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ORIGINAL ARTICLE

Clinical Value of Procalcitonin and Sarcopenia Index in Evaluating Intra-Abdominal Infection in Trauma Patients

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ABSTRACT

Background: **The aim is to evaluate the predictive value of serum procalcitonin (PCT) and the sarcopenia index (SI) for intra-abdominal infection (IAI) during hospitalization in patients with abdominal trauma; to compare the discriminatory performance of single indicators versus their combination, and to conduct gender-stratified and clinical application assessments.**

Methods: **A single-center cohort study was conducted that included patients with abdominal trauma (n = 326) admitted through the emergency department. PCT levels on days 1, 3, and 5 (denoted as PCT1, PCT3, and PCT5, respectively), and SI was calculated using creatinine (Cr) and cystatin C (CysC). The main outcome was IAI during hospitalization. ROC curves and DeLong's test were used to compare the discriminative ability of PCT at different time points. Univariate and multivariate logistic regression analyses were performed stratified by gender. A combined model and nomogram were developed based on PCT3 and 1/SI. Decision curve analysis (DCA) and calibration curves were applied to evaluate clinical net benefit and model consistency.**

Results: **The IAI group had significantly higher PCT levels at all time points compared to the non-IAI group. PCT3 demonstrated the best discriminatory performance, and was significantly superior to PCT1 and PCT5. Baseline comparisons revealed gender differences in SI, with male patients having higher SI than females, while no significant gender differences were found for PCT3 or the proportion of IAI. In gender-stratified regression, PCT3 was a common independent predictor of IAI in both male and female patients, while SI was negatively correlated with IAI. The combined model (PCT3 + 1/SI) outperformed any single indicator in both male and female groups. DCA showed a stable net clinical benefit, and the model was well-calibrated. The nomogram could be used for individualized bedside risk assessment.**

Conclusions: **PCT3 is the strongest single predictor of IAI, and SI is negatively correlated with IAI. Their combination further enhances predictive discrimination, offering clinical net benefit and good calibration. Effective prediction of IAI can be achieved using routine serological indicators from hospital day 3 - serum PCT and SI calculated from routine Cr and CysC.**

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KEYWORDS

abdominal trauma, intra-abdominal infection, procalcitonin, sarcopenia index, gender stratification, ROC curve, nomogram, decision curve analysis

LIST OF ABBREVIATIONS

AUCs - Area under the curve
CI - Confidence interval
DeCi - Decompensated cirrhosis

HBV - Hepatitis B virus
MELD score - Model for End-stage liver disease score
MLR - Monocyte-to-lymphocyte ratio
MPVLR - Mean platelet volume-to-lymphocyte ratio
NLR - Neutrophil-to-lymphocyte ratio
PNR - Platelet-to-neutrophil ratio
PWR - Platelet-to-white blood cell ratio
ROC - Receiver operating characteristic
SIRS - Systemic inflammatory response syndrome
WBC - White blood cell

INTRODUCTION

Trauma is a major global public health challenge, claiming over 6 million lives annually [1]. Among all trauma cases, abdominal trauma accounts for approximately 6%, and is frequently complicated by intra-abdominal infection (IAI), which has a reported incidence of about 20.4% [2]. Among emergency trauma patients, abdominal trauma is more prevalent, accounting for approximately 17.8%, and is associated with an in-hospital mortality rate as high as 18.4%, presenting major challenges to emergency medical care and public health systems [3,4]. IAI often results from perforation or rupture of hollow organs, leading to peritoneal contamination, which may trigger sepsis, septic shock, and multiple organ dysfunction syndrome (MODS), thereby contributing to considerable mortality and complication rates [4]. Early identification and prediction of IAI during hospitalization are therefore critical challenges in the management of abdominal trauma [5].

Existing IAI risk assessments are largely derived from perioperative evidence: albumin (Alb) has been identified as an independent predictor after major hepatectomy, elevated lactate indicates IAI risk following pancreatic resection, and procalcitonin (PCT) has been used to identify IAI after gastric surgery [5,6]. Several predictive models for postoperative IAI have also been proposed [7,8]. However, most of these indicators and models were developed in surgical populations, rely on surgery-related variables, and are relatively complex. Their applicability and generalizability are limited in the context of hospitalized abdominal trauma patients due to trauma-related stress and early inflammatory responses, thereby failing to meet the need for simple, universal, and bedside-accessible clinical assessment tools.

