Change in Age Distribution of the Injuries and Comparison of Different Scoring Tools in Predicting Mortality Among Geriatric Trauma Patients

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Abstract

Purpose:
The aim of this study was to describe the age trend of trauma patients and to compare different scoring tools to predict in-hospital mortality in elderly trauma patients.

Methods:
National Trauma Database (NTDB) in the United States from 2005 to 2015 and the Trauma Register DGU® in German from 1994 to 2012 was searched to describe age change of trauma patients. Then we secondly analyzed the data published in http://datadryad.org/. According to the in-hospital survival status, patients were divided into survival group and non-survival group. Receiver Operating Characteristic Curve (ROC) analysis was used to evaluated the value of ISS (injury severity score); NISS (new injury severity score), APACHE II (Acute Physiology and Chronic Health Evaluation II), SPAS (simplified acute physiology score II) and TRISS (Trauma and Injury Severity Score) in predicting in-hospital mortality among geriatric trauma patients.

Results:
The analysis of NTDB showed the percentage of geriatric trauma has increased from 0.18 to 0.30, 2005-2015. The analysis of DGU showed the mean age rose from 39.11 in 1993 to 51.10 in 2013, and the percentage of patients aged ≥60 rose from 16.5% to 37.5%. A total of 311 patients aged more than 65 years were secondly analyzed. One hundred and sixty-four (52.73%) patients died in the hospital. ISS, NISS, APACHE, and SAPS in the death group were significantly higher than those in the survival group, but TRISS in the death group was significantly lower than those in the survival group. The AUC of APACHE II was 0.715, ISS was 0.807, NISS was 0.850, SPAS II was 0.725, and TRISS was 0.828.

Conclusion:
The increasing number of trauma in the elderly is a challenge for current and future trauma management. Compared with APACHE and SAPS, ISS, NISS and TRISS are more suitable for predicting in-hospital mortality in elderly trauma patients.

Background
Trauma is the leading cause of death among young population aged less than 44 [1]. The improvement of care system results in decreasing of trauma associated death [2]. However, along with the aging population, we face new challenge in managing geriatric trauma patients [3]. Complicated underlying diseases, various medication use, and limited physical reserve made geriatric trauma patients more vulnerable to bad prognosis [4–6]. Studies have reported higher mortality rates in older trauma patients than in younger trauma patients [7–10]. Now more and more countries and regions gradually pay attention to the treatment of elderly trauma patients, and even some regions have establishedelderly
trauma treatment centers [11–13]. However, the trend of age change of trauma patients and the gradual increase of the number of elderly trauma patients has not aroused global attention. Prognosis prediction of trauma patients is an important part of making diagnosis and treatment decisions [14–16]. A number of scoring tools have been used to predict mortality in trauma patients [15]. Some researchers have even proposed a prognostic scoring tool specific to older trauma patients, although its predictive accuracy does not appear to be significantly superior to traditional scoring tools [14, 16–18]. At the same time, there is a lack of research comparing traditional prognostic assessment tools in elderly patients with trauma. The aim of this study was to describe the age trend of trauma patients by analyzing the annual reports of the two trauma databases, and to compare the ability of ISS (Injury severity score), NISS (New injury severity score), APACHEⅡ (Acute Physiology and Chronic Health EvaluationⅡ), SAPSⅡ (Simplified acute physiology scoreⅡ) and TRISS (Trauma and Injury Severity Score) to predict in-hospital mortality in elderly trauma patients.

Methods

We searched the annual reports of the National Trauma Database (NTDB) in the United States from 2005 to 2015 and the Trauma Register DGU® in German from 1994 to 2012 to describe the change in age distribution of trauma patients. Then we secondly analyzed the data published in https://datadryad.org/stash/dataset/doi:10.5061/dryad.2v6wwpzhk[19]. The authors in the original article evaluated the effects of standards of practice (SOP) on geriatric trauma patients [19]. Finally, they included 311 geriatric trauma patients and found the implementation of SOP could decrease the mortality rate of geriatric trauma patients. Categorical variables were represented as frequency (%), and continuous variables were represented as median (inter-quartile range). According to the in-hospital survival status, patients were divided into survival group and non-survival group. Difference of baseline information between two groups was evaluated using Chi-square or Fisher exact test for categorical variables, and T test or non-parameter test for continuous variables. We used Receiver Operating Characteristic Curve (ROC) to evaluated the value of TRISS, APACHEⅡ, SAPSⅡ, ISS, and NISS in predicting in-hospital mortality among geriatric trauma patients and corresponding area under the ROC (AUC) was calculated. All statistical process was performed using IBM SPSS 20.0 (Zhejiang University) and P < 0.05 was regarded as statistical significance.

