BMC Research Notes

RESEARCH NOTE

Open Access

Development of a nomogram for individualized prediction of acute gastrointestinal injury in polytrauma patients

Cong Zhang[1], Zhaohui Tang[1], Teding Chang[1], Deng Chen[1], Shunyao Chen[1], Peidong Zhang[1], Zhiqiang Lin[1], Chunqiu Pan[2], Jialiu Luo[1] and Liming Dong[1*]

Abstract

Objective Previous reports have indicated the occurrence of acute gastrointestinal injury (AGI) in critically ill individuals. Yet, there is limited information regarding the frequency and potential causes of AGI in individuals with polytrauma. The complicated diagnostic tools often mistaken and mislead the evaluation of AGI. The objective of this research is to create a nomogram that can predict the likelihood of AGI in individuals with polytrauma.

Results Among 836 polytrauma patients, AGI occurred in 61.2%, significantly higher than the 9.5% in monotrauma patients ($P < 0.001$).The predictors included Injury Severity Score (ISS) > 16, Glasgow Coma Scale (GCS) < 8, Acute Physiology and Chronic Health Evaluation II (APACHE II) > 16, Sequential Organ Failure Assessment (SOFA) > 5, presence of shock, lactate level > 3.2, and Activated Partial Thromboplastin Time (APTT) > 40 in the individualized prediction nomogram. The nomogram showed good discrimination (C-index = 0.719) and satisfactory calibration.

Keywords Polytrauma, Acute Gastrointestinal Injury, Risk factors, Nomogram, Retrospective analysis

Introduction

Polytrauma is a multifaceted condition characterized by adverse outcomes and elevated mortality rates stemming from extensive injuries and intricate complications, thus posing an enduring health challenge [1, 2]. With advancements in prehospital interventions, contemporary intensive care strategies, the establishment of specialized trauma facilities, and enhanced surgical interventions, the survival rate of severely injured individuals in the initial phase has risen from 60% to 85–88% in recent years [3, 4].The improved chances of survival in the initial phases of polytrauma have made patients more prone to experiencing sudden complications like acute kidney injury (AKI), acute respiratory distress syndrome (ARDS), acute gastrointestinal dysfunction(AGI), and sepsis, also known as multiple organ dysfunction syndrome (MODS). These complications are associated with prolonged hospitalization, higher expenses, and increased mortality rates [5–7].

Despite a reduction in the frequency of multiple organ dysfunction syndrome (MODS) after polytrauma in recent years, it remains a major cause of death following severe trauma [8]. The gut has been proposed as the predominant component of MODS, considering that its dysfunction predisposes MODS being acknowledged for an extended period [9].In instances of multiple insults

*Correspondence:
Liming Dong
lmdong@tjh.tjmu.edu.cn
[1]Department of Trauma Surgery, Emergency Surgery & Surgical Critical, Tongji Trauma Center, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430030, China
[2]Department of Trauma Surgery, Trauma Center, Nanfang Hospital, Southern Medical University, Guangzhou 510000, China

such as trauma, infection, and shock, the gastrointestinal tract is not only a site of direct damage but also a source of exacerbation of such injuries [10].A recent multicenter study reported that acute gastrointestinal injury (AGI) occurs frequently in critically ill patients [11]. However, the pathophysiologic role of gastrointestinal dysfunction in MODS has not been sufficiently explored.

AGI poses significant patient's health deterioration and harm due to its difficulty in recognition and diagnosis and its atypical and misleading symptoms [12].The absence of clear markers for assessing gastrointestinal function, coupled with subjective and vaguely defined symptoms, often results in the oversight of gastrointestinal injury [11].An attempt is being made to construct a nomogram that can predict polytrauma patients' likelihood to develop AGI.

Patients and methods

Design of the study and participants

This study was conducted with approval from the institutional review board, and involved retrospective observation with informed consent from participants. From August 2020 to July 2023, every patient was taken to the Advanced Trauma Center's (Level I, certified by CTRTA) Traumatic Intensive Care Unit(TICU) or Intensive Care Unit(ICU) at Tongji Hospital (Wuhan).Approval for this research was granted by the Institutional Review Board of Tongji Hospital at Huazhong University of Science and Technology, with the IRB number TJ-IRB20200720 and approval date of 22 July 2020.As outlined in the Helsinki Declaration, the research was conducted according to these principles. Consent was obtained from every patient or their legally authorized representative participating in the study. To be eligible for the study, participants had to meet the following criteria: being over 18 years old, having a traumatic injury, being admitted within 24 hours, and having laboratory values (IL-6, PCT, CRP, and serum lactate) collected within 48 hours. The exclusion criteria were: 1) stomach, intestinal medical or primary injury to the gastrointestinal tract at admission; 2)terminal malignant tumor; 3)hormones or immune preparations used; 4) missing clinical records. Polytrauma patients are classified according to the 'new Berlin' definition as having AIS≥3 in two or more body regions, along with at least one additional parameter such as hypotension, unconsciousness, acidosis, coagulopathy, or being over 70 years old [13]. Monotrauma, on the other hand, is defined as an AIS severity of ≥2 in one body region with no injuries in other regions [14, 15].

