BMC Emergency Medicine

RESEARCH Open Access

Predictive value of qSOFA and hypothermia combined with PT for prognosis in patients with severe trauma: a single-center retrospective cohort study

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Abstract

Background Trauma represents a significant global health challenge.The development of an effective scoring tool capable of predicting mortality risk in trauma cases is essential. This study aimed to investigate the combined effects of quick sequential organ failure assessment (qSOFA) and hypothermia (H) along with prothrombin time (PT) in predicting the prognosis of patients with severe trauma.

Methods A retrospective cohort study was conducted to analyze data from severe trauma patients in the Trauma Database of the Trauma Center at the Second Affiliated Hospital of Soochow University between January 2017 and December 2021. Patients were categorized into survival and non-survival groups based on clinical outcomes. Baseline and clinical data were compared between the groups, and prognostic factors were explored using logistic regression analysis. Receiver operating characteristic (ROC) curves generated by 10-fold cross-validation using the caret in R programming language were used to assess the predictive efficacy of Injury Severity Score (ISS) and qSOFA + H + PT score for trauma patient mortality.

Results A total of 509 severe trauma patients (377 males and 132 females) were included, with a median age of 53 years (range: 42–65 years). The mortality rate was found to be 23.4%. Logistic regression analysis revealed that age, ISS, and qSOFA + H + PT were significant predictors of death in severe trauma patients, with odds ratios of 1.035 (95%CI:1.014–1.057), 1.052 (95%CI:1.017–1.090), and 6.124 (95%CI:3.107–12.072), respectively ($P < 0.05$). The predictive efficacy of ISS and qSOFA + H + PT for mortality prediction was 0.742 and 0.816, respectively.The predictive efficacy of qSOFA + H + PT for emergency blood transfusion and operation was 0.743 and 0.702.

Conclusion qSOFA + H + PT are identified as significant predictors to the death of severe trauma patients. They could be utilized as early intervention indicators in emergency departments, facilitating clinical management strategies such as emergency blood transfusion, emergency operation, and prognosis prediction.

Keywords Severe trauma, qSOFA, Prothrombin time, Hypothermia, Prognosis

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Background

Trauma represents a significant global health challenge. According to the World Health Organization's 2020 statistics, trauma remains among the top ten causes of death in low and lower-middle-income countries [1] and it stands as a primary cause of permanent disability in adults [2].

Severe trauma denotes traumatic incidents accompanied by severe physiological disturbances, often leading to death or profound disability, necessitating immediate surgical intervention or blood product transfusion. Such cases typically encompass: (1) blunt trauma patients with a pre-hospital index (PHI) of ≥4 points [3] or an Injury Severity Score (ISS) of ≥16 points [4]; (2) individuals with unstable vital signs following chest or abdominal penetrating injuries; and (3) those experiencing uncontrollable external bleeding. Examples of severe trauma include conditions such as intracranial hypertension induced by intracranial hematoma, brain contusion, and laceration; airway obstruction resulting from maxillofacial open fractures and massive hemorrhages; neck or cardiac vascular injuries; tracheal or diaphragmatic ruptures; flail chest or cardiac compression injuries; intra-abdominal hemorrhages; severe genitourinary or kidney injuries; pelvic fractures; spinal fractures coupled with nervous system injuries; open limb fractures; significant blood vessel injuries; extensive soft tissue injuries with massive hemorrhages; or crush syndromes [5, 6].

Despite advancements in prehospital care, in-hospital emergency resuscitation, surgical intervention, and intensive care, managing severe trauma remains a persistent challenge for healthcare systems worldwide. The development of an effective scoring tool capable of predicting mortality risk in trauma cases is essential.

While the ISS serves as a widely employed tool for assessing trauma severity and prognosis [7, 8], it necessitates extensive data and related information, often challenging to obtain promptly. Occasionally, ISS evaluation mandates computed tomography (CT) scans or surgical procedures, thereby lacking immediacy. Furthermore, ISS lacks direct assessment of vital signs and exhibits certain deficiencies in evaluating disease risk potential.

