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Denver ED Trauma Organ Failure Score outperforms traditional methods of risk stratification in trauma★,★,★

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Abstract

Background—Early identification of trauma patients at risk for in-hospital mortality may facilitate goal-directed resuscitation and secondary triage to improve outcomes. The objective of this study was to compare prognostic accuracies of the Denver Emergency Department (ED) Trauma Organ Failure (TOF) Score, ED Sequential Organ Failure Assessment (SOFA) score, and ED base deficit and ED lactate for in-hospital mortality in adult trauma patients.

Methods—Consecutive adult trauma patients from 2005 to 2008 from the Denver Health Trauma Registry were included. Prognostic accuracies of the Denver ED TOF Score, ED SOFA score, ED base deficit, and ED lactate for in-hospital mortality were evaluated with receiver operating characteristic curves.

Results—Of the 4355 patients, the median age was 37 years (interquartile range [IQR], 26–51 years), median Injury Severity Score was 9 (IQR, 4–16), and 81% had blunt mechanisms. In addition, 38% (1670 patients) were admitted to the intensive care unit with a median intensive care unit length of stay of 2.5 days (IQR, 1–8 days), and 3% (138 patients) died. The areas under the receiver operating characteristic curves for the Denver ED TOF, ED lactate, ED base deficit, and ED SOFA were 0.94 (95% confidence interval [CI], 0.94–0.96), 0.88 (95% CI, 0.85–0.91), 0.82 (95% CI, 0.78–0.86), and 0.78 (95% CI, 0.73–0.82), respectively.

Conclusions—The Denver ED TOF Score more accurately predicts in-hospital mortality in adult trauma patients compared to the ED SOFA score, ED base deficit, or ED lactate. The Denver ED TOF Score may help identify patients early who are at risk for mortality, allowing for targeted resuscitation and secondary triage to improve outcomes

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1. Background

Trauma is the leading cause of death in the United States in people 1 to 44 years old and accounts for 41 million emergency department (ED) visits per year [1-3]. Almost 2 million individuals are hospitalized each year due to trauma, and of these, approximately 45000 patients die before hospital discharge [4,5].

A multitude of tools have been developed in an attempt to accurately predict mortality outcomes in trauma. Commonly used scores to predict mortality outcomes include the Injury Severity Score (ISS), the new ISS, the International Classification of Diseases, Ninth Revision (*ICD-9*)–based ISS, and the Trauma Mortality Prediction Model [5-9,4,10,11]. Although these scores have demonstrated good predictive abilities for inhospital mortality in adult trauma patients [5-9,4,10-13], in many instances, the scores are not readily available early in the postinjury course due to the calculations necessary to determine the scores [14].

The ability to predict early in the injury course the likelihood of mortality after trauma is important to facilitate secondary triage, focus resuscitative efforts, and guide resource allocation. Several clinical indicators available early in the postinjury course have been determined to be associated with mortality after trauma including the Sequential Organ Failure Assessment (SOFA) score [15-17], base deficit [18-24], and lactate [22,23,19,1,25-31]. However, the predictive ability for these clinical indices for mortality when assessed shortly after injury has been variable [15,26,28,31].

The Denver ED Trauma Organ Failure (TOF) Score, which uses data within 4 hours of injury, has been demonstrated to predict multiple-organ failure in adult trauma patients (Fig. 1) [32]. No data are available on the ability of the Denver ED TOF Score to predict inhospital mortality. The objective of this study was to compare the prognostic accuracies of the Denver ED TOF Score, SOFA score, ED base deficit, and ED lactate for inhospital mortality in a heterogeneous adult trauma population.

2. Methods

2.1. Study design and setting

This was a retrospective cohort study from Denver Health Medical Center in Denver, Colorado. Denver Health Medical Center is a 477-bed, urban safety net hospital that houses the Rocky Mountain Regional Level 1 Trauma Center, the only academic level 1 trauma center in Colorado [33]. The ED is the primary receiving facility for all trauma patients and has an approximate annual adult census of 60000 visits, of which approximately 2000 are included in the trauma registry and approximately 500 of which are classified as major trauma (defined by an ISS >15).

The study was approved by the Colorado Multiple Institutional Review Board.