Serum PCT aids in distinguishing bacterial infection from non-infectious causes and is widely used in the evaluation of sepsis and septic shock, as well as in guiding antibiotic therapy, with additional prognostic value [9-11]. Kinetically, PCT begins to rise within 3 - 4 hours after endotoxin exposure, reaches a plateau at 8 - 24 hours, and has a serum half-life of approximately 24 - 30 hours, making it suitable for dynamic assessment during early hospitalization [12]. In contrast, CRP and WBC responses are more delayed, typically peaking around 36 hours, and are susceptible to persistent influences from surgical and traumatic stress, limiting their specificity [13,14]. Multiple studies in abdominal surgery cohorts have demonstrated the discriminative power of PCT for infectious complications and postoperative IAI [14,15]. Nevertheless, the optimal timing and actual incremental value of multi-timepoint PCT monitoring (D1/3/5) in hospitalized abdominal trauma patients remain unclear and warrant systematic evaluation of its clinical diagnostic utility.

The sarcopenia index (SI) has recently gained attention [16-18]. Defined as (serum creatinine [Cr]/cystatin C [CysC]) × 100, SI was initially proposed as an approximate indicator of skeletal muscle mass [19]. Compared to CT-based muscle assessment, which involves higher cost and radiation exposure, SI is derived from routine laboratory tests, is readily available at the bedside, and incurs no additional cost [20]. Studies have shown that SI is associated with reduced muscle mass/sarcopenia and correlates with adverse outcomes in various populations [21-23]. However, the relationship between SI and IAI, as well as its predictive value in hospitalized abdominal trauma patients, has not been established.

Accordingly, this study is designed to systematically evaluate the predictive value of PCT and SI for IAI in hospitalized patients with abdominal trauma admitted via the emergency department, as well as to explore the clinical feasibility of their combined use. Additionally, a practical and generalizable prediction tool will be developed and validated using routinely available clinical and laboratory indicators. The model's performance metrics, including discriminatory power, calibration, and clinical net benefit, will be systematically assessed to support early identification and risk stratification of IAI.

MATERIALS AND METHODS

Study participants

This study consecutively enrolled patients with abdominal trauma who presented to the emergency department at our hospital and were hospitalized between June 2021 and January 2025. The inclusion criteria were: 1) Patients aged between 20 and 65 years, representing adulthood with relatively stable muscle metabolism and immune function. 2) Patients admitted with a diagnosis of blunt or penetrating abdominal trauma. 3) Patients who underwent initial laboratory testing within 24 hours of admission and completed follow-up tests according to the predefined time windows on days 1, 3, and 5. 4) Patients with complete clinical data and specimen collection conditions. The exclusion criteria were: 1) Patients with severe renal dysfunction as defined by international guidelines [24] or those receiving renal replacement therapy (which may interfere with the interpretation of Cr and CysC levels). 2) Patients with missing key data (e.g., PCT, Cr, or CysC). 3) Patients with comorbidities significantly affecting muscle metabolism (e.g., active malignant tumors, chronic wasting dis-

Table 1. Serum PCT levels at day 1, 3 and 5 in patients with IAI and non-IAI.

Variables	Total (n = 326)	IAI (n = 92)	Non-IAI (n = 234)	p-value
PCT1 (μg/L)	7.27 ± 3.13	9.15 ± 3.61	6.54 ± 2.58	< 0.001
PCT3 (μg/L)	4.96 (2.53, 8.24)	9.23 (5.63, 14.22)	3.95 (2.00, 5.93)	< 0.001
PCT5 (μg/L)	3.92 (1.63, 7.24)	7.98 (4.42, 14.36)	2.91 (1.04, 5.08)	< 0.001

PCT1, PCT3, and PCT5 denote procalcitonin on days 1, 3, and 5 (μg/L). Data are presented as mean ± standard deviation for normally distributed variables or median [interquartile range, IQR] for non-normally distributed variables. p-values were calculated by Student's *t*-test or Mann-Whitney U test, as appropriate. p < 0.05 was considered statistically significant.

Table 2. Diagnostic performance of PCT at day 1, 3 and 5 for intra-abdominal infection.

Model	AUC	Cut-off (μg/L)	Sensitivity (%)	Specificity (%)	FPR (%)	FNR (%)	Youden index	p-value
PCT1	0.712	9.76	46.7	89.3	10.7	53.3	0.361	< 0.001
PCT3	0.818	6.84	67.4	83.3	16.7	32.6	0.507	-
PCT5	0.794	6.04	67.4	83.8	16.2	32.6	0.512	0.009

PCT1, PCT3, and PCT5 denote procalcitonin on days 1, 3, and 5. The optimal cutoff was determined by the Youden index (sensitivity + specificity - 1). Sensitivity, specificity, false positive rate (FPR), and false negative rate (FNR) were calculated at this cutoff. AUCs with 95% confidence intervals (CI) were estimated using the DeLong method. p-values represent pairwise comparisons versus PCT3 using DeLong's test. p < 0.05 was considered statistically significant.

eases). The study was conducted in accordance with the Declaration of Helsinki and was approved by the local institutional ethics committee. Written informed consent was obtained from all participants.