The trauma centers admitted a combined total of 1350 patients with trauma injuries.73 individuals were not included because of incomplete data, while 32 individuals were not included because of an ambiguous AGI categorization.1245 trauma patients in a row were included based on the criteria. After data query, trauma patients were separated into cohorts based on their site of injury: monotrauma group versus polytrauma group; and based on the occurrence of AGI or not: AGI group versus N-AGI group.

Definition

AGI was diagnosed based on a definition developed by the European Society of Intensive Care Medicine's Working Group on Abdominal Problems (ESICM) in 2012 [16].The AGI grade was evaluated each day based on the ESICM grading system guidelines while the patient was in the hospital [16].

Data collection

Initial clinical data was gathered retrospectively from electronic medical and nursing records within 48 h of admission, including details such as age, gender, locations and types of injuries, Glasgow Coma Scale (GCS) score, Injury Severity Score (ISS), Sequential Organ Failure Assessment (SOFA) score, Acute Physiology and Chronic Health Evaluation (APACHE II) score, Shock index (SI), various laboratory values (IL-6, PCT, APTT, serum lactate, etc.), and discharge records. Administering vasoactive medications like norepinephrine and dopamine is necessary during the patient's stay in the hospital. The specification of the drugs used was according to the existing research [17].

Statistical analysis

All data were examined for normality and homogeneity before analysis. Categorical variables are often analyzed by percentages, while continuous variables are most often analyzed by mean plus standard deviation. When dealing with categorical and continuous variables, the chi-squared test or Fisher test, as well as the Mann-Whitney U test or t-test, are employed individually. An analysis using multivariate logistic regression was carried out to pinpoint the autonomous risk elements linked to AGI in patients with multiple traumas. Following this, a nomogram was created based on the outcomes of the multivariate logistic regression analysis done using the R. Each coefficient from the regression was converted into a scale of 0-100 points, with the variable showing the highest β coefficient being assigned a score of 100 points. Probabilities were estimated by aggregating total points from various variables. The C-index was used to evaluate model accuracy, overfitting was determined through bootstrap validation, nomogram performance was assessed with calibration plot analysis, and predictive accuracy was evaluated using ROC curve analysis. R software was utilized for statistical analysis, with a significance level of $P<0.05$.Analysis was conducted using SPSS 23.0, GraphPad Prism software 9.3.1, and displayed with R software.

Result

Characteristics observed in patients with Polytrauma

Between August 2020 and July 2023, the trauma centers received 1350 patients who had experienced trauma. Patients excluded from the study were 73 because of incomplete date and 32 because of an ambiguous AGI categorization.1245 patients who met the inclusion criteria were categorized into two groups: polytrauma patients (n=836) and monotrauma patients (n=409) (Fig. 1).Table 1 displays the patient population's demographics and attributes.

A total of 836 consecutive polytrauma patients were enrolled from two Level I trauma centers, with a majority being male (64.6%) and a mean age of 43.6±8.6 years. The mean Injury Severity Score (ISS) was 26.6, with Glasgow Coma Scale (GCS) and Shock Index (SI) values of 10.6 and 0.9, respectively, indicating a population with severe injuries. Specifically, 54.5% (456/836) of patients experienced head injuries, 61.1% (511/836) had thoracic injuries, 21.2% (177/836) suffered spine injuries, and 16.1% (135/836) sustained pelvic injuries, while 71.4% (597/836) had limb trauma. The primary reason for the injury was a traffic accident, accounting for 70.2% (587/836) of cases, with high-energy falls being the second most common cause at 22.2% (186/836), followed by other types of accidents at 7.6% (63/836).(Table 1).

Incidence of AGI in patients after polytrauma

The 44.3% (551 out of 1245) of trauma patients enrolled experienced AGI. In polytrauma patients, 61.2% (512 out of 836) experienced AGI, with 17.8% classified as grade I (91 cases), 46.9% as grade II (240 cases), 30.6% as grade III (157 cases), and 4.7% as grade IV (24 cases).The polytrauma group and monotrauma group showed notable disparities in AGI occurrence. The polytrauma patients had higher incidence of AGI(61.2% vs.9.5%,P<0.001) than monotrauma patients. As for the distribution of the AGI grades, the polytrauma group had higher ratio of severe AGI(AGIIII, IV)(35.3% vs.2.5%,P<0.001) than monotrauma group.(Table 1).