2.2. Study population

Consecutive trauma patients (≥ 18 years old) who presented to Denver Health Medical Center from January 1, 2005, to December 31, 2008, and who were entered in the trauma

registry were included in this study. The trauma registry contains trauma patients who are admitted to the ED observation unit for at least 12 hours, admitted to the hospital, die in the ED, or are transferred from outside hospitals for further trauma care. Patients were excluded from this study if they (1) were younger than 18 years, (2) died in the ED, or (3) were transferred from another hospital.

2.3. Data collection

Patients included in the trauma registry are identified daily from the ED log by a team of personnel specifically trained in the oversight of the trauma registry and in the acquisition of data. Data are systematically abstracted from the patients' medical records and entered into an electronic database. To maintain quality assurance, an internal review of approximately 20% of the trauma registry records is conducted on a regular basis using a standardized institutional protocol. Each review is completed by registry staff members who did not perform the initial abstraction for the patient. Any discrepancies identified in this quality assurance review are presented to the trauma registry committee, and corrections are made through a consensus process.

Clinical data for each patient entered into the trauma registry are abstracted from the medical record. Structured trauma nursing records from the ED are used to obtain the clinical data from the initial evaluation and treatment of the patient. Diagnoses and procedures are entered into the registry database according to *ICD-9* codes.

Data recorded in the trauma registry and obtained for purposes of this study included demographics (age, race, ethnicity, and sex), prehospital care characteristics (paramedic response time, scene time, and transport time), date and time of presentation to the ED, prehospital and ED vital signs within 4 hours of arrival (heart rate, respiratory rate, and systolic blood pressure), prehospital and ED Glasgow Coma Scale (GCS) score within 4 hours of arrival, prehospital and ED intubation or cricothyroidotomy, the Abbreviated Injury Scale for each body region (head, face, neck, chest, abdomen/pelvis, extremities, and skin), ISS, *ICD-9* external cause of injury code, hospitalization characteristics (whether the patient was admitted; admitted to the intensive care unit [ICU] and, if so, the number of ICU days; and survival to hospital discharge), and final diagnoses (*ICD-9* codes).

Laboratory data obtained within 4 hours of arrival were obtained from the hospital's computerized laboratory reporting system (MiSYS Healthcare Systems, Raleigh, NC) and linked to all patients obtained from the trauma registry. If more than 1 laboratory value was available within 4 hours of hospital arrival for calculation of the SOFA score or the Denver ED TOF Score, the most extreme value was used; the highest value of the blood urea nitrogen, creatinine, lactate, total bilirubin, and white blood cell count were used, and the lowest value of the base deficit, hematocrit, and platelet count was used for purposes of this study.

2.4. Outcome measures

The primary outcome, in-hospital mortality, was determined using mortality data recorded in the Denver Health Medical Center trauma registry.

The medical records of all study patients admitted to the ICU from the ED were systematically reviewed in a blinded fashion by trained physician abstractors to determine the SOFA score on admission [34]. The SOFA score consists of measures of function across 6 organ systems [35]. The lowest values of the PaO₂/fraction of inspired oxygen ratio, platelet count, GCS score, mean arterial pressure, and urine output and the highest values of total bilirubin, adrenergic agent use, and creatinine were recorded and used in the score calculation. In instances in which an ICU patient did not have a platelet count, total bilirubin, or creatinine obtained in a 24-hour period, the value for these absent laboratory test results was assumed to be normal in the calculation of the SOFA score. The data for the SOFA score were recorded in an electronic closed-response data collection instrument (Microsoft Access; Microsoft Corporation, Redmond, WA). The abstractors were trained to use the data collection instrument to systematically abstract each end point using standardized medical record abstraction methodology [34].

Ten percent of the charts were reabstracted to verify reliability of the abstraction process. Interrater reliability was assessed to determine the overall agreement and the median κ was 0.92 (interquartile range [IQR], 0.81-0.98).