Results

The analysis of NTDB showed the percentage of geriatric trauma has increased from 0.18 to 0.30, whereas the percentage of trauma patients aged less than 65 has been declining during the period 2005–2015 (Fig. 1a). The mortality rate of geriatric trauma patients was significantly higher than that of younger counterparts. And the mortality of male geriatric trauma patients was higher than that of female geriatric trauma patients (Fig. 1b). Eighty nine thousand patients with ISS (injury severity score) ≥ 9 in the DGU was analyzed (Prof. Dr. Rolf Lefering (Institut für Forschung in der Operativen Medizin; Fakultät für Gesundheit der Universität Witten/Herdecke). The mean age rose from 39.11 in 1993 to 51.10 in 2013,
and the percentage of patients aged ≥ 60 rose from 16.5–37.5% (Fig. 1c, 1d). In China, major trauma accounts for more than 60 million visits annually to Chinese hospitals, and is related to 700 000 to 800 000 deaths.[20] According to the National Bureau of Statistics of the People’s Republic of China, the percentage of population aged ≥ 65 increased from 0.077 to 0.101 between 2005 and 2014 Fig. 1e.

A total of 311 patients aged more than 65 years were extracted from the study by Lorenz [19], of which 59.00% were male. One hundred and sixty-four (52.73%) patients died in the hospital. Table 1 shows the detailed characteristics of included patients. There was no significantly statistical difference between the survival group and death group in trauma mechanism, base excess, body mass index, leucocytes, thrombocytes, prothrombin, systolic blood pressure, mean artery pressure, and temperature. Patients in the death group were older, had lower Glasgow coma Scale (GCS) scores, lower hemoglobin levels, higher lactate levels, shorter intensive care unit (ICU) hospital stays, and shorter overall hospital stays, compared to patients in the survival group.
Table 1
Characteristics of included patients

|                     | Survival | Death          | P value |
|---------------------|----------|----------------|---------|
| Number of patients  | 147      | 164            |         |
| Trauma mechanism    |          |                |         |
| Blunt               | 144(48.30%) | 154(51.70%)   | 0.07    |
| Penetrating         | 3(23.10%)  | 10(76.90%)     |         |
| GCS                 |          |                |         |
| 3–8                 | 47(27.30%) | 125(72.7-%)    | <0.01   |
| 9–12                | 22(61.10%) | 14(38.90%)     |         |
| 13–15               | 78(75.70%) | 25(24.30%)     |         |
| Age                 | 74.00 (68.25 to 80.00) | 78.00(72.00 to 83.00) | <0.01   |
| Base excess [mEq/L] | -2.80 (-5.50 to -0.80) | -3.25(-7.80 to -0.55) | 0.32    |
| Body mass index     | 25.95 (22.89 to 28.40) | 25.90(22.04 to 29.16) | 0.74    |
| Hemoglobin [g/L]    | 11.80 (9.90 to 13.10) | 10.60(8.10 to 12.20) | <0.01   |
| Lactate [mmol/L]    | 1.90 (1.15 to 2.80)  | 2.10(1.40 to 3.40) | 0.03    |
| Los of hospital [days] | 16.50 (9.00 to 25.00) | 1.50(1.00 to 3.00) | <0.01   |
| Leucocytes [10^9/L] | 10.49 (7.33 to 13.96) | 11.12(6.96 to 14.24) | 0.86    |
| Thrombocytes [10^9/L] | 190.50(152.00 to 239.50) | 174.00(132.00 to 230.00) | 0.07    |
| Prothrombin [% normal] | 80.00 (59.00 to 95.00) | 74.00(52.00 to 89.25) | 0.08    |
| Systolic pressure mmHg | 142.50 (115.00 to 160.000) | 125.00(110.00 to 158.75) | 0.09    |
| Mean artery pressure [mmHg] | 100.00 (82.00 to 112.75) | 92.00(76.50 to 113.50) | 0.22    |
| Temperature         | 35.40(34.50 to 36.20) | 35.25(34.10 to 36.00) | 0.31    |
| Los of ICU [days]   | 5.00 (2.00 to 12.00)  | 1.00(0.50 to 2.00) | <0.01   |
| Los of MV [days]    | 1.00(0.00 to 6.25)   | 1.00(0.25 to 2.00) | 0.04    |

GCS, Glasgow score; Los, length of stay; ICU, Intensive care unit; MV, mechanical ventilation.