Early risk factors for AGI in polytrauma patients

An analysis of univariate data is shown in Table 2 for polytrauma patients with or without AGI. When compared with patients without AGI, those with AGI had a higher ISS, higher SI, higher APACHE II, higher SOFA, higher levels of heart rate, serum lactate, PCT, IL-6 and APTT and lower GCS(P<0.05),which were retrospectively collected in the first 48 h after admission. No significant variations were observed in age (P=0.129) and gender (P=0.810) between the AGI and N-AGI groups (Table 2).Furthermore, polytrauma individuals experiencing AGI exhibited a greater proportion of mechanical

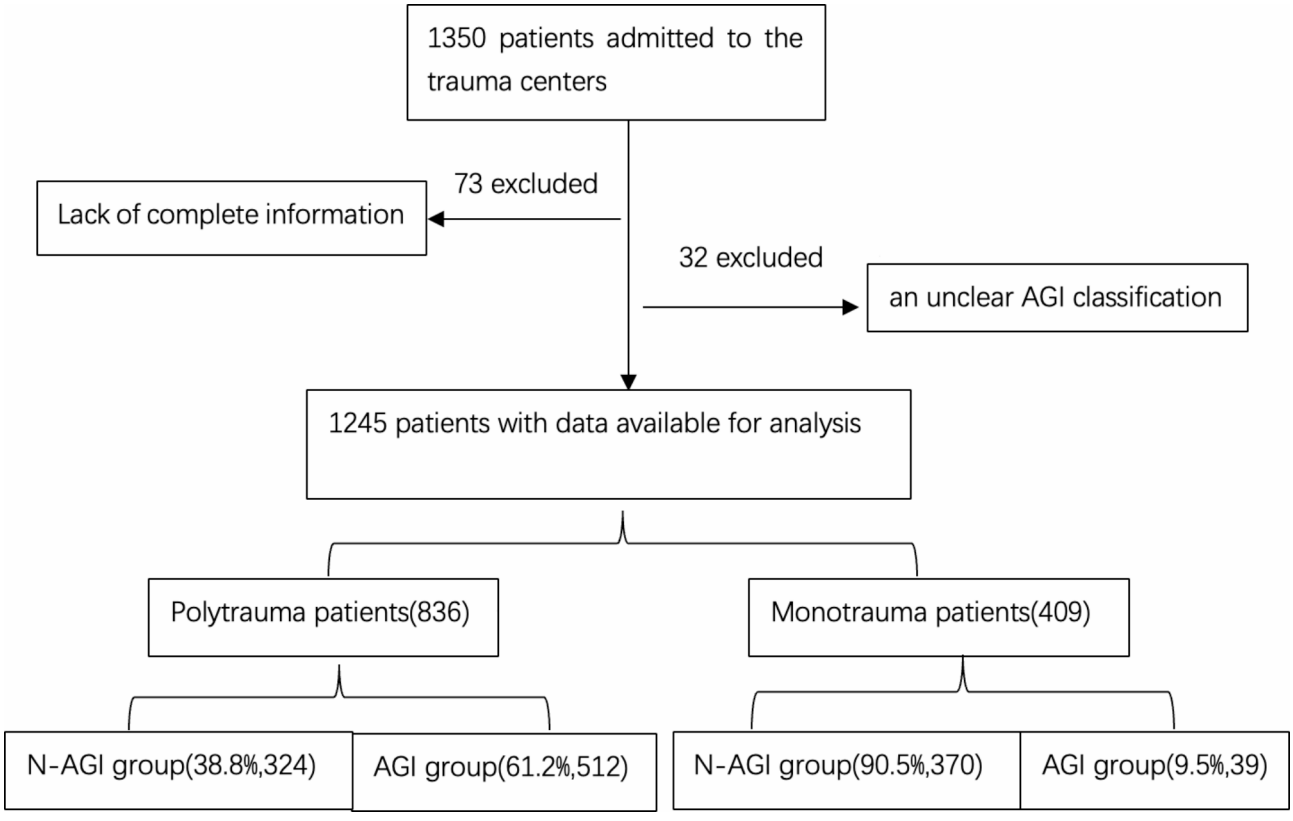

Fig. 1 Case identification procedure

Table 1 Patient demographics and characteristics

Characteristics	All patients (*n* = 1245)	Polytrauma group (*n* = 836)	Monotrauma group (*n* = 409)	*P*
Age, mean (SD), y	42.4 ± 7.6	43.6 ± 8.6	42.7 ± 7.8	0.065
Gender		-	-	0.391
male, n(%)	794(63.8)	540(64.6)	254(62.1)	-
female, n(%)	451(36.2)	296(35.4)	155(37.9)	-
ISS, mean (SD)	20.4 ± 7.3	26.6 ± 7.5	11.4 ± 4.3	< 0.001
GCS, mean (SD)	11.9 ± 3.6	10.6 ± 3.8	12.1 ± 3.6	< 0.001
SI, mean (SD)	1.2 ± 0.4	0.9 ± 0.6	1.4 ± 0.4	< 0.001
Cause of injury		-	-	0.003
Traffic accident, n(%)	867(69.6)	587(70.2)	280(68.5)	-
high-energy fall, n(%)	199(16.0)	186(22.2)	13(3.2)	-
other, n(%)	179(14.4)	63(7.6)	116(28.3)	-
Injury site		-	-	< 0.001
Head, n(%)	534(42.9)	456(54.5)	78(19.1)	-
Thorax, n(%)	537(43.1)	511(61.1)	26(6.4)	-
Spine, n(%)	212(17.0)	177(21.2)	35(8.6)	-
Pelvis, n(%)	140(11.2)	135(16.1)	5(1.2)	-
Limb trauma, n(%)	862(69.3)	597(71.4)	265(64.7)	-
Incidence of AGI, n(%)	551(44.3)	512(61.2)	39(9.5)	< 0.001
AGI grades, n(%)		-	-	< 0.001
I	123(22.3)	91(17.8)	32(82.1)	-
II	246(44.6)	240(46.9)	6(15.4)	-
III	158(28.7)	157(30.6)	1(2.5)	-
IV	24(4.4)	24(4.7)	0(0)	-

ISS: injury severity score; GCS: Glasgow coma scale; **SI**: shock index; **AGI**: acute gastrointestinal injury

ventilation (69.7%vs.30.2%, $P<0.001$), administration of vasoactive medication (61.3% vs. 23.5%, $P<0.001$), extended ICU durations (14 vs. 6, $P<0.001$), and elevated in-hospital mortality rates (13.3% vs. 4.7%, $P<0.001$) in contrast to polytrauma patients lacking AGI (Table 2).

Multivariate examinations of key factors for AGI