2.5. Data management and statistical analyses

Data were transferred electronically from the trauma registry and MiSYS into separate electronic spreadsheets (Microsoft Excel; Microsoft Corporation), and all outcome data were manually entered into an electronic database (Microsoft Access). Each electronic file was then transferred into native SAS format using translational software (dfPower DBMS copy; DataFlux Corporation, Cary, NC) and concatenated. All analyses were performed using SAS version 9.3 (SAS Institute, Inc, Cary, NC) or Stata version 10.1 (Stata Corporation, College Station, TX).

Continuous data are reported as medians with IQRs, and categorical data are reported as percentages with 95% confidence intervals (CIs). Multiple imputation was performed with SAS-callable IVEware (Survey Methodology Program; Survey Research Center, Institute for Social Research, University of Michigan, Ann Arbor, MI). Multiple imputation has been shown to be a valid and effective way of handling missing data and minimizes the bias that may result from excluding such patients from the analyses and has been shown to be a valid strategy when the proportion of the missing data is large [36-38]. In this study, 10 replications of imputation were performed.

3. Results

During the 4-year study period, 4355 consecutive trauma patients met criteria for inclusion and, therefore, represent our study sample. The median age was 37 years (IQR, 26-51 years); 72% were male, 78% experienced a blunt injury mechanism, and the median ISS was 9 (IQR, 4-16). A complete description of the demographics and characteristics of the study sample is presented in Table 1.

Of the 4355 patients, 138 patients (3%) died in the hospital. A complete description of the outcomes for the study sample is presented in Table 2. In the nonsurvivors, the median

values for the 4 clinical indicators were ED SOFA of 5.0 (IQR, 0.0-8.0), Denver ED TOF of 5.0 (IQR, 4.0-5.0), ED base deficit of 12.5 mEq/L (IQR, 8.0-19.0 mEq/L), and ED lactate of 6.6 mmol/L (IQR, 4.5-12.0 mmol/L). Additional information regarding the physiologic and laboratory characteristics of survivors and nonsurvivors in the study cohort is described in Table 3. The accuracy of the Denver ED TOF Score, ED lactate, ED base deficit, and ED SOFA Score for the prediction of in-hospital mortality is described in Table 4. The area under the receiver operating characteristic curves (AUROC) for each of the 4 clinical indicators including lactate, base deficit, SOFA, and Denver ED TOF are depicted in Fig. 2.

4. Discussion

The goal of our study was to determine the predictive ability of the Denver ED TOF, SOFA, lactate, and base deficit for in-hospital mortality. This investigation demonstrates that the Denver ED TOF Score more accurately predicts inhospital mortality in adult trauma patients when compared to the ED SOFA score, ED base deficit, or ED lactate. Previously, the Denver ED TOF Score had not been used in the prediction of inhospital mortality.

Our study demonstrated that the Denver ED TOF Score outperformed the ED SOFA, lactate, and base deficit in the prediction of inhospital mortality. Our findings for the predictive ability of the SOFA score for mortality in trauma patients are similar to previous investigations. Fueglistaler et al [15] found the day 1 SOFA score predicted 30-day mortality of adult trauma patients with an AUROC of 0.79 (95% CI, 0.73-0.86), which is close to our finding of SOFA AUROC of 0.78 (95% CI, 0.73-0.82). Hwang et al [16] found the AUROC for SOFA to predict 30-day mortality was 0.95 (95% CI, 0.94-0.97) in a single-center study. However, this investigation differed from our investigation in that they excluded patients who died within 24 hours of injury and those patients without complete SOFA data available. In addition, the investigators used the SOFA score from the first 24 hours of intensive care unit admission, not the ED SOFA score in determining the prognostic ability of the score for mortality prediction.

Several studies have demonstrated the association of base deficit [18-24] and lactate [22,23,19,1,25-41] with mortality in adult trauma patients. In our study, the AUROC for lactate was 0.77 (95% CI, 0.72-0.83), and the AUROC for base deficit was 0.72 (0.66-0.77). Parsikia et al [28] evaluated the prognostic accuracy of the serum lactate obtained within 24 hours of initial presentation in adult trauma patients for inhospital mortality and found an AUROC of 0.63. Pal et al [31] found an AUROC for admission serum lactate levels to predict mortality in trauma patients of 0.72. Martin et al [26] examined the prognostic ability of both admission lactate and base deficit to predict inhospital mortality and demonstrated AUROC of 0.70 (95% CI, 0.67-0.74) and 0.66 (95% CI, 0.61-0.70), respectively. This study also demonstrated that, in the setting of a normal lactate, the base deficit had limited predictive ability for mortality, AUROC of 0.48. In the patients with normal base deficit, the lactate level retained its ability to predict mortality, AUROC of 0.67. The authors concluded that although both base deficit and lactate may be useful in prediction of mortality, an increased base deficit level was not predictive in the setting of a normal lactate [26].