We compared the differences in ISS, NISS, TRISS, APACHE, and SAPS between the survival and the death groups. ISS, NISS, APACHE, and SAPS in the death group were significantly higher than those in the survival group, but TRISS in the death group was significantly lower than those in the survival group. It is important to note that TRISS calculates the survival probability (Table 2 and Fig. 2). AUC was calculated.
to assess the ability of different scoring instruments to predict in-hospital mortality. Table 3 and Fig. 3 shows the AUC of APACHE II was 0.715, ISS was 0.807, NISS was 0.850, SPAS II was 0.725, and TRISS was 0.828. Table 4 compares the AUCs with different scores. Compared with APACHE II and SAPS II, the ISS, NISS, and TRISS scores appear to be better predictors of in-hospital mortality in older trauma patients. The AUC of the NISS score was the largest.

Table 2

|          | Survival          | Death             | P value |
|----------|-------------------|-------------------|---------|
| SPAS I   | 34.00 (27.00 to 55.00) | 55.00 (34.75 to 61.00) | < 0.01  |
| APACHE II| 15.00 (10.00 to 22.00) | 23.00 (19.00 to 29.00) | < 0.01  |
| ISS      | 24.00 (14.50 to 29.00) | 34.00 (25.00 to 75.00) | < 0.01  |
| NISS     | 27.00 (22.00 to 38.00) | 50.00 (34.00 to 75.00) | < 0.01  |
| TRISS    | 0.96 (0.78 to 0.99)  | 0.51 (0.11 to 0.82) | < 0.01  |

SPAS I, simplified acute physiology score II; APACHE II, Acute Physiology and Chronic Health Evaluation II; ISS, injury severity score; NISS, new injury severity score; TRISS, Trauma and Injury Severity Score.

Table 3

|          | AUC   | 95% CI of AUC     |
|----------|-------|-------------------|
| APACHE II| 0.715 | 0.644 to 0.778    |
| ISS      | 0.807 | 0.743 to 0.861    |
| NISS     | 0.850 | 0.790 to 0.898    |
| SPAS II  | 0.725 | 0.655 to 0.788    |
| TRISS    | 0.828 | 0.766 to 0.880    |

SPAS II, simplified acute physiology score II; APACHE II, Acute Physiology and Chronic Health Evaluation II; ISS, injury severity score; NISS, new injury severity score; TRISS, Trauma and Injury Severity Score; AUC, area under the receiver operating characteristic curve.
Table 4
The matrix of AUC comparison between different scoring tool using P value

|       | SPAS | APACHE | ISS  | NISS | TRISS |
|-------|------|--------|------|------|-------|
| SPAS  | 0.61 | 0.07   | <0.01| <0.01|       |
| APACHE| 0.61 | 0.03   | <0.01| <0.01|       |
| ISS   | 0.07 | 0.03   | 0.02 | 0.34 |       |
| NISS  | <0.01| <0.01  | 0.02 | 0.37 |       |
| TRISS | <0.01| <0.01  | 0.34 | 0.37 |       |

SPAS, simplified acute physiology score; APACHE, Acute Physiology and Chronic Health Evaluation; ISS, injury severity score; NISS, new injury severity score; TRISS, Trauma and Injury Severity Score; AUC, area under the receiver operating characteristic curve.

Discussion

With the aging of the population, the number of elderly trauma is increasing, which brings great challenges to the treatment of trauma. In this study, several databases were used to describe the age changes of trauma patients, further confirming the increasing number of elderly trauma patients. At the same time, this study compared the predictive value of different scoring tools for in-hospital mortality of elderly trauma patients. We found that the ISS, NISS, and TRISS scores were better than the SAPS II and APACHE II scores at predicting in-hospital mortality in older trauma patients. And the NISS may be the best scoring tool.

Currently, injury is the seventh leading cause of death in the elderly (https://webappa.cdc.gov/). In addition to the United States, Germany, a number of other countries have reported an increase in the number of elderly trauma patients [21, 22]. Dealing with these patients is challenging. Firstly, several studies have reported that most geriatric trauma patients were under-triaged, which may be associated with a higher risk of death [23]. Some studies have reported that adding age to triage criteria may improve outcomes in older traumatic patients [24, 25]. Moreover, Guidelines recommend lowering criteria for initiating trauma teams in older trauma patients to improve the outcome of such patients [26]. Therefore, future studies should establish a more accurate pre-hospital triage criterion for older trauma, which should include at least the following indicators: age, comorbidities, and physiological reserve, etc.

