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Does age matter? The relationship between age and mortality in penetrating trauma

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ABSTRACT

Purpose: Trauma is a significant cause of mortality among elderly patients, with blunt mechanisms accounting for the majority of deaths in this population. Penetrating trauma promises to evolve as an increasingly important aetiology of mortality in the elderly; particularly as the age composition of the overall population continues to shift. Unfortunately, very little data regarding outcomes following penetrating trauma in the elderly exists. The purpose of this study was to define the relationship between age and mortality following penetrating injuries and determine if differences between outcomes of elderly patients sustaining penetrating and blunt trauma exist.
Methods: After IRB approval, we conducted a retrospective trauma registry review at an urban Level 1 trauma centre between January 1, 1998 and December 31, 2005. Demographic, injury, and mortality data for all patients were recorded. The relationship between age and mortality for both blunt and penetrating injuries was examined by comparison of age-specific mortality and relative risk of mortality for both mechanisms at 10 year age intervals. Additionally, the relative risk and 95% confidence interval for mortality in each age group were compared.
Results: There were 26,333 blunt trauma admissions and 8843 penetrating trauma admissions during the 8-year study period. The mortality following both blunt and penetrating trauma remained stable until the age of 55 and increased steadily thereafter. When differences in mortality following blunt and penetrating mechanisms were examined, the overall mortality of penetrating trauma was found to be 2.63 times that of blunt (11.0% vs. 4.2%, RR 2.63; 95% CI: 2.42, 2.85, $p < 0.0001$). After adjustment for age and other confounding factors, the relative risk of mortality due to penetrating mechanisms was 1.65 (95% CI: 0.88, 2.89, $p = 0.10$) that of blunt mechanism counterparts. Although statistically higher in penetrating trauma, the relative risk of mortality between penetrating and blunt trauma decreased with increasing age.
Conclusion: The mortality rate with respect to penetrating trauma remains relatively constant until the age of 55, increasing thereafter. When compared to blunt trauma, the relationship between age and mortality in penetrating trauma is similar except that the relative mortality in penetrating trauma is significantly higher for each age group.

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Introduction

According to U.S. Census Bureau projections, the age of the American population will continue to mature in the coming decades. In the year 2000, Americans over the age of 45 comprised 34.5% of the population. By the year 2020, this figure is predicted to reach 41.2%. According to 2004 projections, this shift in age demographics is anticipated to continue well into the 21st century.[9]

While penetrating mechanisms are less common sources of trauma among more elderly members of the population, the number of older individuals sustaining these injuries is likely to increase as the national age demographic evolves. Unfortunately, comparatively less is known about the outcomes of older patients following penetrating trauma than more common blunt mechanisms. Even as understanding of the effects of age-related

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physiological responses to trauma continues to evolve,[4,5] the relationship between age and outcomes of penetrating trauma remains poorly appreciated.

Patients and methods

After approval from the Institutional Review Board, a retrospective review of the trauma registry at the Los Angeles County+University of Southern California (LAC+USC) Medical Center was performed to identify all trauma patients admitted between January 1, 1998 and December 31, 2005. Demographic and clinical data, including age, gender, injury mechanism, Glasgow Coma Scale (GCS), Injury Severity Score (ISS), Abbreviated Injury Score (AIS) and mortality were obtained and entered into a computerised spreadsheet (Microsoft Excel 2003, Microsoft Corporation, Redmond, WA). All statistical analysis was performed using SPSS for Windows©, version 12.0 (SPSS Inc., Chicago, IL).

For the analysis, age was considered in 10-year intervals beginning at 15 years and other continuous variables were dichotomised using clinically relevant cut-points (GCS ≤ 8 or >8, ISS ≥ 16 or <16 and AIS >3 or ≤ 3). Differences in baseline demographic and clinical characteristics between patients with blunt and penetrating injury mechanisms were assessed using chi-square or Fisher's exact test for comparison of proportions and Student's *t*-test or Mann–Whitney for comparison of means.

In order to identify a possible cut-off age after when a significant increase in mortality occurs, the mortality rate within each age group was calculated with the relative risk of death compared to the prior age group was derived. This analysis was performed separately for patients with a blunt and for those with a penetrating mechanism of injury.

Bivariate analysis was performed to identify differences in mortality between blunt and penetrating injuries within each age group. Relative risk and 95% confidence interval was derived. A graphic comparison of the mortalities by mechanism within each age group was obtained by plotting the age-specific mortality for blunt and penetrating injuries and identifying the overlaps of the error bars representing the 95% confidence intervals for each age-specific mortality rate.