Although several scoring systems exist to stratify trauma patients into mortality risk groups, identification of a score of clinical measure that can be applied at the bedside early after injury to predict mortality outcomes is especially important. The Denver ED TOF Score, which uses data within 4 hours of injury to predict mortality outcomes, may facilitate early recognition of at-risk patients. With early identification, aggressive, targeted trauma resuscitation and interventions along with secondary triage may be implemented to improve outcomes. The potential to decrease the incidence of trauma-related mortality would have a significant impact on individuals of all ages, but most prominently on young, productive members of society who are disproportionately impacted by trauma [39]. Moreover, use of a prediction tool to accurately identify those patients at risk for worse outcomes early in the postinjury course would be especially beneficial for patients, families, and health care providers alike in discussing prognosis and determining resuscitation strategies and goals of care.

We evaluated the prognostic ability of the Denver ED TOF Score using data from the Denver Health trauma registry. The Denver ED TOF Score demonstrated excellent predictive ability for inhospital mortality in this population. However, large, prospective multicenter studies are indicated to further assess the ability of the Denver ED TOF Score to predict mortality in a heterogeneous trauma population when compared to other clinical indices. Future investigations of the Denver ED TOF Score may include a trial of use of the score in secondary triage to assess the ability of the score to efficiently and accurately identify at-risk patients who would benefit from transfer to level I trauma centers with a cadre of trauma specialists.

The principal difficulty with this study is the use of a database not specifically designed for the study. This was a secondary analysis of a large, prospectively collected data set, and although predictors were collected in a way to facilitate our analysis of the data, they were not collected specifically for this study. In addition, because this was a secondary analysis of a trauma registry, a proportion of all trauma patients who presented to our ED during the study period were not included as they were evaluated and discharged directly from the ED without requiring hospital admission. It is possible, albeit unlikely, that a small portion of these patients may have subsequently died as a result of their injuries, which could have impacted the findings or our study.

Missing data are a common concern in research, especially when conducting retrospective observational research, and there were missing data in our project. To minimize the bias introduced by excluding the patients with missing data, we used multiple imputation for variables with missing values. Multiple imputation replaces missing data with plausible values determined based on the remainder of the data set. This allows all variables to be included in the analysis, thereby minimizing the potential for bias associated with excluding patients with missing data [36-38]. Although this is a rigorous approach to handling missing data, additional studies are warranted in which complete data are available on base deficit, lactate, ED SOFA, and Denver ED TOF to verify our study findings.

In this study, we imported the laboratory data used for the project from the hospital's laboratory data system. Although it may have been possible for errors to occur during data

transfer, our research team has extensive experience linking these types of data sets and with these methods of data transfer from the laboratory system. We have successfully linked laboratory data to study databases in previous studies without data compromise [40-42].

5. Conclusions

The Denver ED TOF Score more accurately predicts inhospital mortality in adult trauma patients compared to the ED SOFA score, ED base deficit, or ED lactate. The Denver ED TOF Score may help identify patients early who are at risk for mortality, allowing for targeted resuscitation, focused resource allocation, and secondary triage to improve outcomes.

