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Evaluation of the effect of intensity of care on mortality after traumatic brain injury

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Abstract

Objectives—To evaluate the effect of age on intensity of care provided to traumatically brain-injured adults and to determine the influence of intensity of care on mortality at discharge and 12 months postinjury, controlling for injury severity.

Design—Cohort study using the National Study on the Costs and Outcomes of Trauma (NSCOT) database. Risk ratio and Poisson regression analyses were performed using data weighted according to the population of eligible patients.

Setting and Patients—A total of 18 level 1 and 51 level 2 non-trauma centers located in 14 states in the United States and 1,776 adults aged 25–84 yrs with a diagnosis of traumatic brain injury.

Measurements—Injury severity was determined by the motor component of the Glasgow Coma Scale score, the Injury Severity Score, pupillary reactivity, and presence of midline shift. Factors evaluated as contributing to intensity of care included: admission to the intensive care unit, mechanical ventilation, placement of an intracranial pressure monitor, placement of a jugular bulb catheter, placement of a pulmonary artery catheter, critical care consultation, the number of specialty care consultations, mannitol use, treatment with barbiturate coma, decompressive craniectomy, number of nonneurosurgical procedures performed, the presence of a do-not-resuscitate order, and withdrawal of therapy.

Main Results—Controlling for injury-related factors, sex, and comorbidity, as age increased, the overall likelihood of receiving various interventions decreased. After controlling for injury severity, sex, and comorbidity, factors associated with higher risk of in-hospital death were: being aged 75–84 yrs (relative risk [RR] 1.32, 95% confidence interval [CI] 1.13, 1.55), pulmonary artery catheter use (RR 1.56, 95% CI 1.30, 1.86), intubation (RR 4.17, 95% CI 2.28, 7.61), the presence of a do-not-resuscitate order (RR 3.21, 95% CI 2.21, 4.65), and withdrawal of therapy (RR 2.33, 95% CI 1.69, 3.23). In contrast, a higher number of specialty care consultations (surgical consults: RR 0.63, 95% CI 0.54, 0.74; medical consults: RR 0.87, 95% CI 0.79, 0.95; and other consults: RR 0.43, 95% CI 0.26, 0.69) were associated with decreased risk of death. The results were similar for factors associated with death at 12 months, with the exception that the number of medical consultations was not significant, whereas the number of nonneurosurgical procedures performed was associated with lower risk of death (RR 0.96, 95% CI 0.92, 0.99), as was obtaining critical care consultation services (RR 0.84, 95% CI 0.71, 1.0).

Conclusions—There is a lower intensity of care provided to older adults with traumatic brain injury. Although the specific contributions of specialists to patient management are unknown, their

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consultation was associated with decreased risk of in-hospital death and death within 12 months. It is important that careproviders have an increased awareness of the potential contribution of multidisciplinary clinical decision making to patient outcomes in older traumatically brain-injured patients.

Keywords

head injury; critical care consultation; specialty care consultation; pulmonary artery catheter; older adult

By the year 2030, the number of Americans aged ≥ 65 will exceed 70 million, doubling current figures (1). Along with this increase in the number of older Americans, there has been a rise in the number of older adults sustaining a traumatic brain injury (TBI). In 2003, the age-adjusted rate of hospitalization for TBI in the general population was 87.9 per 100,000 population, for adults 65–74 yrs of age, the rate was 104.6 per 100,000, and for those >75 yrs of age, this rate increases substantially to 287.3 (2).

Not only are older adults more likely to be hospitalized after a TBI, but they are more likely to die as a result of their injury. Mortality rates with severe TBI in adults >55 yrs of age range from 30% to 80% (3–6), significantly higher than those reported in younger patients. In a meta-analysis evaluating the association between age and outcome, Hukkelhoven et al. (7) reported that mortality substantially increases beyond age 60. Mortality rates for older adults with mild TBI are also substantially higher than their younger counterparts (8,9). However, limitations of evaluating mortality as the primary outcome in the majority of studies to date have included the use of case series, the exclusion of multiple trauma patients, and a lack of adequate adjustment for severity of injury or comorbidity. In a study of Medicare patients with TBI, the 2-yr mortality rate was higher than uninjured controls of the same age and sex (10). These findings are in contrast to the study by Flaada et al. (11), also using proportional hazards techniques, that reported that the relative risk of 10-yr mortality in elderly patients (>65 yrs) was similar to younger adults, indicating that the discrepancy may simply reflect age-associated mortality in general. In addition, studies to date have not considered the influence of decision making by families or clinicians on case fatality.