Previous landmark studies have identified iatrogenic and resuscitation-related causes of posttraumatic coagulopathy bleeding, with hypothermia, metabolic acidosis, and dilutional coagulopathy recognized as major contributors to posttraumatic bleeding [9, 10]. Without timely and appropriate diagnosis and treatment, posttraumatic hemorrhage and related acute traumatic coagulopathy (ATC) emerge as primary factors leading to multiple organ failure and death in patients [11]. The diagnostic criteria for ATC vary, encompassing parameters such as prolonged prothrombin time (PT), activated partial thromboplastin time (APTT), and thrombin time (TT), each exceeding 1.5 times the upper limit of normal value as defined by Brohi [12, 13], or an international normalized ratio (INR) greater than or equal to 1.5 as per Niles [14] Additionally, in recent years, the Quick Sequential Organ Failure Assessment (qSOFA), which evaluates three vital signs including consciousness, blood pressure, and respiration, has emerged as a screening tool for sepsis outside the intensive care unit (ICU) [15–17]. It has also been utilized to predict the risk of death in non-infected patients in the emergency department [18]. This study aims to assess the predictive value of qSOFA and hypothermia combined with PT in determining the poor prognosis of patients with severe trauma.

Methods

Study population

A retrospective cohort study was conducted to gather data on severe trauma patients (ISS ≥ 16 points) from the Trauma Database of the Trauma Center at the Second Affiliated Hospital of Soochow University between January 2017 and December 2021. Based on hospital clinical outcomes, patients were categorized into survival and non-survival groups. The survival group included the patients who were discharged home or went to rehabilitation hospital for further rehabilitation treatment, and the non-survival group was the patients who died in hospital.Inclusion criteria were as follows: (1) trauma patients resulting from various mechanical causes; (2) age ≥ 18 years; (3) Injury Severity Score (ISS) ≥ 16 [4]; (4) patients who underwent relevant laboratory tests and received initial treatment either in the emergency treatment room within 24 h post-admission or were directly admitted to the intensive care unit (ICU), operating room, or other departments from the emergency department. Exclusion criteria were: (1) out-of-hospital traumatic cardiac arrest; (2) burns and chemical injuries; (3) pregnant trauma patients; (4) use of anticoagulant drugs within 6 months prior to injury or previous coagulopathy. Further details regarding the patient enrollment algorithm are provided in Fig. 1.

This study was approved by the Ethic Committee of the Second Affiliated Hospital of Soochow University (JD-HG-2023-08), and all participants provided written informed consent signed by the patients or their legal guardians upon admission.The patients' source data was kept confidential, and the information in the database for the study was de-identified.

All patients received initial trauma treatment following the standard procedure for trauma care in Suzhou. Upon arrival at the trauma resuscitation unit, the on-duty nurse promptly activated the trauma resuscitation team, consisting of emergency surgeons, ICU doctors, and nurses. The team aimed to complete initial emergency treatment within 30 min, which included establishing an