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References

1. Aslar AK, Kuzu MA, Elhan AH, Tanik A, Hengirmen S. Admission lactate level and the APACHE II score are the most useful predictors of prognosis following torso trauma. *Injury*. 2004; 35:746–52. [PubMed: 15246796]
2. National Center for Injury Prevention and Control. WISQARS Leading Causes of Death Reports. Centers for Disease Control and Prevention National Center for Health Statistics; Atlanta, GA: 1999 – 2005. [Available at <http://webappa.cdc.gov/sasweb/ncipc/leadcaus10.html>.] [9/26/14]
3. Injury in the United States Chartbook. Centers for Disease Control and Prevention National Center for Health Statistics; Atlanta, GA: 2007. [Available at <http://www.cdc.gov/nchs/data/misc/injury2007.pdf>.] [9/26/14]
4. Osler T, Glance L, Buzas JS, Mukamel D, Wagner J, Dick A. A trauma mortality prediction model based on the anatomic injury scale. *Ann Surg*. 2008; 247:1041–8. [PubMed: 18520233]
5. Ownes, PL.; Russo, CA.; Stocks, C. [9/26/14] Frequency and cost of hospital admissions for injury.. HCUP statistical brief no 18. 2004. [Available at: <http://www.hcup-us.ahrq.gov/reports/statbriefs/sb18.pdf>.]
6. 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. *J Trauma*. 1974; 14:187–96. [PubMed: 4814394]
7. Tay SY, Sloan EP, Zun L, Zaret P. Comparison of the new Injury Severity Score and the Injury Severity Score. *J Trauma*. 2004; 56:162–4. [PubMed: 14749583]
8. Osler T, Baker S, Long W. A modification of the Injury Severity Score that both improves accuracy and simplifies scoring. *J Trauma*. 1997; 41:922–6. [PubMed: 9420106]
9. Osler T, Rutledge R, Deis J, Bedrick q. ICISS: an International Classification of Disease-9–based injury severity score. *J Trauma*. 1996; 41:380–6. [PubMed: 8810953]
10. Osler TM, Rogers FB, Glance LG, Cohen M, Rutledge R, Shackford SR. Predicting survival: length of stay, and cost in the surgical intensive care unit: APACHE II versus ICISS. *J Trauma*. 1998; 45:234–8. [PubMed: 9715178]
11. Rutledge R, Osler T, Emery S, Kromhout-Schiro S. The end of the Injury Severity Score and the Trauma and Injury Severity Score: ICISS an International Classification of Diseases Ninth Revision–based predication tool outperforms both ISS and TRISS as predictors of trauma patient and survival, hospital charges, and hospital length of stay. *J Trauma*. 1998; 44:41–9. [PubMed: 9464748]