A recent systematic review found that traumatically injured older adults have both higher short- and long-term mortality rates than their younger counterparts (12). This relationship persisted even after adjusting for number and severity of injury, comorbid health conditions, and complications. Another recent systematic review in critically ill elders found that with appropriate adjustment for other confounders in addition to age, the effect of the latter was greatly reduced (13). When ascertaining mortality risk of older adults after critical illness, severity of illness seems to be the more important prognostic indicator (13–19). Other variables shown to affect mortality rates among critically ill older adults include chronic health conditions, mechanical ventilation, pulmonary artery (PA) catheterization, complications, residing in a nursing home, preadmission functional ability, sex, and ethnicity (12,20–22).

Although previous studies of adults with TBI have contributed to the care of this population, they are frequently limited by the failure to discern that the older TBI patient presents with different needs than their younger counterparts. A greater knowledge of the contribution of clinical and personal decision making to outcome after TBI in older adults would allow providers the ability to better identify and provide age-appropriate care. Thus, we undertook the present study 1) to evaluate the effect of age on intensity of care provided to traumatically brain-injured adults, and 2) to determine the influence of intensity of care on mortality at discharge and 12 months postinjury while controlling for injury. We hypothesized that controlling for injury severity, intensity of care to TBI patients decreases with increasing age

in a nonlinear fashion and that this lower intensity of care would explain a significant portion of the variance in mortality after TBI in older adults.

METHODS

The study protocol was approved by the institutional review boards at the participating centers. Informed written consent for use of data in secondary analyses was provided by subjects in the parent study.

Parent Study

The National Study on the Costs and Outcomes of Trauma (NSCOT) was a prospective cohort study conducted in 69 hospitals (18 designated trauma centers, 51 nontrauma centers) in 14 states in the United States (23). The primary objective of the study was to address the differences in costs and outcomes associated with treatment in designated vs. nondesignated trauma centers. Patients were eligible for the parent study if they were between 18 and 84 yrs of age, arrived alive at a participating hospital, and had at least one injury of ≥ 3 on the Abbreviated Injury Scale ($n = 18,198$). Exclusion criteria included absent vital signs at arrival to hospital, being pronounced dead within 30 mins, delay of >24 hrs in seeking treatment after injury, patients ≥ 65 yrs old with primary diagnosis of hip fracture, major burn injury, incarcerated or homeless at time of injury, non-U.S. resident, or speaking neither English nor Spanish. A detailed description of the enrollment and data collection procedures has been previously published (23). Briefly, all patients who died in hospital ($n = 1,438$) were selected, and a sample of patients who were discharged alive ($n = 8,021$) using a quota sampling strategy were selected for follow-up 3 and 12 months postinjury. The sampling strategy required data to be weighted according to the population of eligible patients. This weight reflects both the conditional probability of being selected and the probability of being enrolled and having data obtained given that the patient was selected.

Subjects

To be eligible for this secondary analysis, subjects were selected from the NSCOT database if they met the following criteria: adult patient with a TBI. Both isolated and multiple trauma patients were included in the analysis. Due to brain development, an *adult* was defined as a subject >24 yrs of age (24) and *TBI* was defined as a primary diagnosis of International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes 800.00–801.9, 803.0–804.9, 850.0–854.1, or 959.01 (25). A total of 1,776 patients within the NSCOT database met these criteria.

Injury Severity

Variables measured for injury severity included Glasgow Coma Score–Motor (GCS-M) component, pupillary response, the Abbreviated Injury Scale–Head, Injury Severity Score (ISS), and presence of midline shift.

Glasgow Coma Score–Motor—For the purposes of this study, the variable used was the GCS-M score first reported in the emergency department. Patients who received a score of 1 were further categorized by the presence or absence of chemical paralysis.

Pupillary Response—Pupillary response was defined as the first documented pupillary response at admission to the emergency department. Pupils were categorized as either 1) equal and reactive or 2) unequal or unreactive.

Abbreviated Injury Scale–Head—The Abbreviated Injury Scale–Head is a systematic method for rating the severity of individual injuries to the cranium and brain and is scored from 1 (minor) to 6 (maximum/nonsurvivable) (26).

Injury Severity Score—The ISS (27) is a measure of the overall severity of multiple trauma. The ISS is the sum of the squares of the most severe injury in each of the three most severely injured body regions and is scored on a scale of 1 (least severe) to 75 (most severe) (28). The six body regions on which the ISS is based are head/neck, face, chest, abdomen/pelvic contents, extremities/pelvic girdle, and external.

Midline Shift—Presence of midline shift was determined by the first head CT scan.

Comorbid Health Conditions—Charlson comorbidity index score was calculated from conditions identified in the patient's medical record. The Charlson comorbidity score is a weighted index based on 17 preexisting conditions. An index score of 0 indicates no serious comorbid condition (29).