Following univariate examination, variables with a $P<0.05$ in the initial group were chosen for multivariate analysis utilizing a stepwise multiple regression approach. Multivariate analysis using logistic regression indicated that having an ISS > 16 (OR 3.614, 95% CI 1.525–9.472), GCS < 8 (OR 3.527, 95% CI 1.981–7.225), APACHEII > 16 (OR 2.801, 95% CI 1.506–5.209), SOFA > 5 (OR 4.599, 95% CI 2.034–10.396), experiencing shock (OR 2.863, 95% CI 1.398–5.863), Lactate > 3.2 (OR 2.348, 95% CI 1.215–4.538), and APTT > 40 (OR 3.841, 95% CI 1.593–9.263) were all linked to an increased risk of AGI.(Table 3).

Development of the risk score and nomogram-driven tool

A nomogram, serving as a visualization tool, illustrates the relative weights of variables within a model and facilitates the calculation of outcome probabilities. In this study, a nomogram was constructed to estimate the risk of acute gastrointestinal infection (AGI) within the cohort using independently associated risk factors. Nomograms require individuals to locate all variables on the corresponding axis, connect them to the points axis, then add up the points for each variable and connect the total points to determine the probability of AGI(Fig. 2A). The nomogram's calibration curve showed strong agreement between predicted and observed values for AGI probability in the cohort. Based on the Hosmer-Leme test ($P=0.237$), the values were not significantly deviating from ideal fit (Fig. 2B).Within the group, the nomogram's sensitivity and specificity were analyzed using ROC curve analysis, resulting in an AUC of 0.719(Fig. 2C).

Discussion

The gastrointestinal system has long been acknowledged as a key factor in the onset of multiple organ dysfunction syndrome (MODS), with the gut believed to be a major contributor to this condition. It is widely recognized that severe illness can cause major changes in the balance of microorganisms in the gut and trigger immune responses in the mucosal lining, which could increase the risk of bacteria moving from the gut to other parts of the body, leading to infections that could develop into sepsis and MODS [18].Despite the development of various scoring systems for MODS, the gastrointestinal system has yet to be incorporated into any widely utilized scoring systems. Recent studies have shown that 50% of severely ill patients were found to have acute gastrointestinal injury