Patient data and laboratory testing

Patient data, including gender, age, height, weight, body mass index (BMI = weight [kg]/height² [m²]), medical history, and admission vital signs (heart rate [HR], respiratory rate [RR], systolic blood pressure [SBP], diastolic blood pressure [DBP]) were collected from the hospital medical record system. The trauma type (blunt or penetrating) and details of diagnosis and treatment were recorded. The Injury Severity Score and the Sequential Organ Failure Assessment (SOFA) score were also assessed. Peripheral venous blood was collected from all participants on the morning of hospital days 1, 3, and 5 for laboratory testing. Samples were preferably obtained under awake conditions; although not under strict fasting requirements, sampling was generally performed in a fasting state.

Blood samples for complete blood count were collected in two dipotassium EDTA (K_2EDTA) anticoagulant tubes (2 mL × 2 tubes). Samples for serological testing were collected in serum separator tubes with a clot activator (5 mL). After standing at room temperature for 30 minutes, samples were centrifuged at 3,000 rpm for 10 minutes to separate the serum. All analyses were completed within 2 hours of blood collection, or alternatively, serum samples were stored at -80°C for batch testing.

All testing was performed by the hospital's central clinical laboratory using the Beckman Coulter system platform. Serum PCT was measured using the Beckman Coulter DxI 800 automated chemiluminescence immunoanalyzer and its matched reagents (B76324). The assay's lower limit of detection was approximately 0.02 ng/mL, with intra-assay and inter-assay coefficients of variation both < 10%. Alb, Cr, and CysC were measured using an AU5800 automated biochemical analyzer. A DxH 800 automated hematology analyzer was used for complete blood count (white blood cells [WBC], red blood cells [RBC], platelets [PLT]). All testing procedures adhered to standard clinical laboratory quality control protocols.

Definition of IAI

The main outcome measure of this study was the occurrence of intra-abdominal infection (IAI) during hospitalization. The diagnosis of IAI was established according to the SIS-IDSA 2024 guidelines [25], requiring the presence of any two or more of the following criteria: 1) Clinical manifestations (e.g., fever, abdominal pain, peritoneal irritation signs); 2) Laboratory abnormalities (e.g., elevated WBC, CRP, or Interleukin-6); 3) Imaging findings suggestive of infection-related changes; 4) Microbiological evidence (e.g., positive culture from peritoneal fluid/drainage fluid or blood); 5) Surgical

Table 3. Baseline characteristics of the study population by gender.

Variables	Total (n = 326)	Male (n = 246)	Female (n = 80)	p-value
Age (years)	46.86 ± 10.38	46.45 ± 10.18	48.13 ± 10.95	0.227
BMI (kg/m2)	23.54 ± 3.05	23.67 ± 2.79	23.16 ± 3.74	0.267
HR (/min)	92.37 ± 14.34	92.04 ± 15.00	93.39 ± 12.10	0.416
RR (/min)	19.80 ± 3.84	19.60 ± 3.87	20.41 ± 3.70	0.092
SBP (mmHg)	119.69 ± 20.89	119.26 ± 21.26	120.99 ± 19.78	0.507
DBP (mmHg)	72.92 ± 9.86	72.88 ± 9.77	73.03 ± 10.19	0.909
Albumin (g/L)	37.14 ± 5.33	37.25 ± 5.31	36.83 ± 5.42	0.345
WBC (10^9/L)	8.24 ± 3.34	8.26 ± 3.35	8.19 ± 3.32	0.879
RBC (10^{12}/L)	4.46 ± 0.57	4.56 ± 0.56	4.16 ± 0.47	< 0.001
PLT (10^9/L)	199.21 ± 83.86	192.40 ± 89.57	220.18 ± 58.83	0.002
Cr (mg/L)	0.76 ± 0.27	0.81 ± 0.26	0.60 ± 0.22	< 0.001
CysC (mg/L)	0.81 ± 0.29	0.84 ± 0.30	0.72 ± 0.23	< 0.001
MV (%)	62 (19.0)	46 (18.7)	16 (20.0)	0.870
Vasopressor (%)	44 (13.5)	34 (13.8)	10 (12.5)	0.852
SOFA > 2 (%)	117 (35.9)	87 (35.4)	30 (37.5)	0.789
ISS	15.09 ± 3.73	15.02 ± 3.74	15.33 ± 3.71	0.519
PCT3 (μg/L)	5.97 ± 4.89	6.21 ± 4.86	5.25 ± 4.91	0.070
SI	96.41 ± 26.08	99.89 ± 24.02	85.68 ± 29.22	< 0.001
Non-IAI (%)	234 (71.8)	172 (69.9)	62 (77.5)	0.418
Non-survivor (%)	22 (6.7)	18 (7.3)	4 (5.0)	0.640
Type of Abdominal Trauma				0.475
Blunt (%)	275 (84.4)	205 (83.3)	70 (87.5)	
Penetrating (%)	51 (15.6)	41 (16.7)	10 (12.5)	