Insurance Status—Insurance status was identified from the patient's medical record and classified into the following categories: no insurance, private insurance, Medicare only, private + Medicare, Medicaid, other.

Intensity of Care

Intensity of care was operationalized by enumerating separate aspects of intensity of care frequently provided to TBI patients and included the following measures: 1) intensive care admission; 2) intubation: mechanical ventilation required; 3) placement of intracranial pressure monitor; 4) placement of jugular bulb catheter; 5) mannitol use: high intracranial pressure/low cerebral perfusion pressure treated with mannitol; 6) barbiturate coma: high intracranial pressure/low cerebral perfusion pressure treated with barbiturate coma; 7) decompressive craniectomy: high intracranial pressure/low cerebral perfusion pressure treated with decompressive craniectomy; 8) placement of PA catheter; 9) critical care consultation; 10a) number of surgical specialty care consults: the number of different surgical specialty consults ordered; 10b) number of medical specialty care consults: the number of different medical specialty consults ordered; 10c) number of other specialty care consults: the number of other specialty consults ordered; and 11) number of procedures. In addition, two measures that may affect mortality directly were selected for assessment: 12) presence of a do-not-resuscitate order and 13) withdrawal of therapy (interventional therapies withdrawn before death).

Definition of Outcomes

The outcomes of interest were in-hospital death and death by 12 months postinjury. Deaths that occurred after discharge were documented either via proxy interview or through the National Death Index.

Statistical Methodology

All analyses were performed with the use of data weighted to the population of eligible patients based on the selection protocol to prevent sampling biases (see MacKenzie et al [23]). Chi-square analyses were used to explore differences among groups. To justify for missing covariates, multiple imputation techniques were employed. Ten imputed data sets were created along with robust standard errors using Rubin's combining rules (30). Models were developed using Poisson regression analyses with robust standard errors to explain the relationship between intensity of care and risk of death. We used the injury severity variables noted above (GCS-M, Abbreviated Injury Scale–Head, ISS, etc.) and Charlson Index to control for the

degree of physiologic derangement and premorbid health. We fit a second model and controlled for insurance status as a proxy for social economic status. Goodness of fit of the final models was assessed, and both models had a p value of 1.000, rejecting the hypothesis that the model fit was poor. All p values were two-tailed, and a value of $<.05$ was considered statistically significant. No adjustment was made for multiple comparisons (31). Analyses were performed using SAS software (SAS Institute, Cary, NC).

RESULTS

A total of 1,776 patients who sustained a TBI were included in this study (Fig. 1); those subjects who died in the hospital were more likely to be older and to have higher injury severity scores (ISS, GCS-M, Abbreviated Injury Scale) and more comorbid health conditions (unadjusted) (Table 1). These high mortality rates in older TBI patients are in contrast to the fact that they were more likely to present to the emergency department with a higher GCS-M score (Table 2). The overall in-hospital mortality rate was 32.4% (Fig. 1), and an additional 117 patients (6.6%) died in the first year postinjury. Subjects in the oldest age category (75–84 yrs of age) were more likely to be women, in contrast to the other age categories, in which the proportion of men sustaining a TBI exceeded women (Table 2). In addition, the observed rates of midline shift in persons 75–84 yrs of age were higher (21%) vs. those of younger age groups: 25–54 yrs (12.6%); 55–64 yrs (11.1%); and 65–74 yrs (17.3%) (Table 2).

As age increased, there was an overall lower intensity of care provided to TBI patients, unadjusted for severity (Table 3). However this was not true of critical care consultation, which was ordered equally across all age categories, or of medical consultative services, for which the observed likelihood and number were higher with increasing age (Table 3).

After adjusting for injury severity (GCS-M, Abbreviated Injury Scale–Head, pupillary reactivity, midline shift, ISS) and comorbid health conditions (Charlson Index), older adults had a higher relative risk of in-hospital death compared with younger adults across all treatment categories (Table 4). The oldest adults (aged 75–84 yrs) with a do-not-resuscitate order had the highest relative risk of in-hospital death (RR 8.16, 95% CI 5.32, 12.53), and their likelihood of death was significantly higher even when therapy was not withdrawn (RR 2.26, 95% CI 1.48, 3.46). For younger adults (aged 25–54 yrs) with TBI, only critical care consultation (RR 0.70, 95% CI 0.51, 0.95) and specialty care consultation (one consult: RR 0.63, 95% CI 0.47, 0.84) were associated with significantly lower case fatality rates compared with those of the same age group not receiving intervention (Table 4). For all age groups, two interventions were significantly associated with an increased risk of in-hospital death: PA catheter monitoring and intubation (Table 4).