Table 2 Variables in AGI group and N-AGI group in polytrauma patient

Variables	AGI(*n* = 512)	N-AGI(*n* = 324)	*P*
Age	42.4 ± 7.1	43.2 ± 7.6	0.129
Male	314(61.3)	196(60.5)	0.810
BMI, mean (SD), kg/m2	20.8 ± 4.0	21.2 ± 3.4	0.123
ISS, mean (SD)	29.6 ± 14.4	18.5 ± 12.3	< 0.001
GCS, mean (SD)	10.2 ± 3.1	12.1 ± 2.9	< 0.001
SI, mean (SD)	1.2 ± 0.4	0.7 ± 0.3	< 0.001
APACHE II	18.4 ± 5.6	13.6 ± 5.1	< 0.001
SOFA	7.7 ± 2.6	5.1 ± 2.2	< 0.001
Heart rate, mean (SD), beats/minute	121.8 ± 26.3	107.1 ± 24.4	< 0.001
Glucose, mean (SD), mmol/L	8.6 ± 4.1	8.9 ± 3.6	0.267
hemoglobin, mean (SD), g/L	112.9 ± 25.6	116.2 ± 22.8	0.052
Serum lactate, median (IQR), mmol/L	3.6(1.8,5.2)	1.9(1.7,2.3)	< 0.001
PCT, mean (SD), ng/mL	5.2 ± 2.3	1.4 ± 0.7	< 0.001
CRP, mean (SD), mg/L	92.1 ± 41.4	86.7 ± 55.3	0.132
IL-6, median (IQR), pg/mL	89.3(49.3,130.1)	23.1(19.6,46.2)	< 0.001
AST, mean (SD), U/L	51.2 ± 31.3	47.1 ± 31.5	0.067
ALT, mean (SD), U/L	61.1 ± 33.2	57.2 ± 31.7	0.089
Albumin, mean (SD), g/L	33.1 ± 6.2	32.2 ± 6.7	0.052
CYC, mean (SD), mg/L	0.9 ± 0.7	1.0 ± 0.8	0.057
Serumcreatinine, median(IQR),μmol/L	83.5 (56.2–91.9)	86.1 (72.8–96.1)	0.215
APTT, mean (SD), s	57.3 ± 16.4	31.2 ± 11.3	< 0.001
D dimer, median (IQR), ug/mL	22.3(12.1,35.9)	17.1(9.1,22.7)	< 0.001
Use of vasoactive drug, n(%)	314(61.3)	76(23.5)	< 0.001
Mechanical ventilation, n(%)	357(69.7)	98(30.2)	< 0.001
Duration of ICU, median (IQR), days	14(7,21)	6(3,13)	< 0.001
In-hospital mortality, n(%)	24(4.7)	43(13.3)	< 0.001

BMI: Body mass index ;**ISS**: injury severity score; **GCS**: Glasgow coma scale; **SI**: shock index; **SOFA**: Sequential Organ Failure Assessment; **APACHE II**: Acute Physiology and Chronic Health Evaluation

Table 3 Multivariate analyses of early risk factors for AGI in polytrauma patients

Variables	B	OR	odds ratio (95% CI)	*P*
ISS > 16	1.285.	3.614	1.525–9.472	0.021
GCS < 8	1.261	3.527	1.981–7.225	0.001
APACHEII > 16	1.030	2.801	1.506–5.209	0.001
SOFA > 5	1.526	4.599	2.034–10.396	0.001
Shock	1.052	2.863	1.398–5.863	0.004
Lactate > 3.2	1.154	2.348	1.215–4.538	0.011
APTT > 40	1.346	3.841	1.593–9.263	0.003

within the initial week of their intensive care unit admission, and these patients with AGI experience a higher rate of in-hospital mortality (31.1% vs. 18.8%) compared to those without AGI [19].Polytrauma is characterized by adverse outcomes and elevated mortality rates stemming from extensive injuries and intricate complications. Regrettably, there is a lack of extensive clinical information regarding the prevalence of AGI in individuals with multiple traumatic injuries. As expected, our study indicated that polytrauma patients have a higher risk (61.2%) accompanied by AGI when compared with monotrauma patients(9.5%).More importantly, polytrauma patients with AGI were presented relatively higher in-hospital mortality(13.3%vs.4.7%) when compared with polytrauma patients without AGI.

