression analysis was used to assess the effect of age, gender, mode of injury and hour of arrival on mortality. Multivariate analyses were adjusted for pre-existing medical conditions (PMCs), a category to account for year of injury, pre-1995 and post-1994, was included in our model, as previous work identified improved survival by year from 1989 to 1994, after which it reached a plateau and no further improvement by year was observed [17].

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As the effect of gender on outcome is modified by age, we also examined this effect in our analysis by testing for an interaction between age and gender. The initial analysis revealed an increased mortality in patients over the age of 65 years presenting between midnight and 8 a.m., therefore we also examined the interaction between age and hour of arrival, for improvements in model fit using likelihood ratio (LR) tests and area under the receiver operator curve. Mortality rates by hour of arrival were examined for each of three mechanisms of injury: high falls (>2 m), low falls (<2 m) and RTC, stratified by ISS. Where diurnal variation in mortality was detected, within an age group, logistic regression analysis examined the impact of the ‘mechanism and time of arrival interaction’. In the case of significant interactions with age, separate logistic regression models were considered for predicting mortality at 30 days by age group <65 and ≥65 years for interpretation of the odds ratios. A separate analysis of two-way interactions between ‘hour of arrival’ and ‘mechanism of injury’ was considered within the individual age groups. Odds ratios and 95% confidence intervals (CIs) are presented. Statistical significance at $P < 0.05$ is assumed. Goodness of fit was assessed using the Hosmer–Lemeshow test and analyses were performed in STATA statistical software version 10.

**Results**

The TARN database consisted of 219,000 trauma patients, 24.9% were over the age 65 years at the time of analysis. Cases where data were incomplete were excluded from the analysis ($n = 28,880$). Patients who were transferred between hospitals when their final outcome was unknown were also excluded from the analysis ($n = 22,563$). In the mechanism of injury category ‘other’, the numbers of older deaths and survivors per hour in these groups were small, making modelling of their impact impossible within a stable model. This group was also excluded from the analysis ($n = 30,036$). The final study cohort was limited to patients who sustained blunt trauma, with a mechanism of injury of RTC or low fall, resulting in 137,521 trauma patients in the final study cohort; 40,755 (29.6%) were over the age of 65 years (Table 1).

**Table 1.** Descriptive analysis of the study population (1989–2006)

<table>
<thead>
<tr>
<th></th>
<th>Age &lt;65 years</th>
<th>Age ≥65 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dead</td>
<td>Alive</td>
</tr>
<tr>
<td>$n$ (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median age</td>
<td>29.0</td>
<td>35.0</td>
</tr>
<tr>
<td>Median ISS</td>
<td>34</td>
<td>9</td>
</tr>
<tr>
<td>Gender, $n$ (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>3,008 (5)</td>
<td>57,655 (95.9)</td>
</tr>
<tr>
<td>Female</td>
<td>1,061 (2.9)</td>
<td>35,042 (93.1)</td>
</tr>
<tr>
<td>Time of arrival, $n$ (%)</td>
<td>8:00–5:59</td>
<td>36,340 (96.5)</td>
</tr>
<tr>
<td>Age, $n$ (%)</td>
<td>1,974 (4.4)</td>
<td>42,267 (95.6)</td>
</tr>
<tr>
<td>6:00–7:59</td>
<td>800 (5.4)</td>
<td>14,090 (94.6)</td>
</tr>
<tr>
<td>RTC, $n$ (%)</td>
<td>3,659 (6.7)</td>
<td>51,334 (93.3)</td>
</tr>
<tr>
<td>Fall &lt;2 m, $n$ (%)</td>
<td>410 (1.6)</td>
<td>41,363 (99)</td>
</tr>
</tbody>
</table>

ISS, injury severity score; RTC, road traffic collision.
Univariate analysis of mortality rates by ISS (mild, moderate and severe) and hour of arrival revealed a distinct diurnal variation in mortality in patients over the age 65 years who were injured as a result of a low velocity fall mechanism (<2 m, Figure 1). This increased mortality was exclusive to older low velocity fallers and was observed in older patients injured by other mechanisms or patients aged less than 65 years. Confounding influences on survival from injury could account for this observation. To determine whether this finding was the result of factors other than time of day, detailed multivariate logistic regression analyses adjusting for known confounders of survival were then undertaken.

The initial logistic regression analysis considered factors predicting death for all age groups. Age was observed to be an important determinant of outcome, with increased odds of death of 9.58 (95% CI: 8.78–10.45) in the over 65-year group, compared with their younger counterparts (Table 2). When age by arrival time interaction was considered, this contributed statistically to the overall fit of the model (LR; $\chi^2 = 47.91, P < 0.0001$). Gender also had a statistically significant effect on outcome; females had a lower odds of death compared with males; OR = 0.9 (95% CI: 0.84–0.96). When the age by gender interaction was examined, nested within the model, it significantly contributed to the statistical fit of the model (LR; $\chi^2 = 31.95, P < 0.0001$) (Supplementary data are available in Age and Ageing online, Appendix 1).