After controlling for injury severity, sex, and comorbidity, factors associated with higher risk of in-hospital death were: being aged 75–84 yrs (RR 1.32, 95% CI 1.13, 1.55), PA catheter use (RR 1.56, 95% CI 1.30, 1.86), intubation (RR 4.17, 95% CI 2.28, 7.61), the presence of a do-not-resuscitate order (RR 3.21, 95% CI 2.21, 4.65), and withdrawal of therapy (RR 2.33, 95% CI 1.69, 3.23) (Table 5). In contrast, a higher number of surgical, medical, and other specialty consultations was associated with decreased risk of death (Table 5).

Factors associated with higher risk of death within 12 months, controlling for other factors, were: being aged 65–74 yrs (RR 1.44, 95% CI 1.17, 1.77), aged 75–84 yrs (RR 2.03, 95% CI 1.59, 2.59), mannitol use (RR 1.26, 95% CI 1.06, 1.50), PA catheter use (RR 1.52, 95% CI 1.21, 1.90), intubation (RR 2.26, 95% CI 1.67, 3.05), the presence of a do-not-resuscitate order (RR 2.5, 95% CI 1.86, 3.36), and withdrawal of therapy (RR 1.65, 95% CI 1.29, 2.12) (Table 6). Controlling for other factors, decreased risk of death within 12 months was associated with a higher number of specialty care consultations (surgical consults: RR 0.77, 95% CI 0.62, 0.95;

other consults: RR 0.41, 95% CI 0.25, 0.69) and the number of nonneuro-surgical procedures performed (RR 0.96, 95% CI 0.92, 0.99) (Table 6). Obtaining critical care consultation services for TBI patients approached, but did not reach, statistical significance for reducing the risk of death within 12 months (RR 0.84, 95% CI 0.71, 1.0) (Table 6).

Adjusting for insurance status did not make substantial changes in the case fatality rates or regression models; therefore, the data are not presented.

DISCUSSION

We estimated that at discharge, those 75–84 yrs of age were almost 1.4 times as likely to have died as compared with younger adults (ages 25–54) of the same injury severity, comorbidity, and sex; at 12 months, they were more than two times as likely, and those 65–74 yrs old were >1.4 times as likely to have died. This could be associated with the less aggressive care provided to older adults seen in the present study or the influence of do-not-resuscitate orders. The present study is in agreement with previous reports that demonstrated that older adults are less likely to be provided care at a level 1 trauma center (32,33).

Age has been shown in the SUPPORT study (Study to Understand Prognoses and Preferences for Outcomes and Risks of Treatments) to be a predictor of survival in ICU patients, as those >75 yrs of age had do-not-resuscitate orders written more quickly, regardless of prognosis (34). Those findings are supported by the present study in which adults aged 75–84 with a do-not-resuscitate orders had the highest relative risk of in-hospital death. We did not know what proportion of the do-not-resuscitate orders in this study were related to an advance directive by the patient. However, previous reports have showed that only 10% of ICU patients have prepared an advanced directive (35), and almost one half of do-not-resuscitate orders are written within 2 days of death (36). Therefore, the effect of advanced directives on our findings is likely small.

Higher mortality may also be associated with higher rates of midline shift seen in the oldest adults on initial CT, despite also having higher initial GCS-M scores. In older adults (>65 yrs) with mild TBI, no useful clinical predictors of lesion formation have been found; thus, current recommendations include obtaining a CT on all injured adults >65 yrs of age (37). This possibility is also supported by the apparent disparity between initial GCS-M and midline shift in the present report.

In contrast to previous studies of TBI (11,25,38), we note that those persons aged 75–84 hospitalized after a TBI were more likely to be women than men, in contrast to the other age categories, for which the proportion of men sustaining a TBI exceeded women. This finding is in keeping with recent trends in rates of hospitalization from injury of older adult women surpassing that of men (39) or may reflect differences in the populations sampled.

In the present study, we note that controlling for injury severity, sex, and preexisting disease, critical care consultation was associated with a significantly reduced risk of death in younger adults with TBI compared with those who did not receive these services. The specific contribution of the critical care clinician to patient management may be related to dedicated time or specific knowledge of the interplay of multisystem injury and disease. Previous reports in critically ill adults have shown up to a 40% reduction in mortality in intensivist-model ICUs (40,41), and in the previous study of trauma patients who used the NSCOT database, Nathens et al. (42) reported that mortality in patients receiving care in closed ICUs was modified by age, with elderly patients demonstrating a significant decrease (45%). Although the present study did not demonstrate a significant decrease in the likelihood of in-hospital death for those persons >55 yrs of age with TBI who received critical care consultation, there was a trend

toward benefit in those aged 55–64, reinforcing the notion that there are very different responses to treatment among these distinct subgroups classically analyzed together.