12. Hannan EL, Farrell LS, Meaker PS, Cooper A. Predicting inpatient mortality for pediatric trauma patients with blunt injuries: a better alternative. *J Pediatr Surg.* 2000; 35:155–9. [PubMed: 10693657]
13. Ducrocq SC, Meyer PG, Orliaguet GA, Blanot S, Laurent-Vannier A, Renier D, et al. Epidemiology and early predictive factors of mortality and outcome in children with traumatic severe brain injury: experience of a French pediatric trauma center. *Pediatr Crit Care Med.* 2006; 7:461–7. [PubMed: 16885795]
14. Courville XF, Koval KJ, Carney BT, Spratt KE. Early prediction of posttraumatic in-hospital mortality in pediatric patients. *J Pediatr Orthop.* 2009; 29:439–44. [PubMed: 19568013]
15. Fueglistaler P, Amsler F, Schuepp M, Fueglistaler-Montali I, Attenberger C, Pragger H, et al. Prognostic value of Sequential Organ Failure Assessment and Simplified Acute Physiology II Score compared with trauma scores in the outcome of multiple trauma patients. *Am J Surg.* 2010;204–14. [PubMed: 20227058]
16. Hwang SY, Lee JH, Lee YH, Hong CK, Sung AJ, Choi YC. Comparison of the Sequential Organ Failure Assessment, Acute Physiology and Chronic Health Evaluation II scoring system, and Trauma and Injury Severity Score method for predicting outcomes of intensive care unit trauma patient. *Am J Emerg Med.* 2012; 30:749–53. [PubMed: 21802884]
17. Antonelli M, Moreno R, Vincent JL, Sprung CL, Mendoca A, Passariello M, et al. Application of SOFA score to trauma patients. *Intensive Care Med.* 1999; 25:389–94. [PubMed: 10342513]
18. Rutherford EJ, Morris JA Jr, Reed GW, Hall KS. Base deficit stratifies mortality and determines therapy. *J Trauma.* 1992; 33:417–23. [PubMed: 1404512]
19. Smith I, Kumar P, Molloy S, Rhodes A, Newman PJ, Grounds RM, et al. Base excess and lactate as prognostic indicators for patients admitted to intensive care. *Int Care Med.* 2001; 27:74–83.
20. Tremblay L, Feliciano D, Rozycki G. Assessment of initial base deficit as a predictor of outcome: mechanism of injury does make a difference. *Am Surg.* 2002; 68:689–94. [PubMed: 12206603]
21. Hodgman EI, Morse BC, Dente CJ, Mina MJ, Shaz BH, Nicholas JM, et al. Base deficit as a marker of survival after traumatic injury: consistent across changing patient populations and resuscitation paradigms. *J Trauma.* 2012; 72:844–51.
22. Oullet JF, Roberts DJ, Tiruta C, Kirkpatrick AW, Mercado M, Trottier V, et al. Admission base deficit and lactate levels in Canadian patients with blunt trauma: are they useful markers of mortality? *J Trauma Acute Care Surg.* 2012; 72:1532–5. [PubMed: 22695417]
23. Callaway DW, Shapiro NI, Donnino MW, Baker C, Rosen CL. Serum lactate and base deficit as predictors of mortality in normotensive elderly blunt trauma patients. *J Trauma.* 2009; 66:1040–4. [PubMed: 19359912]
24. Davis JW, Parks SN, Kaups KL, Gladen HE, O'Donnell-Nicol S. Admission base deficit predicts transfusion requirements and risk of complications. *J Trauma.* 1996; 41:769–74. [PubMed: 8913202]
25. Husain FA, Martin MJ, Mullenix PS, Steele SR, Elliott DC. Serum lactate and base deficit as predictors of mortality and morbidity. *Am J Surg.* 2003; 185:485–91. [PubMed: 12727572]
26. Martin MJ, FitzSullivan E, Salim A, Brown CV, Demetriades D, Long W. Discordance between lactate and base deficit in the surgical intensive care unit: which one do you trust? *Am J Surg.* 2006; 191:625–30. [PubMed: 16647349]
27. Vandromme MJ, Griffin RL, Weinberg JA, Rue LW 3rd, Kerby JD. Lactate is a better predictor than systolic blood pressure for determining blood requirement and mortality: could prehospital measures improve trauma triage? *J Am Coll Surg.* 2010; 210:861–9. [PubMed: 20421067]
28. Parsikia A, Bones K, Kaplan M, Strain J, Leung PS, Ortiz J, Joshi AR. The predictive value of initial serum lactate in trauma patients. *Shock.* 2014; 42:199–204. [PubMed: 24978889]
29. Manikis P, Jankowski S, Zhang H. Correlation of serial blood lactate levels to organ failure and mortality after trauma. *Am J Emerg Med.* 1995; 13:619–22. [PubMed: 7575797]
30. Cerovic O, Golubovic V, Spec-Marn A, Kremzar B, Vidmar G. Relationship between injury severity and lactate levels in severely injured patients. *Int Care Med.* 2003; 29:1300–5.
31. Pal JD, Victorino GP, Twomey P, Liu TH, Bullard MK, Harken AH. Admission serum lactate levels do not predict mortality in the acutely injured patient. *J Trauma.* 2006; 60:583–9. [PubMed: 16531858]