Trauma patients over the age 65 years presenting between midnight and 8 a.m. had a significantly increased odds of death, OR = 1.5 (95% CI: 1.29–1.73), compared with those arriving between 08:00 and 16:00, OR = 1 (95% CI: 0.9–1.1) (Table 2). Similar analysis in patients less than 65 years revealed the odds of death was reduced in those presenting after midnight, OR = 0.75 (95% CI: 0.66–0.82), compared with those arriving between 08:00 and 16:00, OR 0.8 (95% CI: 0.7–0.9) (Table 2). Separate multivariate analysis of the over 65-year age group identified a doubling of odds of death in those injured as a result of a fall <2 m, if they presented between midnight and 8 a.m., compared with those between midnight and 8 a.m., $OR = 2.1$, (95% CI: 1.32–3.30), compared with those presenting between 08:00 and 16:00, OR = 1.2 (95% CI: 0.9–1.5). This phenomenon was not observed in younger patients.

The median time to death between older and younger trauma patients was significantly different ($P < 0.001$; Mann–Whitney U test). The median time to death in the older group was 98.8 h compared with 26.1 h in those aged less than 65 years. There was no significant difference in the median time to death by hour of arrival in the older age group. Distribution of injury by body region on outcome

Figure 1. Mortality by hour of arrival in the over 65-year age group, injured as a result of a low velocity fall ($n = 40,755$). Univariate analysis of mortality at 30 days in the ≥65-year old group, injured as a result of a low velocity fall (<2 m), by hour of arrival and injury severity, revealed an increased mortality for all grades of injury severity in those presenting between midnight and 8 a.m. ISS, injury severity score; mild (ISS: 1–8), moderate (ISS: 9–15), severe (ISS: >15).
Table 2. Mortality at 30 days by age group (categorical data <65 year and ≥65 years)

<table>
<thead>
<tr>
<th>Mortality @ 30 days</th>
<th>Age &lt;65 years (n = 96,766)</th>
<th>Odds ratio (95% CI)</th>
<th>Odds ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMC</td>
<td>0.7 (0.7–0.7)</td>
<td>0.8 (0.7–0.8)</td>
<td></td>
</tr>
<tr>
<td>ISS</td>
<td>1.1 (1.0–1.0)</td>
<td>1.1 (1.0–1.1)</td>
<td></td>
</tr>
<tr>
<td>Male (reference)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender: female</td>
<td>1.1 (0.9–1.2)</td>
<td>0.8 (0.7–0.9)</td>
<td></td>
</tr>
<tr>
<td>PMC: none (reference)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMC: yes</td>
<td>2.1 (1.8–2.5)</td>
<td>2.9 (2.4–3.5)</td>
<td></td>
</tr>
<tr>
<td>MOI: RTC (reference)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOI: fall &lt;2 m</td>
<td>1.2 (1.1–1.4)</td>
<td>1.0 (0.9–1.1)</td>
<td></td>
</tr>
<tr>
<td>Year: pre-1995 (reference)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrival time: 00:00–05:59</td>
<td>0.7 (0.7–0.8)</td>
<td>0.8 (0.7–0.9)</td>
<td></td>
</tr>
<tr>
<td>Arrival time: 06:00–11:59</td>
<td>0.8 (0.7–0.9)</td>
<td>1.0 (0.9–1.1)</td>
<td></td>
</tr>
<tr>
<td>Arrival time: 12:00–17:59</td>
<td>1.2 (1.1–1.4)</td>
<td>1.0 (0.9–1.1)</td>
<td></td>
</tr>
<tr>
<td>Arrival time: 18:00–23:59</td>
<td>0.75 (0.6–0.8)</td>
<td>1.5 (1.3–1.7)</td>
<td></td>
</tr>
</tbody>
</table>

Age by arrival time interaction significantly contributed to the model (P < 0.0001). We present results by age <65 years and ≥65 years. GMC, Glasgow Coma Score; ISS, injury severity score; PMC, pre-morbid medical condition; MOI, mechanism of injury; RTC, road traffic collision.

by age group and hour of day was not significantly different. The presence of PMCs was associated with increased odds of death in all age groups (Table 2). This impact was slightly greater in those over 65 years; OR = 2.9 (95% CI: 1.8–2.5) compared with those aged less than 65 years; OR = 2.1 (95% CI: 2.4 to 3.5).

Discussion

We observed a 10-fold increased odds of death from trauma in older patients when known confounders of survival were adjusted for [4, 20]. We also identified an unexpected doubling of the odds of death in older patients injured as a result of a low velocity fall, when they presented between midnight and 8 a.m. This increased mortality with trauma presentations at night was exclusive to older fallers and was not seen in younger trauma patients, or in older patients injured by other mechanisms. To the best of our knowledge this observation has not been previously reported.