Presently an area of debate, the use of a PA catheter in the management of trauma patients has been shown to be of benefit in some studies, particularly in older adults (43). However, after adjustment using propensity scoring, its use has been reported to be associated with increased risk of complications in trauma victims (44). In heterogeneous mixes of critically ill patients, although PA catheter use has been shown to be associated with mortality, once adjusting for severity of illness, this association did not remain (45,46), implying that use of the PA catheter was not responsible for the increase in mortality. In the present study, however, even with adjustment for severity of injury, we found an increased risk of death with PA catheter use. This suggests that PA catheter use must be used very selectively in elderly TBI patients.

A criticism of previous studies has been the inadequate adjustment for injury-related factors and comorbidity; however, despite adjusting for numerous injury-related factors and comorbid health conditions, intubation was associated with increased risk of in-hospital death. Thus, it is likely that there exists some residual confounding due to unmeasured aspects of injury severity.

Mannitol use was associated with significantly increased risk of in-hospital death in the univariate analysis. Those receiving mannitol during their hospitalization for treatment of increased intracranial pressure were also more likely to have died by 12 months postinjury after adjustment for differences in injury severity, comorbidity, and sex. A recent systematic review of mannitol use in TBI found a lack of evidence for its effectiveness and identified the need for further randomized clinical trials (47). Our findings echo this need.

Care of the TBI patient may require management of multiple other systems (e.g., complications of TBI such as development of neurogenic pulmonary edema, neurogenic fever vs. complications of critical illness such as gastrointestinal bleeding). After adjusting for patient differences, the risk of in-hospital death was significantly reduced when consultative services (surgical, medical, and other) were obtained. At 1 yr, only surgical consultation was associated with a lower risk of death. Recent reports have noted the benefit of collaborative care on improving outcome from geriatric trauma (48,49). Consultative services categorized as “other” included services such as acute pain service, substance abuse, ostomy nurse, and dentistry. As the majority of these consults would not have been obtained had the patient not been recovering from injury, it is not surprising that this was associated with decreased risk of death.

These results must be interpreted in light of their limitations. The present report is only able to establish an association between certain components measured as indicators of intensity of care and mortality, not establish causality. We are unable to rule out reverse causality, specifically, that services were provided because the patient survived or that the additional consultations were not contributing to survival. As an example, the increased survival associated with the use of surgical consultations might reflect the use of tracheostomy and gastrostomy among those surviving their TBI. There are inherent limitations to the study due to the nature of data available from the medical record. Although the data were collected prospectively in the parent study, some variables of interest, such as social support, were not available for analysis. Abstracted data available from discharge records indicate that subjects who were not enrolled in the parent study were older than those enrolled, suggesting that these results of increased mortality may underestimate the extent of the problem. The NSCOT study excluded patients >84 yrs of age; thus, there may be limited generalizability of the findings to adults >85 yrs of age.

CONCLUSIONS

There is a lower intensity of care provided to older adults with TBI. Whether this is related to aging-related health disparities or family and provider decision making remains to be fully explored. However, our results underscore the complexity in the successful management of TBI across all age groups. As there seems to be subgroups with differing responses to treatment within that classically defined as “older adult,” by age category, it is essential that future studies power appropriately for subgroup analyses to develop best practices for this growing population. Although the specific contributions of specialists to patient management are unknown, consultation was associated with decreased risk of in-hospital death and death within 12 months. The integration of dedicated critical care services in centers providing care to TBI patients may be warranted. It is important that careproviders have an increased awareness of the potential contribution of multidisciplinary clinical decision making to patient outcomes in older TBI patients.

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Figure 1. Patient population and mortality. *NSCOT*, National Study on the Costs and Outcomes of Trauma; *TBI*, traumatic brain injury; *WN*, weighted number to eligible patients.

Table 1
 Characteristics of patients with traumatic brain injury (n = 1776)