To further analyse the relationship between age and mortality in penetrating and blunt trauma, logistic regression was performed to adjust for all factors that were significantly different between the two populations at $p < 0.2$. Adjusted relative risk of mortality between penetrating and blunt injuries, controlling for both age and the confounding factors identified, was converted from the adjusted odds ratio and 95% confidence interval.[10]

Results

During the 8-year period, a total of 35,184 patients were admitted. Of these, 25% sustained penetrating injuries. Individuals older than 55 years represented 3% of the total in the penetrating group and 17% in the blunt group ($p < 0.0001$). As outlined in Table 1, the penetrating and blunt injury groups also differed significantly for gender, GCS, ISS and AIS. Patients in the penetrating group more often were male (92% vs. 73%, $p < 0.0001$), had a GCS ≤ 8 (11% vs. 9%, $p < 0.0001$) and an ISS ≥ 16 16 (22% vs. 13%, $p < 0.0001$).

Table 1
Comparison of patient characteristics and injury severity between blunt and penetrating injuries.

Characteristic	Blunt injury (N = 26,339)	Penetrating injury (N = 8845)	*p*-Value
Male	73% (19,249/26,339)	92% (8111/8845)	<0.0001
Age $\geq$ 55 years	17% (4558/26,339)	3% (290/8845)	<0.0001
ISS $\geq$ 16	13% (3436/26,947)	22% (1973/8830)	<0.0001
Abdominal AIS > 3	1.4% (373/26,339)	6.8% (598/8845)	<0.0001
Chest AIS > 3	1.6% (430/26,339)	7.6% (670/8845)	<0.0001
Head AIS > 3	7.4% (1952/26,339)	5.5% (486/8845)	<0.0001
GCS $\leq$ 8	8.5% (2177/25,676)	11.4%(1000/8744)	<0.0001

Table 2
Relative risk of mortality according to age group for blunt injuries.

Age group in years	Blunt injury		
	%Died (# died/# in group)	Relative risk[a] (95% CI)	*p*-Value
<15	2.5% (60/2303)	–	–
15–24	2.7% (138/4976)	1.06 (0.79, 1.43)	0.75
25–34	2.7% (147/5249)	1.01 (0.89, 1.27)	0.98
35–44	3.5% (176/4907)	1.27 (1.02, 1.58)	0.03
45–54	3.9% (150/3670)	1.13 (0.92, 1.40)	0.27
55–64	6.0% (125/1974)	1.52 (1.20, 1.91)	0.0005
65+	12.3% (303/2155)	2.07 (1.69, 2.53)	<0.0001
Total	4.2% (1099/26,333)	–	–

[a] Compared to prior age group.

Table 3
Relative risk of mortality according to age group for penetrating injuries.

Age group in years	Penetrating injury		
	%Died (# died/# in group)	Relative risk[a] (95% CI)	*p*-Value
<15	12.3% (26/185)	–	–
15–24	11.3% (434/3391)	0.92 (0.64, 1.33)	0.75
25–34	10.3% (257/2244)	0.91 (0.78, 1.05)	0.20
35–44	10.0% (140/1259)	0.97 (0.80, 1.18)	0.83
45–54	9.4% (58/559)	0.94 (0.70, 1.26)	0.73
55–64	14.1% (26/158)	1.50 (0.98, 2.32)	0.09
65+	26.4% (28/78)	1.87 (1.16, 3.01)	0.015
Total	11.0% (969/8843)	–	–

[a] Compared to prior age group.

The age-specific death rates and 95% confidence intervals for the blunt and penetrating injury groups are summarised in Tables 2 and 3, respectively. For blunt injuries, no significant difference in mortality was identified between the age groups up to age 54. Beginning at the 55–64 age group, however, the mortality rate became significantly higher compared to the younger age group. A further increase in mortality was observed for those aged 65 and older, who were at significantly higher risk of death compared to the patients in the 55–64 age group (Table 2).

For penetrating injuries, a similar pattern of age-specific mortality rates was observed. The mortality rates remained constant among the younger age groups, but showed an increase at the 55–64 age group. However, this increase did not reach statistical significance. The relative risk of mortality for the 55–64 age group was 1.5 (95% CI: 0.98, 2.32; $p = 0.09$) compared to the younger age groups. In the age group 65 and older, the mortality rate was significantly higher than the 55–64 age group ($p = 0.015$). Similar to what was observed in the blunt group, the 55–64 age group also appears to be the age group in which mortality begins to increase following penetrating injury.