Secondly, in recent years, frailty has been used more in the elderly. Frailty is defined as a syndrome of low physiologic capacity, decreased resistance to stressors, and increased vulnerability [27]. Frailty is not equal to age and more effective than age [28] In non-trauma patients, frailty has been demonstrated to be associated with poor health outcomes [29]. However, this relationship in geriatric trauma patients has not be comprehensively studied. Current tools to predict the risk of poor prognosis are inadequate, as they fail to include the effects of physiological capacity among geriatric trauma patients. It is necessary to define frailty correctly and measure frailty using an effective tool. Although general or geriatric trauma specific
frailty index have been proposed, and were reported to be independently associated with poor prognosis, and could be used for risk stratification of geriatric trauma patients [30, 31]. But it is complex and time-consuming. Further studies focus on developing trauma specific frailty index and evaluating its effects on decision-making process. Finally, the complex comorbidities and medications use make the management of these patients more challenging. There is approximately 31 million people aged more than 65 use anticoagulant agent, and this number would raise to 68 million by the year 2020 in the United States [32]. Several studies have shown that pre-injury use of anti-platelet or anticoagulant agents are associated with poor outcomes [33]. Therefore, it may be necessary to identify these patients and revisit appropriately. Due to paucity of high quality studies, the standard management of these patients remain unclear [34]. In conclusion, ageing population brings great challenge to the management of trauma patients. A dedicated geriatric trauma protocol is required for quality improvement [35].

It is essential to accurately predict the prognosis of elderly patients with trauma. This is an important part of the conversation between doctors and patients their surrogate decision maker, but also an important basis for decision-making. Several scoring systems have been proposed for predicting mortality in trauma patients [15]. In 1974, the ISS was proposed, primarily based on the AIS score[36]. Later, some researchers pointed out the shortcomings of ISS and proposed NISS. Although studies suggest that NISS is better at predicting mortality in trauma patients than the ISS score, NISS is not widely used clinically [37–39]. Currently, TRISS is a classic scoring tool for predicting mortality in trauma patients[40]. The coefficients come from Major Trauma Outcome Study (MTOS) database. TRISS uses age, ISS, and RTS (physiological parameters: GCS, systolic blood pressure, and respiration rate). In 2010, the Schluter et al. updated its coefficients based on the NTDB database. But compared to the original TRISS, the updated is not widely used[41]. A Severity Characterization of Trauma (ASCOT) is another potential tool for evaluating the prognosis of trauma patients. Unlike the TRISS, the ASCOT incorporates all AIS scores for each body part[42]. Therefore, the calculation is relatively complex, and there may be great differences among different evaluators. The APACHE II score and the SAPS II score are routinely used to assess the severity and prognosis of patients with general critical illness, not just trauma. Although some studies have also assessed the ability of these physiologically-sensitive scoring systems to predict outcome in patients with trauma, the results suggest no significant advantage[43–52]. None of the scoring tools mentioned above are specific to older trauma patients. Both the anatomical scoring system and the physiological parameter scoring system have been reported to predict the prognosis of elderly patients with trauma[14, 53, 54]. But no studies have compared these scoring systems in older patients with trauma. This study compared the ability of ISS, NISS, TRISS, APACHE, and SAPS scores to predict in-hospital mortality in elderly trauma patients by secondary analysis. Our results suggest that the predictive power of ISS, NISS, and TRISS scores may be superior to APACHE II and SAPS II scores. NISS seems to be the best. These results suggest that anatomical injury is more important for the prognosis of elderly patients with trauma. We have already mentioned the specificity of the treatment of trauma in the elderly, so assessing the prognosis of elderly trauma patients may be more complex.

Geriatric Trauma Outcome Score (GTOS) was proposed specifically for predicting the prognosis of elderly trauma patients [55]. Using the variables of ISS, age, and performance of packed red blood cell (PRBC)
transfusion within 24 hours of admission, GTOS was developed through a single center study and validated in a following multi-center study [56]. And in order to predict the unfavorable discharge in geriatric trauma patients, GTOS was developed. Compared with GTOS, GTOS uses the same parameters but has different coefficients [16]. Some studies have compared GTOS with TRISS, and the results suggest that GTOS does not show a significant advantage in predicting accuracy[14, 15]. Unlike TRISS, the physiological parameters obtained for the first time are required. The construction of trauma database makes it possible to obtain a large number of trauma data. On this basis, the popularization of artificial intelligence and deep learning algorithms have promoted the accurate prediction of trauma patients’ clinical outcomes. It has been pointed out that the advanced deep learning algorithm can better predict the adverse outcomes of critically patients than the traditional regression algorithm [57, 58]. Therefore, in the future, we hope to optimize the trauma database and build advanced deep learning algorithm by incorporating more variables, to achieve accurate prognosis of elderly trauma patients.

**Conclusion**

The increasing number of trauma in the elderly is a challenge for current and future trauma management. Compared with APACHE and SAPS, ISS, NISS and TRISS are more suitable for predicting in-hospital mortality in elderly trauma patients. Considering more predictive variables and using deep learning algorithm to construct artificial intelligence real-time prediction model is the future research direction.