Continuous variables are expressed as mean ± standard deviation. Categorical variables are expressed as number (n) and percentage (%). Between-group comparisons were performed using Student's *t*-test for normally distributed continuous variables, Chi-squared test or Fisher's exact test for categorical variables, as appropriate. p < 0.05 was considered statistically significant.
BMI: body mass index, HR: heart rate, RR: respiratory rate, SBP: systolic blood pressure, DBP: diastolic blood pressure, WBC: white blood cell count, RBC: red blood cell count, PLT: platelet count, Cr: creatinine, CysC: cystatin C, MV: mechanical ventilation, SOFA: Sequential Organ Failure Assessment, ISS: Injury Severity Score, PCT3: procalcitonin on day 3, SI: sarcopenia index, calculated as (serum creatinine (mg/dL)/cystatin C (mg/L)) × 100, IAI: intra-abdominal infection.

findings supporting IAI. Outcome assessment was independently performed by two senior clinicians based on medical records, who were blinded to the study variables.

Calculation of the SI

To approximate skeletal muscle mass, the SI was calculated as follows: SI = (serum Cr [mg/dL]/CysC [mg/L]) × 100 [19,26].

Statistical analysis

All data analyses were performed in the R environment, version 4.4.3 (R Foundation for Statistical Computing, Vienna, Austria). Primary R packages used included tidyverse (for data wrangling and import), ggplot2 (for visualization), pROC (for ROC/DeLong tests), rms (for regression and calibration), and rmda (for decision curve analysis [DCA]). Quantitative data were first assessed for normality using the Shapiro-Wilk test. Normally distributed data are presented as mean ± standard deviation and were compared using the independent samples *t*-test. Non-normally distributed data are presented as median (interquartile range) and were compared using the Mann-Whitney U test. Categorical variables are presented as number (percentage) and were compared using the χ^2 test or Fisher's exact test, as appropriate. All tests were two-sided, with a significance level set at $p < 0.05$. To evaluate the discriminatory performance of PCT at different time points, receiver operating characteristic (ROC) curves were plotted for days 1, 3, and 5. The area under the curve (AUC) with a 95% DeLong confidence interval (CI), the optimal cutoff value (determined by the Youden index = sensitivity + specificity - 1), sensitivity, specificity, false positive rate, and

Table 4. Univariate and multivariate logistic regression analyses for risk factors of intra-abdominal infection in male patients.

Variable	Univariate analysis			Multivariate analysis		
	OR	95% CI	p	OR	95% CI	p
Age	1.002	0.552 - 1.816	0.994			
Albumin	0.956	0.907 - 1.006	0.085			
BMI	0.970	0.878 - 1.070	0.547			
DBP	0.989	0.961 - 1.017	0.453			
HR	0.991	0.973 - 1.009	0.347			
ISS	1.04	0.967 - 1.118	0.288			
MV	1.855	0.946 - 3.592	0.068			
PCT3	1.339	1.242 - 1.458	< 0.001	1.307	1.205 - 1.433	< 0.001
PLT	1.000	0.997 - 1.003	0.837			
RBC	0.710	0.429 - 1.160	0.176			
RR	0.999	0.931 - 1.073	0.985			
SBP	0.992	0.979 - 1.005	0.214			
SI	0.955	0.940 - 0.970	< 0.001	0.97	0.953 - 0.986	< 0.001
SOFA	1.759	1.003 - 3.082	0.048	2.067	0.999 - 4.349	0.052
Trauma type (penetrating vs. blunt)	0.488	0.201 - 1.067	0.089			
Vasopressor	2.047	0.965 - 4.287	0.058			
WBC	1.176	1.078 - 1.290	< 0.001	1.138	1.018 - 1.282	0.028

Variables with $p < 0.05$ in the univariate analysis were entered into the multivariate model. $p < 0.05$ was considered statistically significant. OR: odds ratio, CI: confidence interval, BMI: body mass index, DBP: diastolic blood pressure, HR: heart rate, MV: mechanical ventilation, PLT: platelet count, RBC: red blood cell count, RR: respiratory rate, SBP: systolic blood pressure, SOFA: Sequential Organ Failure Assessment, WBC: white blood cell count, ISS: Injury Severity Score, PCT3: procalcitonin on day 3, SI: sarcopenia index, calculated as (serum creatinine (mg/dL)/cystatin C (mg/L)) × 100.

false negative rate were calculated. Pairwise DeLong tests were performed for comparisons. Considering potential gender differences, binary logistic regression models were constructed with stratification by gender. Candidate variables were selected for inclusion in the multivariable model based on clinical plausibility, literature evidence, and results from univariable analysis to identify independent predictors. Model discrimination was characterized by the AUC. Calibration was assessed using apparent and bias-corrected calibration curves (via bootstrap resampling with 1,000 repetitions), the calibration intercept, calibration slope, and the Brier score. Clinical net benefit was evaluated using DCA (across a threshold probability range of 0 to 1, compared with 'treat-all' and 'treat-none' strategies).