The relative risk of death for penetrating injury compared to blunt injury was significantly higher in all age groups (Table 4). Table 4 also shows that the relative risk for mortality, although significantly higher for penetrating trauma in all age groups, decreased with increasing age. Fig. 1 provides additional information on the comparison of age-specific mortality rates according to the mechanism of injury. As demonstrated in this chart, the error bars representing the mortality 95% confidence intervals does not overlap in any of the age groups.

Table 4
Age-specific mortality and relative risk of death according to injury mechanism.

Age group in years	Blunt injury	Penetrating injury	Relative risk (95% CI)	*p*-Value
	%Died (#died/#in group)	%Died (# died/# in group)	Penetrating vs. blunt	
<15	2.5% (60/2303)	12.3% (26/185)	4.85 (3.13, 7.52)	<0.0001
15–24	2.7% (138/4976)	11.3% (434/3391)	4.20 (3.49, 5.07)	<0.0001
25–34	2.7% (147/5249)	10.3% (257/2244)	3.77 (3.10, 4.59)	<0.0001
35–44	3.5% (176/4907)	10.0% (140/1259)	2.89 (2.33, 3.58)	<0.0001
45–54	3.9% (150/3670)	9.4% (58/559)	2.39 (1.79, 3.20)	<0.0001
55–64	6.0% (125/1974)	14.1% (26/158)	2.37 (1.60, 3.52)	<0.0001
65+	12.3% (303/2155)	26.4% (28/78)	2.14 (1.53, 2.99)	<0.0001
Total	4.2% (1099/26,333)	11.0% (969/8843)	2.63 (2.42, 2.85)	<0.0001
		Adjusted for age	3.43 (3.11, 3.78)	<0.0001
		Adjusted for age and severity[a]	1.65 (0.88, 2.89)	0.10

[a] Adjusted for age and significant confounding factors listed in Table 1.

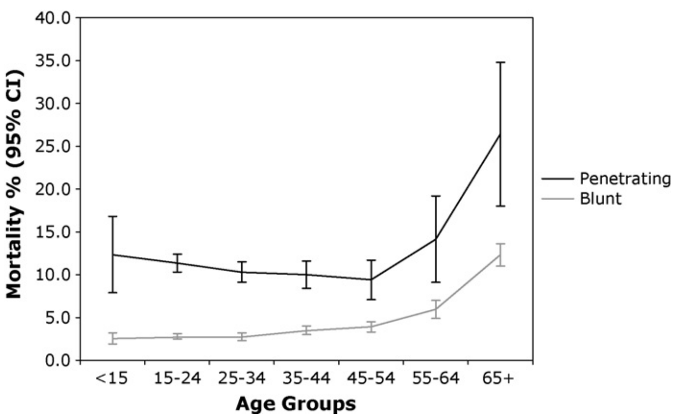

Fig. 1. Comparison of age-specific mortality according to mechanism of injury.

The overall crude mortality rate of penetrating trauma was 2.6 times that of blunt trauma (11.0% vs. 4.2%, $p < 0.0001$) (Table 4). After adjusting for the age composition, the relative risk of death remained significantly higher for penetrating trauma compared to blunt traumas at 3.4 ($p < 0.0001$). However, after adjusting for both age and the other confounding factors listed in Table 1, the relative risk of mortality was 1.65 (95% CI: 0.88, 2.89, $p = 0.10$), which did not reach statistical significance.

Discussion

As the population continues to mature, defining the connection between age and trauma outcomes becomes increasingly important. Several investigators have already suggested that this relationship is significant. Finelli et al.,[3] in a study comparing the outcomes of trauma victims ≥65 year old to a younger cohort of similarly injured younger patients, found that older patients had markedly higher mortality (27% vs. 14%) and complication rates following major trauma. They also noted that the more mature cohort required significantly longer hospital stays and incurred higher health care-related costs. In another retrospective study by Kuhne et al.,[4] multiply injured patients older than age 56 were found to have an increased risk of death and multiple organ failure independent of Injury Severity Score. Additionally, Morris et al.[5] have demonstrated that this age-related discrepancy in outcomes may begin as early as 40 years of age in patients with even moderate injury severity. Most of these investigations, however, have utilised study populations comprised of predominantly victims of blunt trauma.

The relationship between age and penetrating mechanisms of injury has been less well examined. In a small case–control study, Roth et al.[7] compared the outcomes following penetrating trauma of 79 patients of age ≥55 with an identical number of individuals of ages ranging from 15 to 35. They found that despite no difference in mean ISS between severely injured older and younger cohorts, the more mature group required longer ICU and hospital stays. In another retrospective study by Nagy et al.,[6] 85 patients ≥65 year old required longer hospital stays and were less likely to achieve discharge to home than younger counterparts.