**Abbreviations**

GCS  Glasgow score;

Los  Length of stay;

ICU  Intensive care unit;

MV  Mechanical ventilation;

SPAS  Simplified acute physiology score;

APACHE  Acute Physiology and Chronic Health Evaluation;

ISS  Injury severity score;

NISS  New injury severity score;

TRISS  Trauma and Injury Severity Score;

AUC  Area under the receiver operating characteristic curve;

RTS  Revised trauma score;
NTDB  National trauma databank;
ASCOT  A Severity Characterization of Trauma;
MTOS  Major Trauma Outcome Study;
GTOS  Geriatric Trauma Outcome Score.

Declarations

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Authors’ contributions

LBJ and MZ contributed to the design of the study, the acquisition of data, the analysis, and interpretation. LBJ and ZJZ conducted the statistical analysis of the data. LBJ and ZJZ drafted the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of the Second Affiliated Hospital, School of Medicine, Zhejiang University Research Ethics Committee, and the need for informed consent was waived.

Consent for publication

Not applicable
Competing interests

We declare no competing interests.

References

1. Jiang L, Ma Y, Jiang S, Ye L, Zheng Z, Xu Y, Zhang M: **Comparison of whole-body computed tomography vs selective radiological imaging on outcomes in major trauma patients: a meta-analysis.** Scandinavian journal of trauma, resuscitation and emergency medicine 2014, **22**:54.

2. Moore L, Champion H, Tardif PA, Kuimi BL, O'Reilly G, Leppaniemi A, Cameron P, Palmer CS, Abu-Zidan FM, Gabbe B *et al.*: **Impact of Trauma System Structure on Injury Outcomes: A Systematic Review and Meta-Analysis.** World J Surg 2018, **42**(5):1327-1339.

3. Southern AP, Jwayyed S: **Geriatric Trauma.** In: *StatPearls.* edn. Treasure Island (FL); 2019.

4. Benoit E, Stephen AH, Monaghan SF, Lueckel SN, Adams CA, Jr.: **Geriatric Trauma.** Rhode Island medical journal 2019, **102**(8):19-22.

5. Horst MA, Morgan ME, Vernon TM, Bradburn EH, Cook AD, Shtayyeh T, D’Andrea L, Rogers FB: **The geriatric trauma patient: A neglected individual in a mature trauma system.** The journal of trauma and acute care surgery 2020, **89**(1):192-198.

6. Southern AP, Lopez RA, Jwayyed S: **Geriatric Trauma.** In: *StatPearls.* edn. Treasure Island (FL); 2020.

7. Champion HR, Copes WS, Buyer D, Flanagan ME, Bain L, Sacco WJ: **Major trauma in geriatric patients.** American journal of public health 1989, **79**(9):1278-1282.

8. Callaway DW, Wolfe R: **Geriatric trauma.** Emergency medicine clinics of North America 2007, **25**(3):837-860, x.

9. Pohlemann T, Histing T: **Challenges in geriatric trauma care.** Innovative surgical sciences 2016, **1**(2):47-48.

10. Ferrera PC, Bartfield JM, D’Andrea CC: **Outcomes of admitted geriatric trauma victims.** The American journal of emergency medicine 2000, **18**(5):575-580.

11. Friess T, Hartwig E, Liener U, Sturm J, Hoffmann R: [Geriatric trauma centers from the idea to implementation. What has been achieved?]. Der Unfallchirurg 2016, **119**(1):7-11.

12. Gogol M, van den Heuvel D, Luttje D, Pullen R, Reingraber AC, Schulz RJ, Veer A, Wittrich A: [Geriatric trauma centers - requirements catalog. An initiative to promote and guarantee the quality of care of elderly trauma patients receiving inpatient care]. Z Gerontol Geriatr 2014, **47**(4):310-316.

13. Pape HC, Friess T, Liener U, Ruchholtz S, Schmucker U, Sturm JA, Buecking G, Riem S, Hartwig E: **Development of geriatric trauma centers – an effort by the German Society for Trauma and Orthopaedics.** Injury 2014, **45**(10):1513-1515.

14. Barea-Mendoza JA, Chico-Fernandez M, Sanchez-Casado M, Molina-Diaz I, Quintana-Diaz M, Jimenez-Moragas JM, Perez-Barcena J, Llompart-Pou JA, en representacion del Grupo de Trabajo de Neurointensivismo y Trauma de la Sociedad Espanola de Medicina Intensiva CyUC: Predicting
survival in geriatric trauma patients: A comparison between the TRISS methodology and the Geriatric Trauma Outcome Score. *Cirugia espanola* 2018, 96(6):357-362.