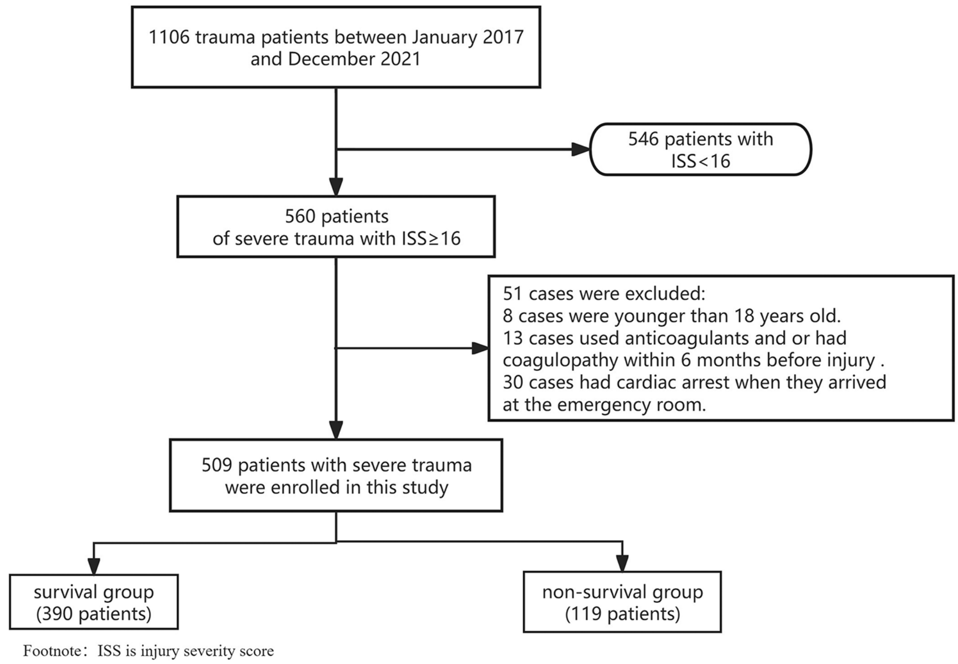


Fig. 1 Procedures for inclusion and exclusion of patients with severe trauma

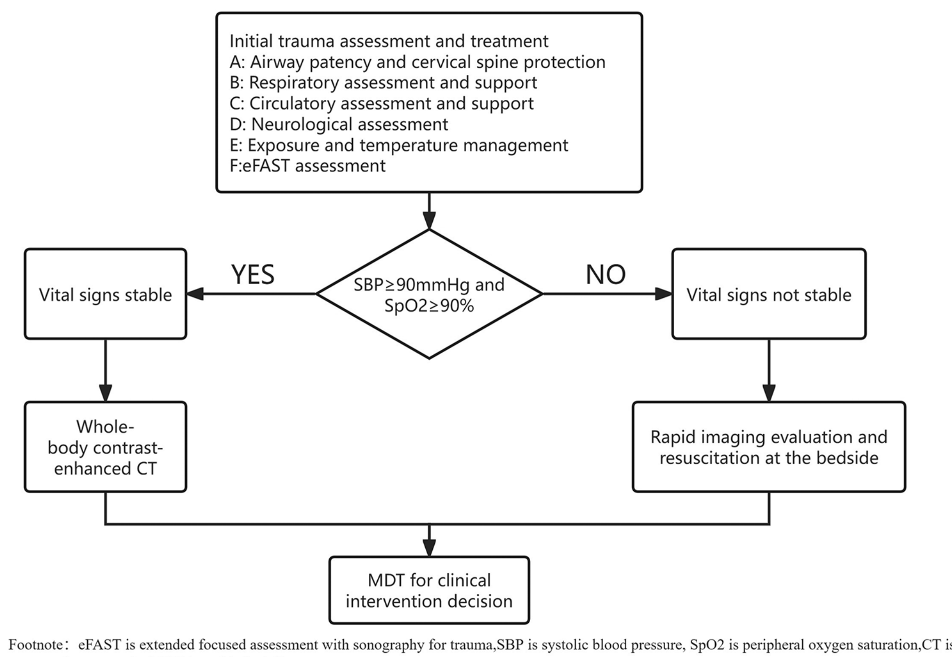


Fig. 2 Treatment procedures for severe trauma in Suzhou

artificial airway, arterial and venous catheterization, fluid resuscitation, heat preservation, and blood specimen collection. Additional procedures such as the extended focused assessment with sonography for trauma (eFAST) program, rapid trauma assessment, and consultation with surgical specialists were also conducted. Patients with unstable vital signs following initial resuscitation were transferred to the operating room, ICU, or digital subtraction angiography (DSA) for hemostasis after bedside chest and pelvis radiography and discussion among specialists and the trauma resuscitation team. Stable patients underwent whole-body enhanced CT scans before being directed to the necessary departments (Fig. 2).

Data collection and definition

Baseline and clinical data of severe trauma patients were extracted from the trauma database. The collected information encompassed gender, age, time of injury, vital signs upon admission (temperature, systolic blood pressure, heart rate, respiratory rate), mechanism of injury (traffic accidents, falls, sharp instrument injuries, others), injury location, Glasgow Coma Scale (GCS) score, initial blood routine test results (prior to blood transfusion and infusion), coagulation function, Revised Trauma Score (RTS), and ISS. Vital signs, including ear temperature, were measured upon admission to the resuscitation room with electrocardiograph (ECG) monitoring, PT was promptly measured by coagulation method upon blood collection in the emergency department, and the ISS was determined following the patient's whole-body CT scan or surgical intervention.

Hypothermia classification was based on the modified early warning score (MEWS) scale [19], with ear temperatures ≤ 35℃ assigned 2 points, temperatures between 35.1℃ and 36℃ assigned 1 point, and temperatures > 36℃ assigned 0 points. PT classification followed the International Society of Thrombosis and Hemostasis (ISTH) overt disseminated intravascular coagulation (DIC) diagnostic criteria [20], with PT prolongation < 3 s designated as 0 points, 3 s ≤ PT prolongation < 6 s designated as 1 point, and ≥ 6 s designated as 2 points. The total qSOFA score ranged from 0 to 3 points, with systolic blood pressure ≤ 100 mmHg, respiratory rate ≥ 22 breaths per minute, and alterations in mental status each recorded as 1 point [15]. The qSOFA + H (hypothermia) + PT score was calculated by summing the qSOFA score, the patient's temperature score, and the PT score.

Deaths were categorized as either early or late. Early death referred to patients who succumbed to injuries within 72 h of admission due to conditions such as cerebral herniation, hypotension, hypoxia, or hypovolemia. Late death referred to patients who died after 72 h of admission from complications such as sepsis, Acute Respiratory Distress Syndrome (ARDS), or multiple organ failure [21].