RESULTS

PCT on day 3 (PCT3) demonstrated the best discriminatory performance for diagnosing IAI

A total of 382 hospitalized patients with suspected or confirmed abdominal trauma were screened during the study period, of whom 56 were excluded according to the predefined criteria, leaving 326 patients for analysis (Figure 1). Among these 326 patients, 92 (28.2%) developed IAI and 234 (71.8%) did not. At all three time points, PCT levels were significantly higher in the IAI group than in the non-IAI group (Table 1): day 1: 9.15 ± 3.61 vs. 6.54 ± 2.58 µg/L ($p < 0.001$); day 3: 9.23 [5.63 - 14.22] vs. 3.95 [2.00 - 5.93] µg/L ($p < 0.001$); day 5: 7.98 [4.42 - 14.36] vs. 2.91 [1.04 - 5.08] µg/L ($p < 0.001$).

ROC analysis (Table 2; Figure 2) revealed that PCT3 had the best discriminatory performance, with an AUC of 0.818, a cutoff value of 6.84 µg/L, a sensitivity of 67.4%, a specificity of 83.3%, and a Youden index of 0.507. In comparison, PCT on day 1 (PCT1) had an AUC of 0.712 (cutoff 12.19 µg/L, sensitivity 46.7%, specificity 89.3%; DeLong test vs. PCT3, $p < 0.001$), and PCT on day 5 (PCT5) had an AUC of 0.794 (cutoff 6.04 µg/L, sensitivity 67.4%, specificity 83.8%; DeLong test vs. PCT3, $p = 0.009$). Consequently, PCT3 was selected as the baseline time point for all subsequent analyses, and the laboratory values from this day were used for the gender-stratified analysis.

Table 5. Univariate and multivariate logistic regression analyses for risk factors of intra-abdominal infection in female patients.

Variable	Univariate analysis			Multivariate analysis		
	OR	95% CI	p	OR	95% CI	p
Age	1.007	0.965 - 1.051	0.762			
Albumin	0.897	0.800 - 0.994	0.047	0.888	0.762 - 1.015	0.097
BMI	0.952	0.826 - 1.097	0.493			
DBP	1.014	0.963 - 1.070	0.607			
HR	1.006	0.962 - 1.051	0.804			
ISS	1.049	0.909 - 1.213	0.507			
MV	1.190	0.297 - 4.054	0.789			
PCT3	1.728	1.257 - 2.625	< 0.001	1.860	1.294 - 2.960	< 0.001
PLT	1.000	0.991 - 1.009	0.926			
RBC	0.904	0.283 - 2.753	0.860			
RR	1.050	0.910 - 1.220	0.512			
SBP	1.004	0.977 - 1.032	0.780			
SI	0.955	0.924 - 0.981	< 0.001	0.961	0.923 - 0.990	0.024
SOFA	2.625	0.903 - 7.881	0.078			
Trauma type (penetrating vs. blunt)	0.346	0.018 - 2.046	0.331			
Vasopressor	4.385	1.079 - 18.052	0.036	1.606	0.136 - 14.455	0.681
WBC	1.188	1.012 - 1.413	0.040	1.029	0.813 - 1.317	0.813

Variables with $p < 0.05$ in the univariate analysis were entered into the multivariate model. $p < 0.05$ was considered statistically significant. OR, odds ratio; CI, confidence interval; BMI, body mass index; DBP, diastolic blood pressure; HR, heart rate; MV, mechanical ventilation; PLT, platelet count; RBC, red blood cell count; RR, respiratory rate; SBP, systolic blood pressure; SOFA, Sequential Organ Failure Assessment; WBC, white blood cell count; ISS, Injury Severity Score; PCT3, procalcitonin on day 3; SI, sarcopenia index, calculated as (serum creatinine [mg/dL] / cystatin C [mg/L]) × 100.

Table 6. Gender-stratified diagnostic performance of PCT3, 1/SI, and their combination.

Model	AUC	Cut-off	Sensitivity (%)	Specificity (%)	FPR (%)	FNR (%)	Youden index	p-value
Male (n = 246)								
PCT3	0.819	6.84	74.3	78.5	21.5	25.7	0.528	< 0.001
1/SI	0.745	0.011	62.2	80.8	19.2	37.8	0.430	< 0.001
PCT3 + 1/SI	0.842	0.285	75.7	79.7	20.3	24.3	0.553	< 0.001
Female (n = 80)								
PCT3	0.814	5.000	77.8	74.2	25.8	22.2	0.520	< 0.001
1/SI	0.767	0.015	61.1	82.3	17.7	38.9	0.434	< 0.001
PCT3 + 1/SI	0.865	0.178	88.9	79.0	21.0	11.1	0.679	< 0.001

PCT3: procalcitonin on day 3 (μg/L). The sarcopenia index (SI) was calculated as SI = (serum creatinine (mg/dL)/cystatin C (mg/L)) × 100. The optimal cutoff was determined by the Youden index (sensitivity + specificity - 1). Sensitivity, specificity, false positive rate (FPR), and false negative rate (FNR) were calculated at this cutoff. For PCT3, the cutoff is in μg/L; for 1/SI, it is unitless; for PCT3 + 1/SI, it represents the model probability (range 0 - 1). $p < 0.05$ was considered statistically significant.