32. Vogel JA, Liao MM, Hopkins E, Seleno N, Byyny RL, Moore EE, et al. Prediction of postinjury multiple-organ failure in the emergency department: development of the Denver Emergency Department Trauma Organ Failure Score. *J Trauma Acute Care Surg*. 2014; 76:140–5. [PubMed: 24368369]
33. Gabow P, Eisert S, Wright R. Denver Health a model for the integration of a public hospital and community health centers. *Ann Intern Med*. 2003; 138:143–50. [PubMed: 12529097]
34. Gilbert EH, Lowenstein SR, Koziol-McLain J, Barta DC, Steiner J. Chart reviews in emergency medicine research: where are the methods? *Ann Emerg Med*. 1996; 27(3):305–8. [PubMed: 8599488]
35. Vincent JL, Moreno R, Takala J, Wilatts S, De Mendonca A, Bruining H, et al. The SOFA (Sepsis-related Organ Failure Assessment) score to describe organ dysfunction/failure. *Intensive Care Med*. 1996; 22:707–10. [PubMed: 8844239]
36. Rothman, KJ.; Greenland, S. *Modern epidemiology*. Lippincott-Raven; Philadelphia, PA: 1998.
37. Haukoos JS, Newgard CD. Advanced statistics: missing data in clinical research—part 1: an introduction and conceptual framework. *Acad Emerg Med*. 2007; 14:662–8. [PubMed: 17538078]
38. Newgard CD, Haukoos JS. Advanced statistics: missing data in clinical research—part 2: multiple imputation. *Acad Emerg Med*. 2007; 14:669–78. [PubMed: 17595237]
39. Blow O, Magliore L, Claridge JA, Butler K, Young JS. The golden hour and the silver day: detection and correction of occult hypoperfusion within 24 hours improves outcome from major trauma. *J Trauma*. 1999; 47:964–9. [PubMed: 10568731]
40. Paulson S, Byyny R, Erickson C, Gravitz C, Haukoos JS. Predicting the need for emergent surgery in adult trauma patients: external validation of a clinical decision rule and implications for trauma triage. *Ann Emerg Med*. 2008; 52:S107.
41. Erickson C, Byyny R, Paulson S, Gravitz C, Haukoos JS. Predicting the need for emergent surgery in adult trauma patients: comparison of a validated clinical decision rule to the American College of Surgeons' major resuscitation criteria. *Circulation*. 2008; 118:766–7.
42. Haukoos JS, Byyny RL, Erickson C, Paulson S, Hopkin E, Sasson C, et al. Validation and refinement of a rule to predict emergency intervention in adult trauma patients. *Ann Emerg Med*. 2011; 58:164–71. [PubMed: 21658802]

Predictor	Score
Age $\geq$ 65 years	1
Emergent intubation§	3
Hematocrit < 20%	2
Hematocrit $\geq$ 20% and < 35%	1
ED systolic blood pressure < 90 mmHg	1
Blood Urea Nitrogen $\geq$ 30 mg/dL	1
White Blood Cell count $\geq$ 20,000 / μ L	1

§Emergent intubation defined as intubation in the prehospital setting or in the emergency department.

Fig. 1.
Denver ED TOF Score [31].

Fig. 2.
Predictive ability of the Denver ED TOF Score, ED SOFA, ED lactate, and ED base deficit.

Table 1

Demographics and characteristics of the study sample

Variable	n (%) or median (IQR)	Missing, n (%)
Total (n)	4355	
Age(y)	37 (26-51)	0 (0)
Male	3146 (72)	2 (0)
Race/ethnicity		43 (1)
White	2148 (49)	
Black	548 (13)	
Hispanic	1492 (34)	
Other	124 (3)	
ISS	9 (4-16)	6 (0)
Mechanism		
Blunt	3391 (78)	0 (0)
Penetrating, stab	358 (8)	0 (0)
Penetrating, gunshot	258 (6)	0 (0)
Other	348 (8)	0 (0)
Emergent intubation (prehospital or ED)	636 (15)	0 (0)
Prehospital total time (min)	25 (19-32)	1021 (23)
Prehospital response time (min)	5 (4-8)	991 (23)
Prehospital scene time (min)	10 (7-14)	996 (23)
Prehospital transport time (min)	8 (5-12)	999 (23)
Prehospital vital signs		
Pulse	98 (88-110)	970 (22)
Systolic blood pressure	128 (110-140)	1060 (24)
Respiratory rate	18 (16-20)	988 (23)
ED vital signs		
Pulse	92 (80-106)	24 (1)
Systolic blood pressure	130 (116-146)	27 (1)
Respiratory rate	18 (16-20)	83 (2)

Abbreviations: ISS, Injury Severity Score; IQR, interquartile range; ED, emergency department. Continuous data are expressed as median and IQRs.

Table 2

Outcomes for the study sample (n = 4355)

Variable	n (% or IQR) ^a	95% CI
Inhospital mortality	138 (3)	3-4
ICU admission	1670 (38)	37-40
ICU length of stay (d), median (IQR)	2.5 (1-8)	2-3
Patients with <24-h ICU stay	589 (35)	33-38
Hospital length of stay (d), median (IQR)	4 (2-7)	4-4

Abbreviations: ICU, Intensive Care Unit, IQR, interquartile range.