Statistical analysis

Statistical analysis was performed using SPSS 24.0 software. The Shapiro-Wilk method was employed to assess the normality of the data. Continuous variables with a normal distribution were presented as mean ± standard deviation (Mean ± SD) and compared using independent sample t-tests or one-way analysis of variance. Continuous variables with skewed distribution were expressed as median and interquartile range [M(Q1, Q3)], while categorical variables were expressed as Number (percentage). The two-sample Mann-Whitney U test was utilized to compare quantitative data that did not conform to a normal distribution between the two groups. The Chi-square test was employed for comparing categorical variables, with Fisher's exact test used when the chi-square conditions could not be met. Multivariate binary logistic regression, conducted using GraphPad Prism 8 software, was employed to assess factors associated with the death of patients with severe trauma. Based on clinical data, the receiver operating characteristic (ROC) curve was generated by 10-fold cross-validation using the caret in R programming language to analyze the efficacy of ISS and qSOFA + H + PT in evaluating the prognosis of trauma patients. All tests were two-sided, with $P < 0.05$ considered statistically significant.

Table 1 Causes of death and time distribution

Causes of death	Death time		Total
	≤ 72 h	> 72 h	
Hemorrhagic shock	14	1	15
Cerebral hernia	37	35	72
Sepsis	1	10	11
Others	15	6	21
Total	67	52	119

Results

A total of 509 patients with severe trauma were included, comprising 377 males and 132 females, with a median age of 53 years [(42, 65) years]. The causes of injury were traffic accidents in 365 cases (71.7%), falls in 49 cases (9.6%), sharp instrument injuries in 23 cases (4.5%), and other causes in 72 cases (14.2%). Among the patients, 323 cases (63.5%) presented severe trauma combined with brain injury (TBI+), 110 cases (21.6%) exhibited severe trauma without brain injury (NTBI), and 76 cases (14.9%) suffered from traumatic brain injury (TBI) alone. The mortality rate of severe trauma was 23.4%, with 67 early deaths and 52 late deaths (Table 1).

The comparison of baseline data between the survival and non-survival groups showed that there were significant differences in age, temperature, systolic blood pressure, hemoglobin, platelet count, PT, APTT, INR, fibrinogen (FIB), GCS, RTS, ISS, qSOFA, and qSOFA + H + PT ($P < 0.05$), as shown in Table 2.

The variables with significant differences ($P < 0.05$) between the aforementioned groups were subjected to binary logistic regression analysis. The odds ratios of age, ISS, and qSOFA + H + PT for death in patients with severe trauma were 1.035 (95%CI:1.014–1.057), 1.052 (95%CI:1.017–1.090), and 6.124 (95%CI:3.107–12.072), respectively (Fig. 3).

After 10-fold cross-verification, the AUC values of ISS and qSOFA + H + PT for predicting death in patients with severe trauma were 0.742 and 0.816, respectively (Fig. 4). The specificity and sensitivity of ISS was 64.6% and 83.2%, qSOFA + H + PT was 70.3% and 80.7%.

Table 2 Comparison of baseline clinical data between survival group and non-survival group [n(%) or *M*(*Q1*, *Q3*)]