Characteristic	n (Weighted n)	Hospital Mortality, %	p
Age, yrs			<.0001
25–54	896 (2642)	10.3	
55–64	211 (559)	13.9	
65–74	293 (536)	16.1	
75–84	376 (614)	25.3	
Sex			.87
Male	1197 (3005)	13.7	
Female	579 (1346)	13.4	
Injury Severity Score			<.0001
<16	263 (729)	1.9	
16–24	419 (1154)	4.2	
25–34	520 (1398)	11.2	
>34	574 (1071)	34.7	
First ED GCS-M score			<.0001
6	1055 (2890)	3.9	
4–5	207 (468)	22.5	
2–3	53 (75)	51.8	
1, not chemically paralyzed	233 (355)	54.2	
1, chemically paralyzed	227 (563)	25	
Charlson Index score			<.0001
0	1036 (2834)	11.7	
1	315 (775)	10.9	
2	168 (317)	19.2	
≥3	257 (426)	26.8	
Midline shift			<.0001
Yes	392 (617)	46.9	
No	1384 (3734)	8.1	
First pupillary response			<.0001
Equal and reactive	1370 (3745)	6.9	
Unequal or unreactive	406 (606)	54.7	
Maximum head AIS			<.0001
≤3	642 (1934)	3.4	
4	650 (1627)	10.3	
5–6	484 (790)	45.3	
Designated trauma center			.51
Yes	1107 (3235)	13.9	
No	669 (1116)	12.6	

ED, emergency department; GCS-M, Glasgow Coma Score—Motor; AIS, Abbreviated Injury Scale.

Table 2
Percentage distribution of characteristics of traumatic brain injury patients by age group

Characteristics	n (Weighted n)	25–54 yrs, %	55–64 yrs, %	65–74 yrs, %	75–84 yrs, %	p
Sex						
Male	1197 (3005)	74.8	68.9	63.7	49.1	<.0001
Female	579 (1346)	25.2	31.1	36.3	50.9	
Injury Severity Score						
<16	263 (729)	16.7	14.8	17.8	17.9	.65
16–24	419 (1154)	25	28.3	28.3	28	
25–34	520 (1398)	31.9	35.7	29.3	32.2	
>34	574 (1071)	26.3	19.4	24.6	22	
First ED GCS-M score						
6	1055 (2890)	60.6	73.7	74.2	78.2	<.0001
4–5	207 (468)	12.5	7.4	9.6	7.6	
2–3	53 (75)	2	0.6	1.4	2.1	
1, not chemically paralyzed	233 (355)	8.9	6.1	9.2	6.1	
1, chemically paralyzed	227 (563)	16.1	12.3	5.6	6.1	<.0001
Charlson Index score						
0	1036 (2834)	79.1	64.3	41.6	26.3	
1	315 (775)	14.5	18.4	25	25.1	
2	168 (317)	2.7	7.9	14.1	20.2	.001
≥3	257 (426)	3.6	9.5	19.3	28.4	
Midline shift						
Yes	392 (617)	12.6	11.1	17.3	21	
No	1384 (3734)	87.4	88.9	82.7	79	.03
First pupillary response						
Equal and reactive	1370 (3745)	84.5	90.5	86.8	88.2	
Unequal or unreactive	406 (606)	15.5	9.5	13.2	11.8	
Maximum head AIS						
≤3	642 (1934)	49.3	44.6	37.1	29.8	<.0001
4	650 (1627)	33	36.4	45	50.5	
5–6	484 (790)	17.7	19.1	17.9	19.7	

ED, emergency department; GCS-M, Glasgow Coma Score—Motor; AIS, Abbreviated Injury Scale.

Table 3
Percentage distribution of intensity of care provided to traumatic brain injury patients by age group, unadjusted for severity

Care Provided	n (Weighted n)	25–54 yrs, %	55–64 yrs, %	65–74 yrs, %	75–84 yrs, %	p
Designated trauma center						
Yes	1107 (3235)	79.3	76.9	71.5	53.1	<.0001 ^a
No	669 (1116)	20.7	23.1	28.5	46.9	
ICU admission						
Yes	1235 (2766)	62.9	71.5	64.8	58.1	.15
No	541 (1586)	37.1	28.5	35.2	41.9	
Intubation						
Yes	868 (1830)	45.7	43.1	34.4	32.2	.04 ^a
No	908 (2521)	54.3	56.9	65.6	67.8	
Intracranial pressure monitoring						
Yes	281 (617)	16.8	13.5	9.2	8.1	.002 ^a
No	1494 (3734)	83.2	86.5	90.8	91.9	
Jugular bulb catheter						
Yes	43 (81)	2.2	1.1	1.9	0.9	.37
No	1733 (4270)	97.8	98.9	98.1	99.1	
Mannitol use						
Yes	348 (573)	14.9	10.9	11.3	9.5	.01 ^a
No	1428 (3778)	85.1	89.1	88.7	90.5	
Decompressive craniectomy						
Yes	70 (157)	4.4	3.4	0.8	2.8	.04 ^a
No	1706 (4194)	95.6	96.6	99.2	97.2	
Barbiturate coma						
Yes	59 (131)	3.7	2.5	1.8	1.4	.05
No	1718 (4220)	96.3	97.5	98.2	98.6	
Pulmonary artery catheter						
Yes	220 (479)	11.8	12.9	11.3	5.7	.02 ^a
No	1555 (3872)	88.2	87.1	88.7	94.3	
Critical care consult						
Yes	338 (923)	20.8	28.9	17.9	18.9	.11
No	1438 (3428)	79.2	71.1	82.1	81.1	
No. of specialty care assessments						
0	717 (1586)	38.6	30.4	34.5	34.4	.02 ^a
1	535 (1279)	30.3	22.4	30	31.5	
2	272 (689)	13.7	22	19.3	16.4	
3	139 (360)	7.3	11.3	7.4	10.6	
4	72 (313)	7.1	12.3	4.6	5.3	
5	41 (124)	3.1	1.6	4.3	1.8	
No. of surgical specialty care assessments						
0	1408 (3134)	68.2	65.3	82.5	85.4	.006 ^a
1	297 (922)	24.4	23.2	12.7	13.0	
≥2	71 (294)	7.4	11.5	4.8	1.6	
No. of medical specialty care assessments						
0	964 (2324)	59.8	44.9	47.1	39.4	<.0001 ^a
1	473 (1162)	23.5	33.7	26.7	34.2	
2	211 (559)	10.5	17.8	16.5	15.0	
≥3	128 (306)	6.2	3.6	9.8	11.5	
No. of other specialty care assessments						
0	1710 (4090)	93.7	88.9	95.1	98.7	.007 ^a
≥1	66 (262)	6.3	11.1	4.9	1.3	
No. of procedures performed (nonneurosurgical)						
0	459 (993)	18.8	22.6	29.5	34.7	.0003 ^a
1	300 (767)	17.1	17.4	17.7	20	