We evaluated some early parameters between the AGI group and N-AGI group in polytrauma patients. Our study discovered that these patients with AGI were significantly more severely ill(higher ISS scores, Sofa scores, APACHE II scores, shock index and lower GCS scores). The AGI groups also stayed longer in ICU and exhibited higher rates of mechanical ventilation and use of vasoactive drug than did patients in N-AGI groups. Reduced movement in the digestive system can result in inhaling foreign substances, which can raise the chances of developing pneumonia from using a ventilator, leading to extended periods of mechanical ventilation and stay in the intensive care unit [20]. We found those early indicators after polytrauma such as ISS score, Sofa scores, APACHE II scores, GCS score, shock index, serum lactate and APTT could distinguish between the AGI group and N-AGI group in polytrauma patients. The finding is consistent with the clinical experience in daily work. A high ISS score, Sofa scores and APACHE II scores as independent high-risk factors help explain why polytrauma patients have higher rate of AGI than those with single injuries. Studies have demonstrated that traumatic

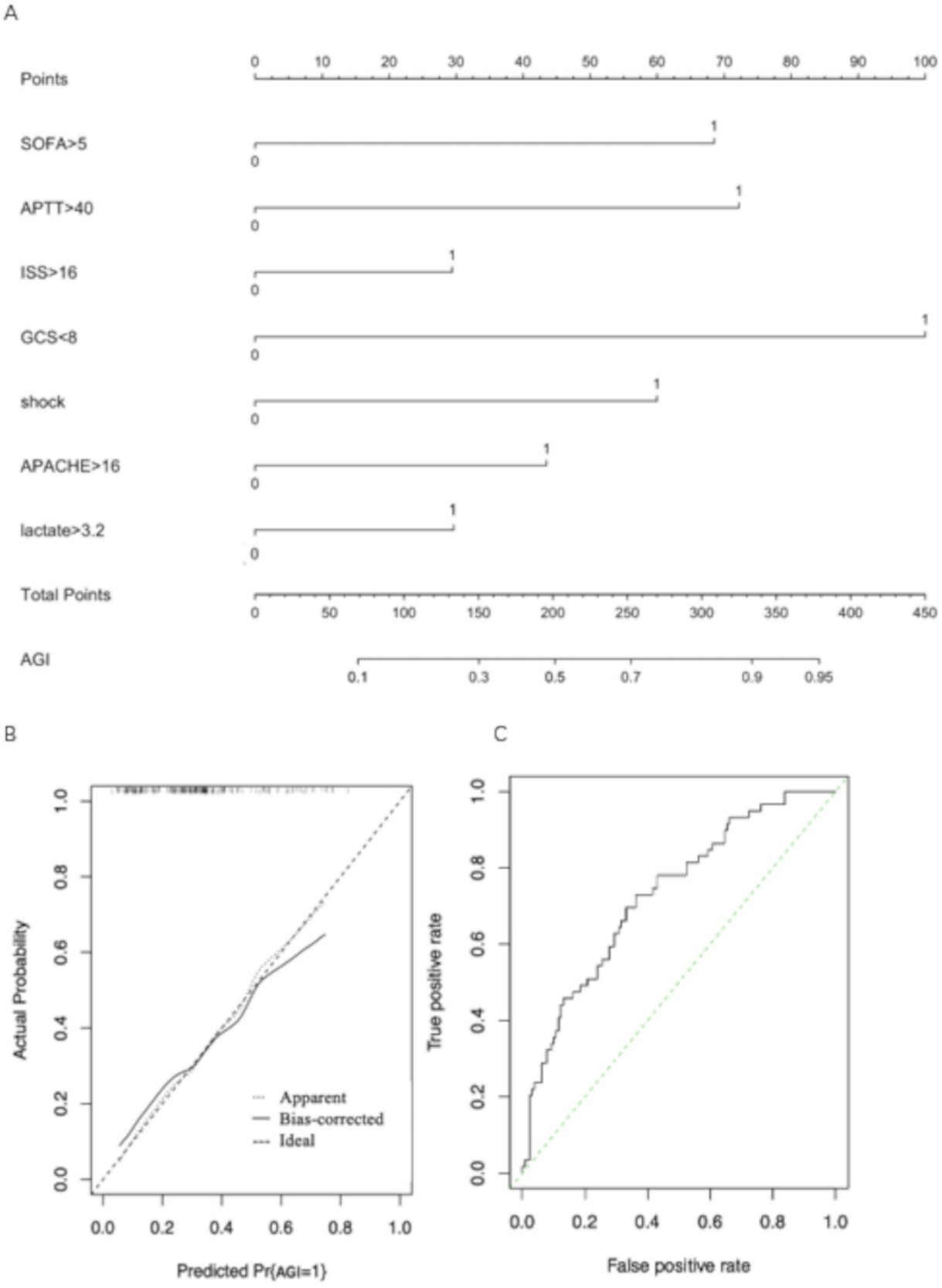

Fig. 2 (See legend on next page.)

(See figure on previous page.)