Variables	All (*n* = 509)	Survivors (*n* = 390)	Non-survivors (*n* = 119)	*P*-value
Age(Years)	53(42,65)	52(41,62)	62(47,70)	< 0.001
Gender				
Male	377(74.1%)	292(74.9%)	85(71.4%)	0.453
Female	132(25.9%)	98(25.1%)	34(28.6%)	
Causes of injuries				
Traffic injuries	365(71.7%)	294(75.4%)	71(59.7%)	0.213
Falls	49(9.6%)	30(7.7%)	19(15.9%)	
Sharp instrument injuries	23(4.5%)	23(5.9%)	0	
Others	72(14.2%)	43(11.0%)	29(24.4%)	
Injured region				
TBI	76(14.9%)	46(11.8%)	30(25.2%)	0.199
TBI+	323(63.5%)	243(62.3%)	80(67.2%)	
NTBI	110(21.6%)	101(25.9%)	9(7.6%)	
Vital signs on admission				
Temperature(℃)	36.5(36.1,36.7)	36.5(36.2, 36.8)	36.0(36.0,36.5)	< 0.001
Systolic blood pressure(mmHg)	126(108, 145)	124(108, 141)	133(110, 162)	0.003
Heart rate(bpm)	85(73, 103)	86(73, 102)	85(73, 106)	0.521
Respiratory rate(bpm)	20(18, 24)	20(18, 24)	20(17, 23)	0.104
Blood test on admission				
Hemoglobin(g/L)	124.5(105, 141)	125(107, 142)	119(96, 136)	0.021
Platelet($\times10^9$/L)	190(145.5, 241)	197(155, 248)	169(103, 219)	< 0.001
PT(s)	13.9(12.5, 15.5)	13.6(12.4, 15.0)	15.6(13.6, 19.4)	< 0.001
APTT(s)	31.8(25.6, 37.8)	30.1(25.1, 35.6)	37.6(30.8, 49.6)	< 0.001
INR	1.12(1.0, 1.3)	1.1(1.0, 1.2)	1.3(1.1, 1.8)	< 0.001
FIB(g/L)	2.0(1.5, 2.6)	2.1(1.6, 2.6)	1.8(1.0, 2.5)	< 0.001
GCS	15(7,15)	15(9,15)	5(3,12)	< 0.001
RTS	7(6,8)	7(6, 8)	5(4, 7)	< 0.001
ISS	22(18,29)	22(18,26)	26(25,35)	< 0.001
qSOFA	1(0,1)	1(0,1)	1(0,2)	< 0.001
qSOFA + H + PT	1(1,2)	1(0,2)	3(2,4)	< 0.001
Emergency blood transfusion	115(22.6%)	85(21.8%)	30(25.2%)	0.713
Emergency operation	155(30.5%)	100(25.6%)	55(29.0%)	0.608

Footnote: TBI is traumatic brain injury, TBI + is severe trauma combined with TBI, NTBI is severe trauma without TBI, PT is prothrombin time, APTT is activated partial thromboplastin time, INR is international standardized ratio, FIB is fibrinogen, GCS is Glasgow Coma Scale, RTS is revised trauma score, ISS is injury severity score, qSOFA is quick Sequential Organ Failure Assessment, and H is hypothermia

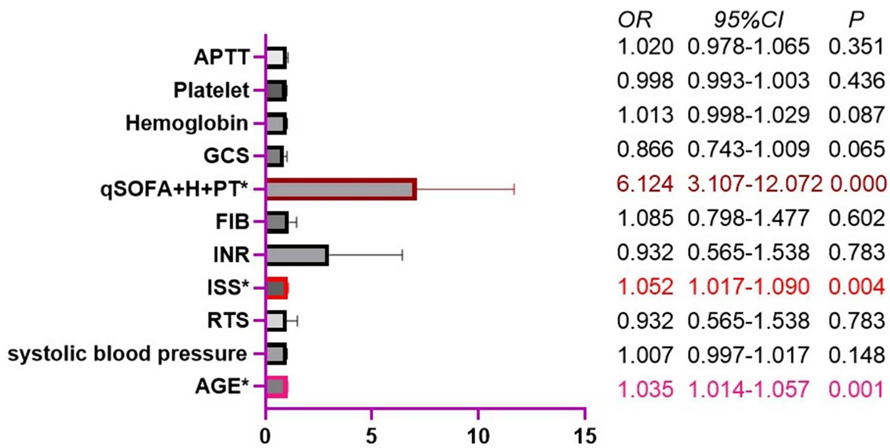
Furthermore, the predictive efficacy of qSOFA + H + PT for death was assessed in patients with TBI, NTBI, and TBI+, yielding values of 0.864, 0.858, and 0.805, respectively, with no statistically significant difference observed (P > 0.05)(Fig. 5).

qSOFA + H + PT had statistical significance on whether patients with severe trauma received blood transfusion in emergency room and emergency surgery (P < 0.05), and the AUC value of qSOFA + H + PT for predicting emergency transfusion in patients with severe trauma was 0.743. AUC value of qSOFA + H + PT for predicting emergency surgery was 0.702, with statistical difference compared with ISS (P < 0.05)(Fig. 6).