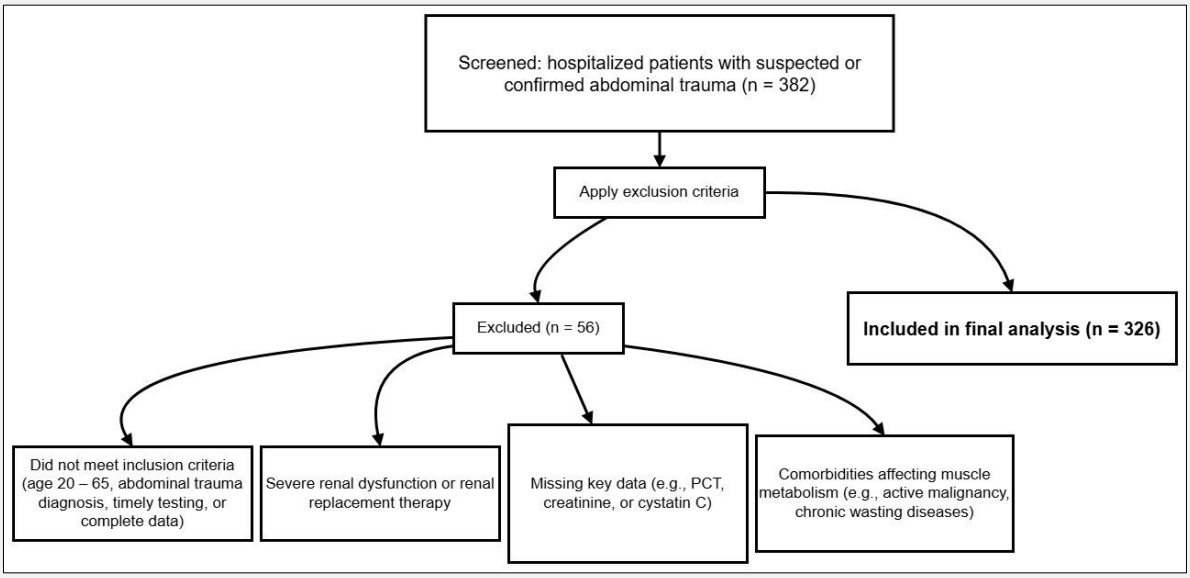


Figure 1. Flow diagram of the study cohort.

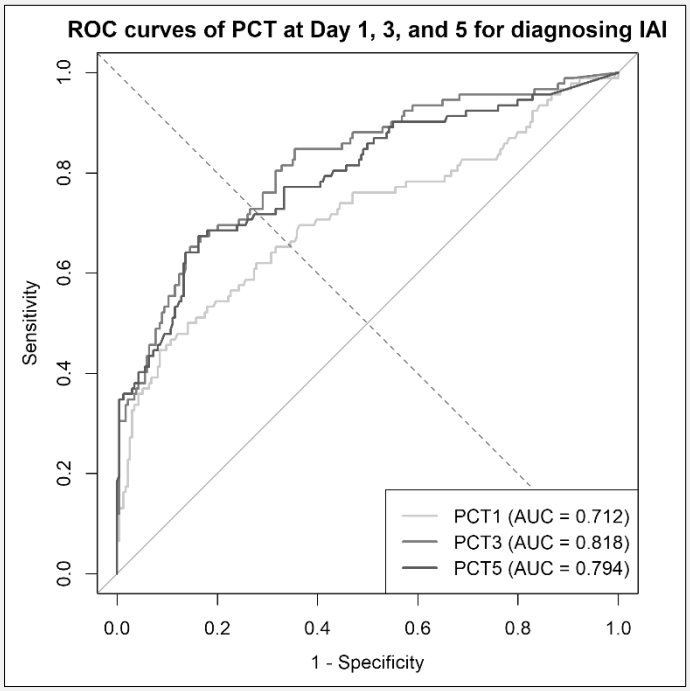


Figure 2. ROC curves of PCT at days 1, 3, and 5 for diagnosing IAI.

Receiver operating characteristic curves comparing PCT1, PCT3, and PCT5. AUC: 0.712 for PCT1, 0.818 for PCT3, and 0.794 for PCT5. ROC: receiver operating characteristic, IAI: intra-abdominal infection, PCT1: procalcitonin on day 1, PCT3: procalcitonin on day 3, PCT5: procalcitonin on day 5, AUC: area under the curve.