Fig. 2 Developed AGI-predicting nomogram and Calibration curves, ROC curve analysis for the sensitivity and specificity of the AGI-predicting nomogram Figure 2**A** Developed AGI-predicting nomogram. The AGI-predicting nomogram was developed in the cohort. ;**ISS**: injury severity score; **GCS**: Glasgow coma scale; **SOFA**: Sequential Organ Failure Assessment; **APACHE II**: Acute Physiology and Chronic Health Evaluation Figure 2**B**: Calibration curves of the AGI -predicting nomogram. Calibration curves depict the agreement between the predicted risks of AGI and observed outcomes of AGI. Figure 2**C**: ROC curve analysis for the sensitivity and specificity of the nomogram in the cohort

brain injury (TBI) can greatly affect the makeup of the gut microbiome, leading to a reduction in beneficial bacteria and a rise in harmful bacteria, potentially exacerbating the development of illness [21–23].Severe shock following polytrauma can lead to reduced perfusion of gastrointestinal organs, as evidenced by the accumulation of serum lactate, resulting in ischemic and hypoxic injury to the gastrointestinal mucosa. Furthermore, severe polytrauma can induce significant stress, an exaggerated inflammatory response (evidenced by elevated levels of IL-6 and TNF-α), and abnormal coagulation function (evidenced by prolonged APTT).The combined effect of these changes resulted in a series of AGI clinical symptoms or signs such as reduced bowel sounds, abdominal distension, and high abdominal pressure or hyperactivity of bowel sounds, abdominal pain, diarrhea, and stress ulcers.

As showed in Fig. 2, a personalized prediction tool, known as a nomogram, was created to forecast AGI in polytrauma patients. this tool includes seven factors: ISS > 16, GCS < 8, APACHE II > 16, SSOFA > 5, presence of shock, lactate level > 3.2,and APTT > 40.The risk score's performance showed acceptable precision, achieving an AUC of 0.719 in the cohort. The calibration curves of the AGI-predicting nomogram suggest potential clinical utility. Clinicians can utilize the AGI-predicting nomogram to assess the individual risk of AGI development in hospitalized patients, as the seven variables required for calculation are typically readily available. In clinical practice, a risk probability exceeding 30–40% is typically considered indicative of high risk for developing AGI. This threshold aligns with recent trauma and critical care studies, which recommend that patients with a probability above 30% should be closely monitored for gastrointestinal complications and may require more intensive treatment or ICU admission. Conversely, patients with a risk probability below 30% are generally classified as low risk and can be managed with routine monitoring and less aggressive interventions [24].

Limitation

However, there are specific constraints that apply to our research. Firstly, the complex nature of AGI manifestations posed challenges in accurately diagnosing and classifying cases, even when adhering to ESICM criteria, potentially introducing bias into the results. Lack of information regarding treatment impeded the ability to identify risk factors, as adjustments for other possible confounding variables were not possible. Lastly, the restricted scope of our single-center observational study, with a limited number of patients, restricts the generalizability of our findings.

Conclusion

Acute gastrointestinal injury (AGI) in polytrauma patients represents a substantial public health concern, as evidenced by its high frequency and in-hospital mortality. Our study characterized the incidence and risk factors of AGI in patients after polytrauma and introduces a nomogram that integrates clinical risk factors, offering potential clinical value for personalized prediction of AGI in polytrauma patients.

Abbreviations

AGI	Acute Gastrointestinal Injury
ISS	Injury Severity Score
GCS	Glasgow Coma Scale
APACHE II	Acute Physiology and Chronic Health Evaluation II
SOFA	Sequential Organ Failure Assessment
APTT	Activated Partial Thromboplastin Time
SI	Shock index
AKI	Acute Kidney Injury
ARDS	Acute Respiratory Distress Syndrome
MODS	Multiple Organ Dysfunction Syndrome
TICU	Traumatic Intensive Care Unit
ICU	Intensive Care Unit
ESICM	European Society of Intensive Care Medicine

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13104-024-07066-2.

Supplementary Material 1

Acknowledgements

We thank the staff at the Department of Clinical Statistics for their assistance in statistical analysis.

Author contributions

L.D. and J.L. participated in the designing of the experiment, collection, analysis, and interpretation of data, and drafting the manuscript. Z.T.,T.C., D.C., S.C.,P.Z., Z.L. and C.P. collected and analyzed data. C.Z. contributed to the collection and analysis of data and drafted the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding

There was no funding in this study.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Approval for this research was granted by the Institutional Review Board of Tongji Hospital at Huazhong University of Science and Technology, with the IRB number TJ-IRB20200720 and approval date of 22 July 2020. Informed consent was obtained from each patient or, in cases where the patient was unable to provide consent due to severe conditions such as impaired consciousness or critical illness, from their legally authorized representative.

Consent for publication
Not Applicable.