Discussion

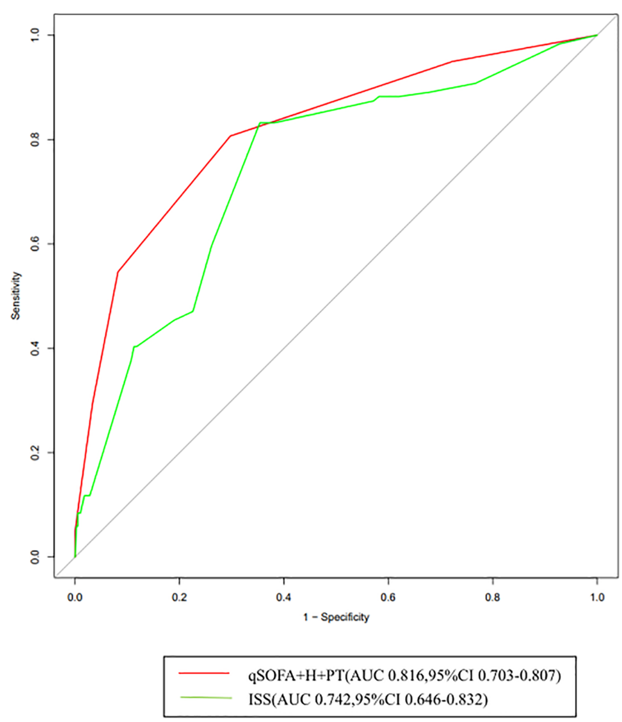
Trauma scoring systems play a crucial role in quantifying the severity of injuries, which is paramount for accurate diagnosis, treatment guidance, and prognosis assessment. In this study, age, ISS, and qSOFA + H + PT emerged as the primary determinants of in-hospital mortality among patients with severe trauma, with qSOFA + H + PT demonstrating superior predictive value compared to ISS.

In the univariate analysis, ISS, qSOFA, hypothermia, and PT exhibited significant differences between the two groups (P < 0.001). There were significant differences in age, ISS, qSOFA + H + PT in multivariate analysis (P < 0.005). Multiple studies [22, 23] have shown that age is an independent factor affecting the poor prognosis of trauma, and the risk of post-trauma death increases by 2.4–5.6 times [24–27]. Especially in elderly patients, with



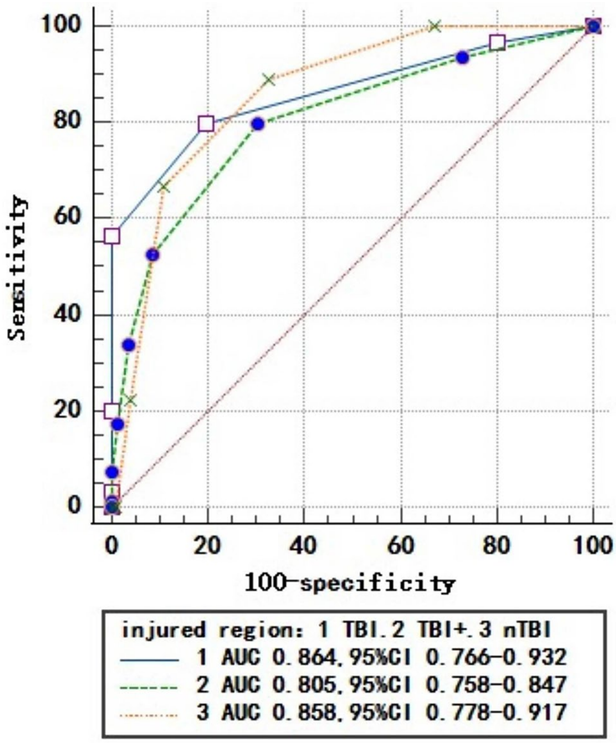
Footnote:APTT is activated partial thromboplastin time,GCS is Glasgow Coma Scale,FIB is fibrinogen,INR is international standardized ratio,ISS is injury severity score,RTS is revised trauma score,qSOFA is quick Sequential Organ Failure Assessment, and H is hypothermia,PT is prothrombin time.

Fig. 3 Binary logistic regression analysis of prognosis in patients with severe trauma



Footnote:ISS is injury severity score, qSOFA is quick Sequential Organ Failure Assessment, H is hypothermia, PT is prothrombin time

Fig. 4 Prediction Value of ISS and qSOFA + H + PT in prognosis of patients with severe trauma



Footnote:TBI is traumatic brain injury, TBI+ is severe trauma combined with TBI,nTBI is severe trauma without TBI

Fig. 5 Prediction Value of qSOFA+H+PT for prognosis of patients with severe trauma at different regions

the growth of age, physiological function declines, underlying diseases increase, and the use of multiple drugs, the older had the higher post-traumatic death rate [25]. ISS is considered as the "gold standard" for evaluating the severity of trauma [28]. Study [7] have shown that ISS is an independent risk factor for poor prognosis of trauma patients. However, it requires a lot of data, some of which can only be determined after whole-body enhanced CT scan or surgery to obtain the final score. Therefore, it is more suitable for inpatient doctors to evaluate the injury condition after receiving emergency treatment.qSOFA was initially developed and validated in patients with suspected infection by evaluating three vital signs [15, 16]. Researches have shown that qSOFA can predict emergency mortality [29] and in-hospital mortality [30] in trauma patients in the emergency room. Hypothermia, one of the triads of death, is caused by massive blood loss, exposure of the body after trauma, and infusion of unheated fluids. Johnston et al. [31] found that the function of coagulation factors II(FII) and XII(FXII) was only 65% of normal when the temperature was 35℃, even without hemodilution. PT, as one of the diagnostic criteria, reflects the exogenous coagulation function. After its initiation, the blood is in a hypercoagulable state, systemic microthrombosis, aggravation of tissue circulation disorders, systemic tissue hypoperfusion, and increase the risk of death. MacLeod [9] showed that PT was an independent risk factor for death in trauma patients, with a 35% increase in >14 S mortality.