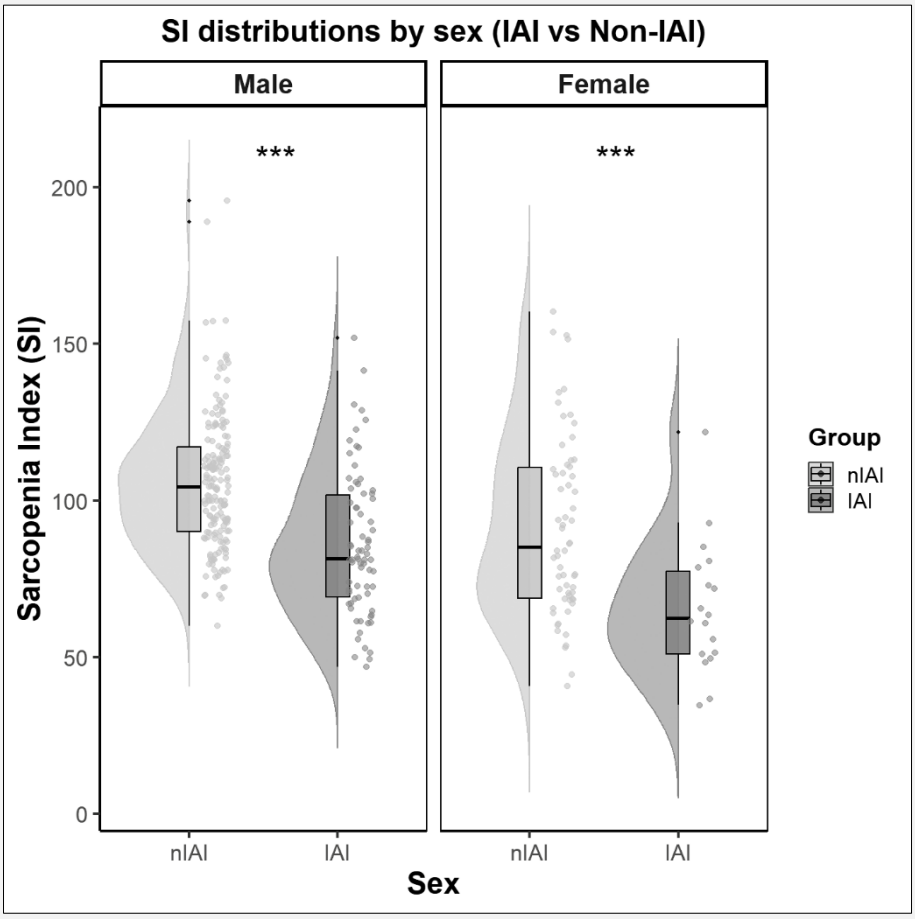


Figure 3. SI distributions by gender (IAI vs. non-IAI).

Raincloud plots (half-violin, boxplot, and jitter) of SI by gender. Colors indicate non-IAI (light) and IAI (dark). Asterisks denote within-gender differences (Wilcoxon test; *, **, *).**
SI: sarcopenia index, IAI: intra-abdominal infection.

Gender differences in SI were observed in the study population

Baseline comparisons (Table 3) revealed that the SI was significantly higher in males than in females (99.89 ± 24.02 vs. 85.68 ± 29.22, $p < 0.001$). The cohort comprised 246 males and 80 females. Compared to females, males had a higher red blood cell count (4.56 ± 0.56 vs. 4.16 ± 0.47, $p < 0.001$). Females had significantly lower Cr and CysC levels (Cr: 0.60 ± 0.22 vs. 0.81 ± 0.26, $p < 0.001$; CysC: 0.72 ± 0.23 vs. 0.84 ± 0.30, $p < 0.001$). No significant gender differences were observed in other vital signs or laboratory parameters, including age, trauma type, HR, RR, SBP, DBP, Alb, or WBC. PCT3 levels did not differ significantly between male and female patients (6.21 ± 4.86 vs. 5.25 ± 4.91 μg/L, $p = 0.070$), and the proportion of IAI was also not significantly different between males and females (69.9% vs. 77.5%, $p = 0.418$). Raincloud plots (Figure 3) further demonstrated that within each gender group, the distribution of SI significantly differed between the IAI and non-IAI subgroups ($p < 0.001$).