Care Provided	n (Weighted n)	25–54 yrs, %	55–64 yrs, %	65–74 yrs, %	75–84 yrs, %	p
2	275 (642)	14.9	14.4	12.7	16.3	
3	156 (325)	6.4	9.2	9.2	8.8	
4	125 (349)	8.6	7	8.7	5.9	
5	83 (220)	5	5.5	5	4.8	
6+	378 (1055)	29.2	23.8	17.2	9.6	
Presence of a do-not-resuscitate order						<.0001 ^a
Yes	428 (472)	5.4	12.5	14.7	29.4	
No	1348 (3879)	94.6	87.5	85.3	70.6	
Withdrawal of therapy						<.0001 ^a
Yes	387 (407)	6.4	10.3	11.4	19.6	
No	1390 (3944)	93.7	89.7	88.6	80.4	
ICU, intensive care unit.						

^a $p < .05$.

Care Provided	Age Group											
	25–54 yrs			55–64 yrs			65–74 yrs			75–84, yrs		
	Wn	Death, %	RR (95% CI)	Wn	Death, %	RR (95% CI)	Wn	Death, %	RR (95% CI)	Wn	Death, %	RR (95% CI)
0	2477	10.9	Ref	497	15.4	1.73 (1.26, 2.39)	510	17.0	1.68 (1.13, 2.49)	606	24.8	2.59 (2.05, 3.28)
≥1	165	1.2	0.24 (0.80, 0.70)	62	1.6	0.21 (0.04, 1.11)	26	0	—	8	66.7	9.70 (4.30, 21.88)
No. of procedures performed (nonneurosurgical)												
≤2	1341	8.6	Ref	304	11.3	1.28 (0.87, 1.88)	321	14.9	1.70 (1.18, 2.44)	436	20	1.94 (1.35, 2.80)
>2	1302	12	0.91 (0.69, 1.18)	255	17	1.80 (1.17, 2.76)	215	17.9	1.42 (0.71, 2.88)	178	38.2	3.95 (2.98, 5.23)
Presence of a do-not resuscitate order												
Yes	143	93.9	5.71 (3.68, 8.86)	70	82.1	6.62 (4.39, 9.99)	79	86.0	7.57 (4.91, 11.69)	181	76.9	8.16 (5.32, 12.53)
No	2500	5.5	Ref	489	4.2	0.94 (0.54, 1.63)	457	4.1	0.84 (0.50, 1.40)	433	3.8	0.97 (0.57, 1.67)
Withdrawal of therapy												
Yes	168	94.3	7.14 (4.71, 10.81)	57	93.3	7.96 (5.09, 12.45)	61	96.7	8.65 (5.55, 13.47)	120	95.1	10.25 (6.67, 15.11)
No	2474	4.6	Ref	502	4.8	1.29 (0.81, 2.04)	475	5.7	1.41 (0.93, 2.16)	494	8.3	2.26 (1.48, 3.46)

Wn, weighted number; RR, relative risk; 95% CI, 95% confidence interval; ref, reference; ICU, intensive care unit.