In this study we found that, at every age interval, patients sustaining penetrating trauma had higher mortality than bluntly injured counterparts. We also noted that mortality for both blunt and penetrating mechanisms remained relatively stable until the age of 55, after which it began to rise. For penetrating trauma, the first statistically significant increase in mortality after penetrating trauma occurred after age 65.

This finding has important implications for trauma care. The value of early intensive monitoring and aggressive management protocols for elderly victims of trauma has already been demonstrated. Scalea et al.[8] have shown that the use of early invasive monitoring in multiply-injured trauma patients older than 65 years of age improves outcomes following these injuries. Demetriades et al.[2] in an examination of 883 elderly trauma patients (age ≥ 70), have also established that the utilisation of age ≥ 70 alone as criteria for activation of a dedicated trauma team will result in improved survival and other outcomes. In another single-institution follow-up study, Battistella et al.[1] found that at a mean follow-up of 5.4 years, the majority of elderly trauma survivors managed with an aggressive protocol were able to live independently and carry out the majority of their daily living activities unsupported. These studies provide support for the aggressive utilisation of resources in the mature trauma patient; however, further research is necessary to precisely define the group of patients most likely to benefit from more intensive resources.

It is important to note that our study has several limitations. In our design we did not specifically identify those patients with penetrating injuries who had sustained isolated brain injuries. The high rate of mortality among this population may represent a potential confounder. The number of victims of penetrating head injury is most likely to have decreased with age, however, making this less likely to significantly influence our findings. We also did not conduct extensive investigation into the types of surgical procedures utilised or the manner in which the timing of these interventions may have affected outcome. Additionally, in our design we chose not to delineate the temporal occurrence of deaths, in order to examine a population inclusive of all trauma victims surviving to reach our trauma centre. The exclusion of early deaths may have revealed a more dramatic difference in outcomes. Finally, the design of our study utilised ISS as a marker for severity of injury. It is possible that better discriminators of penetrating injury, such as the penetrating abdominal trauma index (PATI) or similar scoring systems, may provide more reliable prediction of outcome after these mechanisms of injury. These topics warrant additional examination, ideally in the context of a prospective study.

Conclusion

The mortality rate following penetrating trauma is higher than among blunt counterparts at every age interval and rises significantly after age 65. Defining the relationship between age and outcome in penetrating trauma will prove increasingly important as the population ages. An understanding of this relationship will facilitate the refinements of trauma team activation criteria and management protocols that may improve resource allocation and patient outcomes following penetrating injury.

Conflict of interest

The authors have no conflict of interest to report and have received no financial or material support related to this manuscript.

References

1. Battistella FD, Din AM, Perez L. Trauma patients 75 years and older: long-term follow-up results justify aggressive management. J Trauma 1998;44:618–23 [discussion 623].
2. Demetriades D, Sava J, Alo K, et al. Old age as a criterion for trauma team activation. J Trauma 2001;51:754–6 [discussion 756–7].
3. Finelli FC, Jonsson J, Champion HR, et al. A case control study for major trauma in geriatric patients. J Trauma 1989;29:541–8.
4. Kuhne CA, Ruchholtz S, Kaiser GM, et al. Mortality in severely injured elderly trauma patients—when does age become a risk factor? World J Surg 2005;29:1476–82.
5. Morris Jr JA, MacKenzie EJ, Damiano AM, Bass SM. Mortality in trauma patients: the interaction between host factors and severity. J Trauma 1990;30:1476–82.
6. Nagy KK, Smith RF, Roberts RR, et al. Prognosis of penetrating trauma in elderly patients: a comparison with younger patients. J Trauma 2000;49:190–3 [discussion 193–4].
7. Roth BJ, Velmahos GC, Oder DB, et al. Penetrating trauma in patients older than 55 years: a case–control study. Injury 2001;32:551–4.
8. Scalea TM, Simon HM, Duncan AO, et al. Geriatric blunt multiple trauma: improved survival with early invasive monitoring. J Trauma 1990;30:129–34 [discussion 134–6].
9. US Census Bureau. US interim projections by age, sex, race and hispanic origin. 2004. Available at: http://www.census.gov/ipc/www/usinterimproj/ [Accessed February 21, 2008].
10. Zhang J, Yu KF. What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. JAMA 1998;280:1690–1.