In this study, qSOFA, hypothermia, and PT were amalgamated to reflect the overall vital signs and coagulation function status of severely injured trauma patients upon admission. These parameters could be promptly and broadly assessed, and the severity of hypothermia and PT were directly correlated with qSOFA scores after stratification and allocation. Elevated qSOFA scores were linked to heightened injury severity, increased ICU admissions, and elevated complication rates [30]. The AUC for predicting death in the ED resuscitation room among trauma patients was 0.78 in Huang's study [29]. Hypothermia in trauma patients consistently escalates mortality [32], closely associated with acidosis, hypotension, and coagulopathy (termed the triangle of death) in severe traumatic hemorrhagic shock, ultimately escalating complication incidence and mortality [33].

In the multivariate regression analysis of this study, the risk of death increased by 512.4% for every 1-point increase in qSOFA+H+PT. ISS demonstrates a robust capacity to predict mortality in trauma patients; however, it solely reflects the anatomical severity of trauma and fails to encompass the physiological disturbances induced by trauma. Consequently, ISS exhibits certain limitations in assessing mortality among patients with severe trauma [34].qSOFA+H+PT can effectively assess the severity of patients' post-traumatic vital signs and coagulation function. The predictive ability of qSOFA+H+PT for death in severe trauma patients (AUC=0.816) was significantly higher than that of ISS scoring tools commonly used in trauma patient assessment (AUC=0.742). The scoring method is simpler and more convenient than ISS and is not limited by medical resources. qSOFA+H+PT has a similar efficacy in predicting the prognosis of patients with TBI, TBI+, and NTBI.The predictive efficacy of qSOFA+H+PT for emergency blood transfusion and operation prediction was passable.The higher the qSOFA+H+PT score, the higher the fatality rate, thus prompting clinicians to intensify monitoring and management of patients with severe trauma during early admission stages.

The limitations of this study are as follows: first, it is a single-center retrospective study, the cohort used to develop the model is the same cohort used for validation, with most patients coming from the surrounding area. The hospital is located in a subtropical monsoon marine climate area without extreme cold conditions, which has certain restrictions. Secondly, the use of hypothermia score is novel in this study, lacking previous data and research support. Additionally, only trauma patients with ISS≥16 points were included, possible selection bias, and confounding by unknown or unmeasured variables