15. Madni TD, Ekeh AP, Brakenridge SC, Brasel KJ, Joseph B, Inaba K, Bruns BR, Kerby JD, Cuschieri J, Mohler MJ *et al.*: A comparison of prognosis calculators for geriatric trauma: A Prognostic Assessment of Life and Limitations After Trauma in the Elderly consortium study. *The journal of trauma and acute care surgery* 2017, 83(1):90-96.

16. Cook AC, Joseph B, Mohler MJ, Inaba K, Bruns BR, Nakonezny PA, Kerby JD, Brasel KJ, Wolf SE, Cuschieri J *et al.*: Validation of a Geriatric Trauma Prognosis Calculator: A P.A.L.Li.A.T.E. Consortium Study. *J Am Geriatr Soc* 2017, 65(10):2302-2307.

17. Ahl R, Phelan HA, Dogan S, Cao Y, Cook AC, Mohseni S: Predicting In-Hospital and 1-Year Mortality in Geriatric Trauma Patients Using Geriatric Trauma Outcome Score. *J Am Coll Surg* 2017, 224(3):264-269.

18. Ross SW, Adeyemi FM, Zhou M, Minhaijuddin AT, Porembka MR, Cripps MW, Phelan HA: One-year mortality in geriatric trauma patients: Improving upon the geriatric trauma outcomes score utilizing the social security death index. *The journal of trauma and acute care surgery* 2019, 87(5):1148-1155.

19. Peterer L, Ossendorf C, Jensen KO, Osterhoff G, Mica L, Seifert B, Werner CML, Simmen HP, Pape HC, Sprengel K: Implementation of new standard operating procedures for geriatric trauma patients with multiple injuries: a single level I trauma centre study, v5, Dryad, Dataset, https://doi.org/10.5061/dryad.2v6wppzhk. 2020.

20. Watts G: *Jiang Baoguo: one, two, three against trauma in China*. *Lancet* 2017, 390(10104):1729-1729.

21. Ludi E, Boeck M, South S, Monasterio J, Swaroop M, Foianini E: Geriatric Trauma in Santa Cruz, Bolivia. *The Journal of surgical research* 2019, 244:212-217.

22. Gioffe-Florio M, Murabito LM, Visalli C, Pergolizzi FP, Fama F: Trauma in elderly patients: a study of prevalence, comorbidities and gender differences. *Il Giornale di chirurgia* 2018, 39(1):35-40.

23. Amoako J, Evans S, Brown NV, Khaliqdina S, Caterino JM: Identifying Predictors of Undertriage in Injured Older Adults After Implementation of Statewide Geriatric Trauma Triage Criteria. *Academic emergency medicine : official journal of the Society for Academic Emergency Medicine* 2019.

24. Caterino JM, Brown NV, Hamilton MW, Ichwan B, Khaliqdina S, Evans DC, Darbha S, Panchal AR, Shah MN: Effect of Geriatric-Specific Trauma Triage Criteria on Outcomes in Injured Older Adults: A Statewide Retrospective Cohort Study. *J Am Geriatr Soc* 2016, 64(10):1944-1951.

25. Hammer PM, Storey AC, Bell T, Bayt D, Hockaday MS, Zarzaur BL, Jr., Feliciano DV, Rozycki GS: Improving geriatric trauma outcomes: A small step toward a big problem. *The journal of trauma and acute care surgery* 2016, 81(1):162-167.

26. Calland JF, Ingraham AM, Martin N, Marshall GT, Schulman CI, Stapleton T, Barraco RD, Eastern Association for the Surgery of T: Evaluation and management of geriatric trauma: an Eastern Association for the Surgery of Trauma practice management guideline. *The journal of trauma and acute care surgery* 2012, 73(5 Suppl 4):S345-350.
27. Engelhardt KE, Reuter Q, Liu J, Bean JF, Barnum J, Shapiro MB, Ambre A, Dunbar A, Markzon M, Reddy TN et al: Frailty screening and a frailty pathway decrease length of stay, loss of independence, and 30-day readmission rates in frail geriatric trauma and emergency general surgery patients. *The journal of trauma and acute care surgery* 2018, **85**(1):167-173.

28. Joseph B, Pandit V, Zangbar B, Kulvatunyou N, Hashmi A, Green DJ, O’Keeffe T, Tang A, Vercruysse G, Fain MJ et al: Superiority of frailty over age in predicting outcomes among geriatric trauma patients: a prospective analysis. *JAMA surgery* 2014, **149**(8):766-772.

29. Zampieri FG, Iwashyna TJ, Viglianti EM, Taniguchi LU, Viana WN, Costa R, Correa TD, Moreira CEN, Maia MO, Moralez GM et al: Association of frailty with short-term outcomes, organ support and resource use in critically ill patients. *Intensive care medicine* 2018, **44**(9):1512-1520.