Similar to previous reports we found that the temporal distribution of deaths in patients over the age of 65 years compared with younger trauma patients was significantly different [22]. The majority of deaths were delayed (98.8 h) in the older group compared with the earlier time to death in younger patients (26.1 h). There was no further variation in time to death in the older population by time of presentation. Trauma deaths in the majority of older trauma patients are attributable to multiple organ failure and hence are more commonly delayed deaths [23], in contrast to younger trauma patients who die earlier often irreversible brain injury.

Regarding the clinical relevance of our findings, the question that arises is why is mortality higher in older fallers when they present at night. Isolating the aetiology of these observations is outside the scope of the trauma registry, and requires further prospective study. There are, however, a number of possible explanations for this observation. Intrinsic patient factors may play an important role, i.e. the aetiology of the fall may be different at night. Altered autonomic function predisposes to falls at night (orthostatic hypotension) and may in turn impair of physiological responses to injury [14, 24]. Biological rhythms are integral to physiological homeostasis [9]. Many biological rhythms are circadian and synchronised to the 24-h day and ageing is associated with a decline in circadian function [9]. Circadian and orthostatic blood pressure are also abnormal in CSS, predisposing to falls at night [14]. Furthermore, the arterial baroreflex, a key cardiovascular homeostatic reflex, has a circadian variation, which is modified by the ageing process [9–11]. Ageing is associated with a decline in visual acuity. Recent work indicates that impaired visual acuity in ageing is associated with impaired orthostatic blood pressure control, which may also be a factor contributing to fall risk at night (Finnucane, Kenny, personal communication). Impaired vision coupled with extrinsic factors, such as poor lighting and psychotropic medications, increase the likelihood of nocturnal falls [25] and modify cardiovascular homeostatic responses to injury [26].

Current triage criteria are less effective in identifying older patients requiring immediate care [6, 7]. Initial vital signs are often misleading in this group [6, 27]. This is compounded by a low physiological reserve and a narrow margin between hypovolemic shock and over resuscitation. Improved survival is seen with early invasive monitoring, and in circumstances where a good functional outcome is expected, an aggressive approach to resuscitation has been shown to result in improved outcomes [28]. Involvement of geriatric specialists in the interdisciplinary post resuscitation care of older trauma patients reduces mortality and should be an important consideration in developing systems of care for older trauma patients [29].

Limitations

The findings of this study are limited by those of the TARN database. TARN contains a mixture of urban and rural acute general hospitals with a bias towards larger hospitals. Selection bias through hospital membership is therefore not considered to be a major issue. Data quality are variable from participating hospitals [21]; however, analyses have shown that cases tend to be missing at random [17]. Data are therefore internally consistent and considered to have reasonable generalisability.

Excluding isolated hip fractures in the over 65-year age group will miss up to 20% of fall-related injuries requiring admission. However, this does not alter the validity of the study design or the findings, which are strengthened by the large number of patients in this study. Furthermore, recent evidence emphasises the importance of not including hip
There is a need for prospective studies in this area.

Conclusions

Age is an independent negative predictor of survival from trauma. There is an unexpected doubling of the odds of death in older people injured following a low velocity fall when they present at night. Our understanding of falls biorhythms and the relative contribution of intrinsic and extrinsic factors on falls risk and survival following fall-related injuries is incomplete and requires further prospective studies.

Key points

• Age is an independent predictor of outcome following trauma.
• Factors contributing to this increased mortality remain unclear.
• There is a doubling of the odds of death in older persons presenting at night with injuries resulting from a low velocity fall.
• There is a need for prospective studies in this area.

Acknowledgements

All of the authors listed have had a significant role in the project, its execution and analysis and the writing of the paper. This included the conception and design, analysis and interpretation of data. Dr McMahon drafted the article and it has been critically reviewed and approved by all authors.

Conflicts of interest

None declared.

Ethical approval

It was obtained for research on anonymised data on TARN from the Patient Information and Advisory Group (PIAG).

Funding

TARN is funded by subscription from its participating NHS and European Trusts. All authors declare that the answer to the questions on your competing interest form are all no and have nothing to declare.

Supplementary data

Supplementary data mentioned in the text is available to subscribers in Age and Ageing online.

References

Association between the Geriatric Giants of urinary incontinence and falls in older people using data from the Leicestershire MRC Incontinence Study

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Abstract

Objective: to determine whether urinary incontinence per se and different types of urinary incontinence individually are associated with an increased risk of falls in those aged 70 years and over. To investigate whether the presence of urinary symptoms, poor quality of life and physical limitations in this population with urinary incontinence is associated with falls.

Design: study using data from the cross-sectional postal questionnaire undertaken in the Leicestershire Medical Research Council Incontinence Study.

Setting: Leicestershire.

Participants: a total of 5,474 people aged 70 years or more living in the community randomly selected from general practitioners’ lists.