Competing interests
The authors declare no competing interests.

Received: 8 July 2024 / Accepted: 19 December 2024
Published online: 23 December 2024

References

1. Chen D et al. Venous Thrombus embolism in Polytrauma: special attention to patients with traumatic brain Injury. J Clin Med, 2023. 12(5).
2. Luo J et al. Multifactorial shock: a Neglected Situation in Polytrauma patients. J Clin Med, 2022. 11(22).
3. Cannon JW, et al. Damage control resuscitation in patients with severe traumatic hemorrhage: a practice management guideline from the Eastern Association for the surgery of Trauma. J Trauma Acute Care Surg. 2017;82(3):605–17.
4. Falkenberg L, et al. Long-term outcome in 324 polytrauma patients: what factors are associated with posttraumatic stress disorder and depressive disorder symptoms? Eur J Med Res. 2017;22(1):44.
5. Halvachizadeh S, et al. How to detect a polytrauma patient at risk of complications: a validation and database analysis of four published scales. PLoS ONE. 2020;15(1):e0228082.
6. Kocuvan S, et al. Evaluation of major trauma in elderly patients - a single trauma center analysis. Wien Klin Wochenschr. 2016;128(Suppl 7):535–42.
7. Kamp O, et al. Polytrauma outcome: implementation of health-related quality of life assessment into the German Trauma Registry. Eur J Trauma Emerg Surg. 2021;47(3):869–74.
8. Lentsck MH, et al. Risk factors for death of trauma patients admitted to an Intensive Care Unit. Rev Lat Am Enfermagem. 2020;28:e3236.
9. Tulkens J, et al. Increased levels of systemic LPS-positive bacterial extracellular vesicles in patients with intestinal barrier dysfunction. Gut. 2020;69(1):191–3.
10. Asrani VM et al. A comment on 'Development of the Gastrointestinal Dysfunction Score (GIDS) for critically ill patients - A prospective multicenter observational study (iSOFA study)' (Reintam 2021. Clinical Nutrition, v 40 (8): pp 4932–4940. August 2021. Clin Nutr, 2022. 41(2): pp. 581–582.
11. Zhong M, et al. Association of changes in Acute Gastrointestinal Injury Grade with Prognosis in critically ill patients: a prospective, Single-Center, Observational Study. J Multidiscip Healthc. 2021;14:279–86.
12. Li H et al. Association between acute gastrointestinal injury grading system and disease severity and prognosis in critically ill patients: a multicenter, prospective, observational study in China. J Crit Care, 2016: pp. 24–8.
13. Rau CS et al. Polytrauma defined by the New Berlin definition: a validation test based on propensity-score matching Approach. Int J Environ Res Public Health, 2017. 14(9).
14. Butcher N, Balogh ZJ. The definition of polytrauma: the need for international consensus. Injury. 2009;40(Suppl 4):S12–22.
15. Masson F, et al. Epidemiology of severe brain injuries: a prospective population-based study. J Trauma. 2001;51(3):481–9.
16. Reintam Blaser A, et al. Gastrointestinal function in intensive care patients: terminology, definitions and management. Recommendations of the ESICM Working Group on abdominal problems. Intensive Care Med. 2012;38(3):384–94.
17. Russell JA. Vasopressor therapy in critically ill patients with shock. Intensive Care Med. 2019;45(11):1503–17.
18. Schuijt TJ, et al. The intestinal microbiota and host immune interactions in the critically ill. Trends Microbiol. 2013;21(5):221–9.
19. Hu B, et al. Severity of acute gastrointestinal injury grade is a predictor of all-cause mortality in critically ill patients: a multicenter, prospective, observational study. Crit Care. 2017;21(1):188.
20. Wang Y et al. [Establishment of comprehensive prediction model of acute gastrointestinal injury classification of critically ill patients]. 2018. 21(3): p. 325.
21. Hanscom M, Loane DJ, Shea-Donohue T. Brain-gut axis dysfunction in the pathogenesis of traumatic brain injury. J Clin Invest, 2021. 131(12).
22. You W, et al. Traumatic brain Injury induces gastrointestinal dysfunction and dysbiosis of gut microbiota accompanied by alterations of bile Acid Profile. J Neurotrauma. 2022;39(1–2):227–37.
23. Sundman MH, et al. The bidirectional gut-brain-microbiota axis as a potential nexus between traumatic brain injury, inflammation, and disease. Brain Behav Immun. 2017;66:31–44.
24. Wang Y, et al. Development and validation of a nomogram for predicting 28-day mortality in critically ill patients with acute gastrointestinal injury: prospective observational study. Front Nutr. 2024;11:1469870.

Publisher's note