Table 5

Poisson regression analysis factors contributing to in hospital death, controlling for injury-related factors (Injury Severity Score, Glasgow Coma Score—Motor, midline shift, pupillary response, maximum head Abbreviated Injury Scale, sex, and Charlson score) in the entire study cohort, with traumatically brain-injured patients aged 25–54 yrs serving as the reference group

Variable	Univariate RR (95% CI)	Multivariate RR (95% CI)
Trauma center care	0.94 (0.77, 1.14)	NS
Admission to ICU	1.39 (1.00, 1.94) ^a	NS
No. surgical specialty assess	0.57 (0.43, 0.76) ^a	0.63 (0.54, 0.74) ^a
No. medical specialty assess	0.83 (0.71, 0.98) ^a	0.87 (0.79, 0.95) ^a
No. other specialty assess	0.45 (0.22, 0.92) ^a	0.43 (0.26, 0.69) ^a
Critical care consultant	0.85 (0.69, 1.06)	NS
Intubated	6.21 (3.11, 12.40) ^a	4.17 (2.28, 7.61) ^a
Pulmonary artery catheter use	1.33 (0.92, 1.91)	1.56 (1.30, 1.86) ^a
Mannitol use	1.48 (1.22, 1.80) ^a	NS
Intracranial pressure monitoring	0.94 (0.79, 1.12)	NS
Decompressive craniectomy	0.68 (0.44, 1.05)	NS
Do-not-resuscitate order	7.10 (4.48, 11.24) ^a	3.21 (2.21, 4.65) ^a
Therapy withdrawn	6.96 (4.54, 10.66) ^a	2.33 (1.69, 3.23) ^a
Age, 55–64 yrs	1.63 (1.20, 2.20) ^a	1.05 (0.88, 1.24)
Age, 65–74 yrs	1.68 (1.13, 2.50) ^a	1.08 (0.89, 1.31)
Age 75–84 yrs	2.71 (2.12, 3.45) ^a	1.32 (1.13, 1.55) ^a
No. of nonneurosurgical procedures	1.01 (0.96, 1.05)	NS

RR, relative risk; 95% CI, 95% confidence interval; ICU, intensive care unit; NS, not significant.

^a $p < .05$. Model goodness-of-fit chi-square 811,082, probability chi-square (1755) = 1.0, indicating good fit.

Table 6

Poisson regression analysis factors contributing to 12-month death, controlling for injury-related factors (Injury Severity Score, Glasgow Coma Score—Motor, midline shift, pupillary response, maximal head Abbreviated Injury Scale, sex, and Charlson score) in the entire study cohort, with traumatically brain-injured patients aged 25–54 yrs serving as the reference group

Variable	Univariate RR (95% CI)	Multivariate RR (95% CI)
Trauma center care	0.79 (0.62, 1.01)	NS
Admission to ICU	1.32 (1.02, 1.70) ^a	NS
No. surgical specialty assess	0.70 (0.54, 0.90) ^a	0.77 (0.62, 0.95) ^a
No. medical specialty assess	0.97 (0.85, 1.11)	NS
No. other specialty assess	0.42 (0.23, 0.77) ^a	0.41 (0.25, 0.69) ^a
Critical care consultant	0.83 (0.68, 1.02)	0.84 (0.71, 1.00)
Intubated	2.87 (2.10, 3.93) ^a	2.26 (1.67, 3.05) ^a
Pulmonary artery catheter use	1.39 (0.98, 1.96)	1.52 (1.21, 1.90) ^a
Mannitol use	1.42 (1.15, 1.74) ^a	1.26 (1.06, 1.50) ^a
Intracranial pressure monitoring	1.07 (0.87, 1.32)	NS
Decompressive craniectomy	0.68 (0.43, 1.09)	NS
Do-not-resuscitate order	4.88 (3.52, 6.77) ^a	2.50 (1.86, 3.36) ^a
Therapy withdrawn	4.25 (3.09, 5.85) ^a	1.65 (1.29, 2.12) ^a
Age, 55–64 yrs	1.55 (1.20, 2.01) ^a	1.18 (0.97, 1.43)
Age, 65–74 yrs	1.92 (1.39, 2.66) ^a	1.44 (1.17, 1.77) ^a
Age, 75–84 yrs	3.21 (2.45, 4.20) ^a	2.03 (1.59, 2.59) ^a
No. of nonneurosurgical procedures	0.98 (0.95, 1.01)	0.96 (0.92, 0.99) ^a

RR, relative risk; 95% CI, 95% confidence interval; NS, not significant; ICU, intensive care unit; assess, assessments.

^a $p < .05$. Model goodness-of-fit chi-square = 1378.57, probability chi-square (1753) = 1.0, indicating good fit.