30. Joseph B, Pandit V, Zangbar B, Kulvatunyou N, Tang A, O’Keeffe T, Green DJ, Vercruysse G, Fain MJ, Friese RS et al: Validating trauma-specific frailty index for geriatric trauma patients: a prospective analysis. *J Am Coll Surg* 2014, **219**(1):10-17 e11.

31. Joseph B, Pandit V, Rhee P, Aziz H, Sadoun M, Wynne J, Tang A, Kulvatunyou N, O’Keeffe T, Fain MJ et al: Predicting hospital discharge disposition in geriatric trauma patients: Is frailty the answer? *J Trauma Acute Care* 2014, **76**(1):196-204.

32. Ferraris VA, Bernard AC, Hyde B, Kearney PA: The impact of antiplatelet drugs on trauma outcomes. *J Trauma Acute Care* 2012, **73**(2):492-497.

33. Barletta JF, Hall S, Sucher JF, Dzandu JK, Haley M, Mangram AJ: The impact of pre-injury direct oral anticoagulants compared to warfarin in geriatric G-60 trauma patients. *Eur J Trauma Emerg S* 2017, **43**(4):445-449.

34. Wiegele M, Schochl H, Haushofer A, Ortler M, Leitgeb J, Kwasny O, Beer R, Ay C, Schaden E: Diagnostic and therapeutic approach in adult patients with traumatic brain injury receiving oral anticoagulant therapy: an Austrian interdisciplinary consensus statement. *Critical care* 2019, **23**(1):62.

35. Bradburn E, Rogers FB, Krasne M, Rogers A, Horst MA, Belan MJ, Miller JA: High-risk geriatric protocol: Improving mortality in the elderly. *J Trauma Acute Care* 2012, **73**(2):435-439.

36. Baker SP, O’Neill B, Haddon W, Jr., Long WB: The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *The Journal of trauma* 1974, **14**(3):187-196.

37. Frankema SP, Steyerberg EW, Edwards MJ, van Vugt AB: Comparison of current injury scales for survival chance estimation: an evaluation comparing the predictive performance of the ISS, NISS, and AP scores in a Dutch local trauma registration. *The Journal of trauma* 2005, **58**(3):596-604.

38. Lavoie A, Moore L, LeSage N, Liberman M, Sampalis JS: The New Injury Severity Score: a more accurate predictor of in-hospital mortality than the Injury Severity Score. *The Journal of trauma* 2004, **56**(6):1312-1320.

39. Nogueira Lde S, Domingues Cde A, Campos Mde A, Sousa RM: Ten years of new injury severity score (NISS): is it a possible change? *Revista latino-americana de enfermagem* 2008, **16**(2):314-319.
40. Boyd CR, Tolson MA, Copes WS: Evaluating trauma care: the TRISS method. Trauma Score and the Injury Severity Score. The Journal of trauma 1987, 27(4):370-378.
41. Schluter PJ, Nathens A, Neal ML, Goble S, Cameron CM, Davey TM, McClure RJ: Trauma and Injury Severity Score (TRISS) coefficients 2009 revision. The Journal of trauma 2010, 68(4):761-770.
42. Corbanese U, Possamai C, Casagrande L: Improved prediction from A Severity Characterization of Trauma (ASCOT) over Trauma and Injury Severity Scores (TRISS). The Journal of trauma 1996, 41(3):573-574.
43. Darbandsar Mazandarani P, Heydari K, Hatamabadi H, Kashani P, Jamali Danesh Y: Acute Physiology and Chronic Health Evaluation (APACHE) III Score compared to Trauma-Injury Severity Score (TRISS) in Predicting Mortality of Trauma Patients. Emergency 2016, 4(2):88-91.
44. Dossett LA, Redhage LA, Sawyer RG, May AK: Revisiting the validity of APACHE II in the trauma ICU: improved risk stratification in critically injured adults. Injury 2009, 40(9):993-998.
45. Liang J, Zhou Z: Application of APACHE II scoring in ICU trauma patients. Chinese journal of traumatology = Zhonghua chuang shang za zhi 1998, 1(1):58-60.
46. Polita JR, Gomez J, Friedman G, Ribeiro SP: Comparison of APACHE II and three abbreviated APACHE II scores for predicting outcome among emergency trauma patients. Revista da Associacao Medica Brasileira 2014, 60(4):381-386.
47. Rutledge R, Fakhry S, Rutherford E, Muakkassa F, Meyer A: Comparison of APACHE II, Trauma Score, and Injury Severity Score as predictors of outcome in critically injured trauma patients. American journal of surgery 1993, 166(3):244-247.
48. Thanapaisal C, Saksaen P: A comparison of the Acute Physiology and Chronic Health Evaluation (APACHE) II score and the Trauma-Injury Severity Score (TRISS) for outcome assessment in Srinagarind Intensive Care Unit trauma patients. Journal of the Medical Association of Thailand = Chotmaihet thangphaet 2012, 95 Suppl 11:S25-33.
49. Vasilyeva IV, Shvirev SL, Arseniev SB, Zarubina TV: Prognostic scales ISS-RTS-TRISS, PRISM, APACHE II and PTS in decision support of treatment children with severe mechanical trauma. Studies in health technology and informatics 2013, 190:59-61.
50. Vassar MJ, Lewis FR, Jr., Chambers JA, Mullins RJ, O’Brien PE, Weigelt JA, Hoang MT, Holcroft JW: Prediction of outcome in intensive care unit trauma patients: a multicenter study of Acute Physiology and Chronic Health Evaluation (APACHE), Trauma and Injury Severity Score (TRISS), and a 24-hour intensive care unit (ICU) point system. The Journal of trauma 1999, 47(2):324-329.
51. Vassar MJ, Wilkerson CL, Duran PJ, Perry CA, Holcroft JW: Comparison of APACHE II, TRISS, and a proposed 24-hour ICU point system for prediction of outcome in ICU trauma patients. The Journal of trauma 1992, 32(4):490-499; discussion 499-500.
52. Wong DT, Barrow PM, Gomez M, McGuire GP: A comparison of the Acute Physiology and Chronic Health Evaluation (APACHE) II score and the Trauma-Injury Severity Score (TRISS) for outcome assessment in intensive care unit trauma patients. Critical care medicine 1996, 24(10):1642-1648.
53. Pandit V, Rhee P, Hashmi A, Kulvatunyou N, Tang A, Khalil M, O’Keeffe T, Green D, Friese RS, Joseph B: Shock index predicts mortality in geriatric trauma patients: an analysis of the National Trauma Data Bank. *The journal of trauma and acute care surgery* 2014, 76(4):1111-1115.