^aData are expressed as median (IQR) of subjects unless otherwise indicated.

Table 3

Characteristics of survivors and nonsurvivors (n = 4355)

Variable	Survivor, n = 4217		Missing		Nonsurvivor, n = 138		Missing	
	Median or %	IQR	n	%	Median or %	IQR	n	%
Age	37	26-50	0	0	41	26-59	0	0
Male	72.2		2	0	74.6		0	0
ED GCS	15	15-15	367	9	3	3-11	7	5
ED HR	92	80-106	23	1	90	67-114	1	0
ED SBP	130	117-146	24	1	104	75-140	3	2
ISS	9	4-16	0	0	29.5	26-43	0	0
Base deficit	-7.0	-11 to -4	3402	81	-12.5	-19.0 to -8.0	24	17
Denver ED TOF Score	0	0-2	0	0	4	4-5	0	0
Lactate	3.5	2.5-5.2	3727	88	6.6	4.5-12.0	42	30
SOFA score	0	0-0	0	0	5	0-8	0	0

Abbreviations: HR, heart rate; SBP, systolic blood pressure; ED, Emergency Department; GCS, Glasgow Coma Scale; HR, heart rate; ISS, Injury Severity Score; RTS, Revised Trauma Score; SBP, systolic blood pressure; SOFA, Sequential Organ Failure Assessment Score; TOF, trauma organ failure.

Table 4

Accuracy of the Denver ED TOF Score, ED lactate, ED base deficit, and ED SOFA score for prediction of in-hospital mortality

Risk stratification measure	Mortality		Sensitivity		Specificity	
	Yes	No	%	95% CI	%	95% CI
Denver ED TOF Score						
0	1	1591	0.7	0.0-4.0	62.3	60.8-63.7
>0	137	2626				
1	7	2103	5.1	2.1-10.2	50.1	48.6-51.7
>1	131	2114				
2	12	3601	8.7	4.6-14.7	14.6	13.6-15.7
>2	126	616				
3	28	3975	20.3	13.9-20.8	5.7	5.1-6.5
>3	110	242				
4	73	4127	52.9	44.2-61.4	2.1	1.7-2.6
>4	65	90				
5	112	4191	81.2	73.6-87.3	0.6	0.4-1.0
>5	26	26				
6	137	4216	99.3	96.0-100.0	0.0	0.0-0.1
>6	1	1				
7	138	4217	100	97.3-100.0	0.0	0.0-0.0
>7	0	0				
ED lactate						
2	2	76	2.1	2.5-7.3	84.5	81.0-87.6
>2	94	414				
6	43	395	44.8	34.6-55.3	19.4	16.0-23.2
>6	53	95				
10	62	462	64.6	54.2-74.1	5.7	3.8-8.2
>10	34	28				
14	82	486	85.4	76.7-91.8	0.8	0.2-2.1
>14	14	4				
16	93	488	96.9	91.1-99.4	0.4	0.0-1.5
>16	3	2				
ED base deficit						
-2	3	96	2.6	0.5-7.5	88.2	85.6-90.2
<-2	111	719				
-8	36	502	31.6	23.2-40.9	38.4	35.0-41.7
<-8	78	313				
-16	74	756	64.9	55.4-73.6	7.2	5.5-9.2
<-16	40	59				
-24	106	806	93.0	86.7-96.9	1.1	0.5-2.1
<-24	8	9				

Risk stratification measure	<u>Mortality</u>		<u>Sensitivity</u>		<u>Specificity</u>	
	Yes	No	%	95% CI	%	95% CI
ED SOFA						
2	52	3689	37.7	29.6-46.3	12.5	11.5-13.6
>2	86	528				
6	90	4156	65.2	56.6-73.1	1.4	1.1-1.9
>6	48	61				
10	132	4214	95.7	90.8-98.4	0.1	0.0-0.2
>10	6	3				

Abbreviations: CI, confidence interval; ED, Emergency Department; SOFA, Sequential Organ Failure Assessment Score; TOF, trauma organ failure.