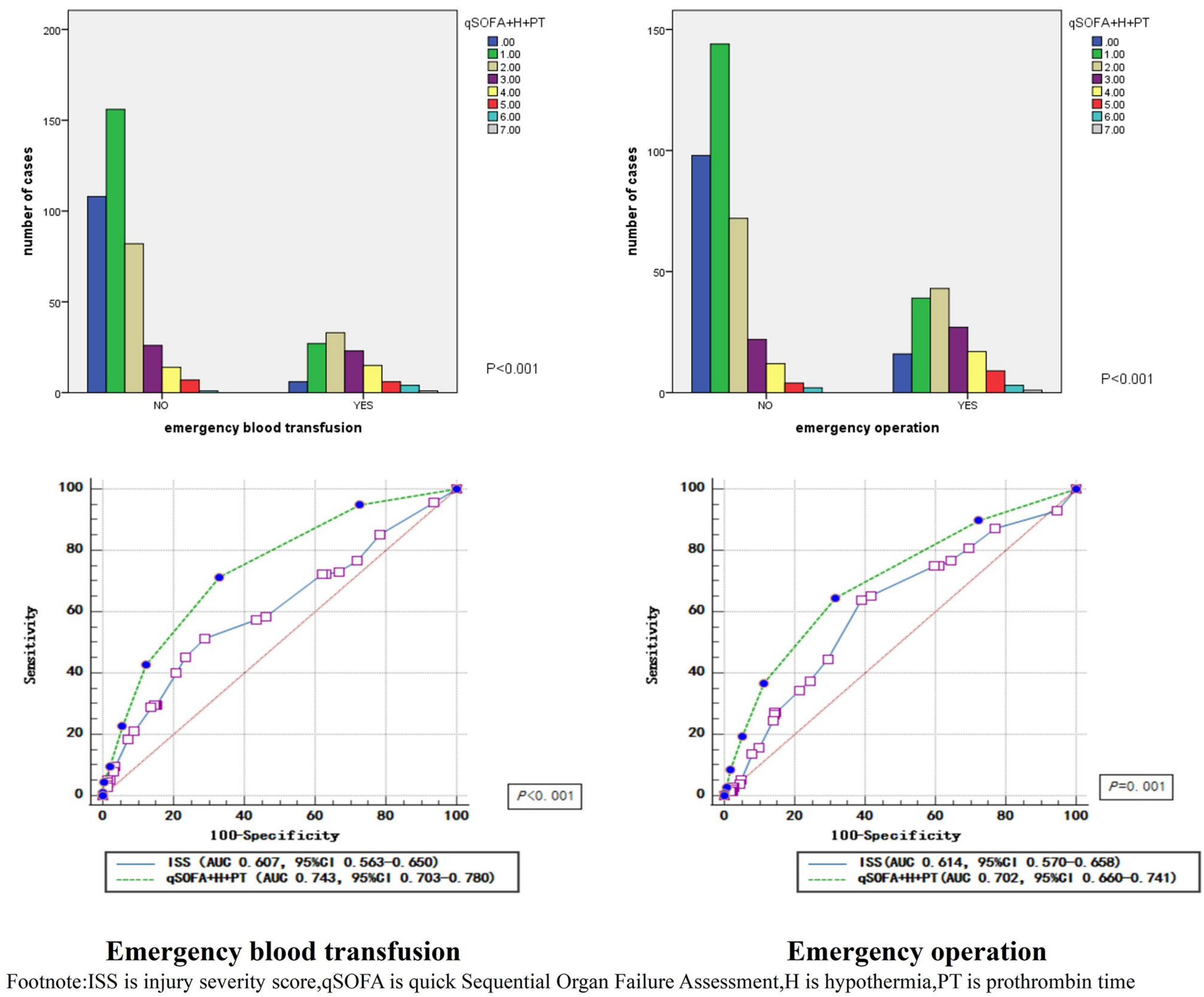


Fig. 6 Prediction Value of qSOFA + H + PT for Emergency blood transfusion and operation of patients with Severe Trauma

such as pre-hospital and in-hospital treatment factors, we might also have a bias in determining the treatment for severe trauma patients. Further prospective observational studies are needed for external validation of our results.

Conclusion

In conclusion, qSOFA+H+PT emerges as the predictors to the death of severe trauma patients. We propose a simple, rapid, and suitable assessment tool for clinicians. Utilizing qSOFA+H+PT, early warnings can be issued in the emergency department, aiding clinical management such as emergency blood transfusion, emergency operation, and prognosis prediction.

Abbreviations

qSOFA	Quick sequential organ failure assessment
H	Hypothermia
PT	Prothrombin time
APTT	Activated partial thromboplastin time
TT	Thrombin time
ROC	Receiver operating characteristic
ISS	Injury Severity Score
PHI	Pre-hospital index
CT	Computed tomography
eFAST	Extended focused assessment with sonography for trauma
DSA	Digital subtraction angiography
ATC	Acute traumatic coagulopathy
ICU	Intensive care unit
GCS	Glasgow Coma Scale
RTS	Revised Trauma Score
ECG	Electrocardiograph
ISTH	International Society of Thrombosis and Hemostasis
DIC	Disseminated intravascular coagulation
ARDS	Acute Respiratory Distress Syndrome
SD	Standard deviation
TBI	Traumatic brain injury
NTBI	Severe trauma without TBI
FII	Coagulation factors II
FXII	Coagulation factors XII

Acknowledgements
None.

Author contributions
Limei Ma, Chen Yang, Cen Chen, Yan Wu, Rong Tang, Xiaolong Cheng and Haifei Wu carried out the studies, participated in collecting data, and drafted the manuscript. Jianjun Zhu and Bing Ji performed the statistical analysis and participated in its design. All authors read and approved the final manuscript.

Funding
None.

Data availability
All data generated or analyzed during this study are included in this article.

Declarations

Ethics approval and consent to participate
This work has been carried out in accordance with the Declaration of Helsinki (2000) of the World Medical Association. This study was approved by the Ethic Committee of the Second Affiliated Hospital of Soochow University (JD-HG-2023-08), and all participants provided written informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 15 April 2024 / Accepted: 7 November 2024
Published online: 17 November 2024

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