54. Brooks SE, Mukherjee K, Gunter OL, Guillamondegui OD, Jenkins JM, Miller RS, May AK: Do models incorporating comorbidities outperform those incorporating vital signs and injury pattern for predicting mortality in geriatric trauma? *J Am Coll Surg* 2014, 219(5):1020-1027.

55. Zhao FZ, Wolf SE, Nakonezny PA, Minhajuddin A, Rhodes RL, Paulk ME, Phelan HA: Estimating Geriatric Mortality after Injury Using Age, Injury Severity, and Performance of a Transfusion: The Geriatric Trauma Outcome Score. *Journal of palliative medicine* 2015, 18(8):677-681.

56. Cook AC, Joseph B, Inaba K, Nakonezny PA, Bruns BR, Kerby JD, Brasel KJ, Wolf SE, Cuschieri J, Paulk ME et al: Multicenter external validation of the Geriatric Trauma Outcome Score: A study by the Prognostic Assessment of Life and Limitations After Trauma in the Elderly (PALLIATE) consortium. *The journal of trauma and acute care surgery* 2016, 80(2):204-209.

57. Becalick DC, Coats TJ: Comparison of artificial intelligence techniques with UKTRISS for estimating probability of survival after trauma. *UK Trauma and Injury Severity Score*. *The Journal of trauma* 2001, 51(1):123-133.

58. Kim SY, Kim S, Cho J, Kim YS, Sol IS, Sung Y, Cho I, Park M, Jang H, Kim YH et al: A deep learning model for real-time mortality prediction in critically ill children. *Critical care* 2019, 23(1):279.

**Figures**
Figure 1

a) The change trend of trauma patients aged <65 vs ≥65 using the data of NTDB. b) The mortality change trend of trauma patients aged <65 vs ≥65 using the data of NTDB. c,d) The age change trend of trauma patients using data of DGU. e) The age change trend of Chinese people.
Figure 2

The comparison of ISS, NISS, APACHE II, SPAS II and TRISS between the survival group and death group. ISS, injury severity score; NISS, new injury severity score; SPAS II, simplified acute physiology score II; APACHE II, Acute Physiology and Chronic Health Evaluation II; TRISS, Trauma and Injury Severity Score.
Figure 3

The AUC of ISS, NISS, APACHE II, SPAS II and TRISS in predicting in-hospital mortality among geriatric trauma patients. ISS, injury severity score; NISS, new injury severity score; SPAS II, simplified acute physiology score II; APACHE II, Acute Physiology and Chronic Health Evaluation II; TRISS, Trauma and Injury Severity Score.