PCT3 increased IAI risk, while SI was inversely associated with IAI

Gender-stratified regression results (Tables 4 - 5) demonstrated that PCT3 was a strong predictor in both male and female patients, whereas SI was inversely associated with IAI. In males, PCT3 (odds ratio [OR] 1.307, 95% CI 1.205 - 1.433, $p < 0.001$) and WBC (OR 1.138, 95% CI 1.018 - 1.282, $p = 0.028$) were identified as independent risk factors, while lower SI was also a risk factor (OR 0.970, 95% CI 0.953 - 0.986, $p < 0.001$;

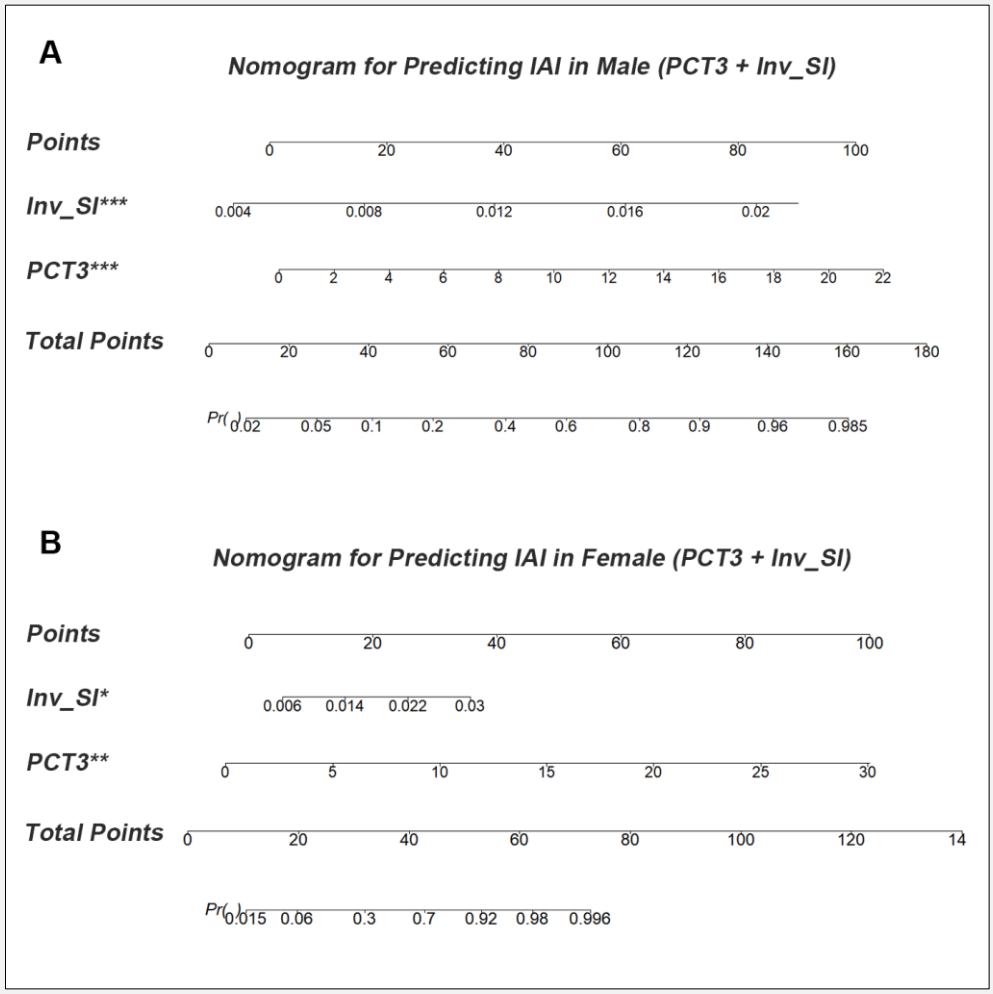


Figure 4. Gender-stratified nomograms for predicting IAI.

A: Male nomogram (predictors: PCT3 and 1/SI). For each predictor, read the points on the top scale, sum to total points, then map to the predicted probability of IAI at the bottom. Units: PCT in µg/L; 1/SI is unitless. B: Female nomogram (predictors: PCT3 and 1/SI). Construction and use are identical to panel (A).
IAI: intra-abdominal infection, PCT3: procalcitonin on day 3, SI = (serum Cr (mg/dL)/CysC (mg/L)) × 100.

SOFA showed borderline significance, p = 0.052). In females, both PCT3 (OR 1.860, 95% CI 1.294 - 2.960, p < 0.001) and SI (OR 0.961, 95% CI 0.923 - 0.990, p = 0.024) remained significant in the multivariable model, while other variables were not significant. In summary, PCT3 was positively associated with IAI risk, whereas SI was inversely associated with IAI risk. Consequently, for all subsequent analyses, SI was represented by its reciprocal (1/SI, designated as Inv_SI) to align the direction of risk association and to facilitate ROC and threshold evaluation.

The combined PCT3 + 1/SI model showed superior predictive performance compared to single indicators

Based on the predictors PCT3 and 1/SI derived from the gender-stratified logistic regression models, two separate nomograms were constructed for males and females (Figure 4A, B) to enable bedside individualized Estimation of IAI probability. By reading the points corresponding to PCT3 (µg/L) and 1/SI on the nomogram scales and summing them to obtain a Total Points score, the predicted probability of IAI could be determined. In both male and female patients, the combined model achieved the highest AUC: 0.842 in males (compared to

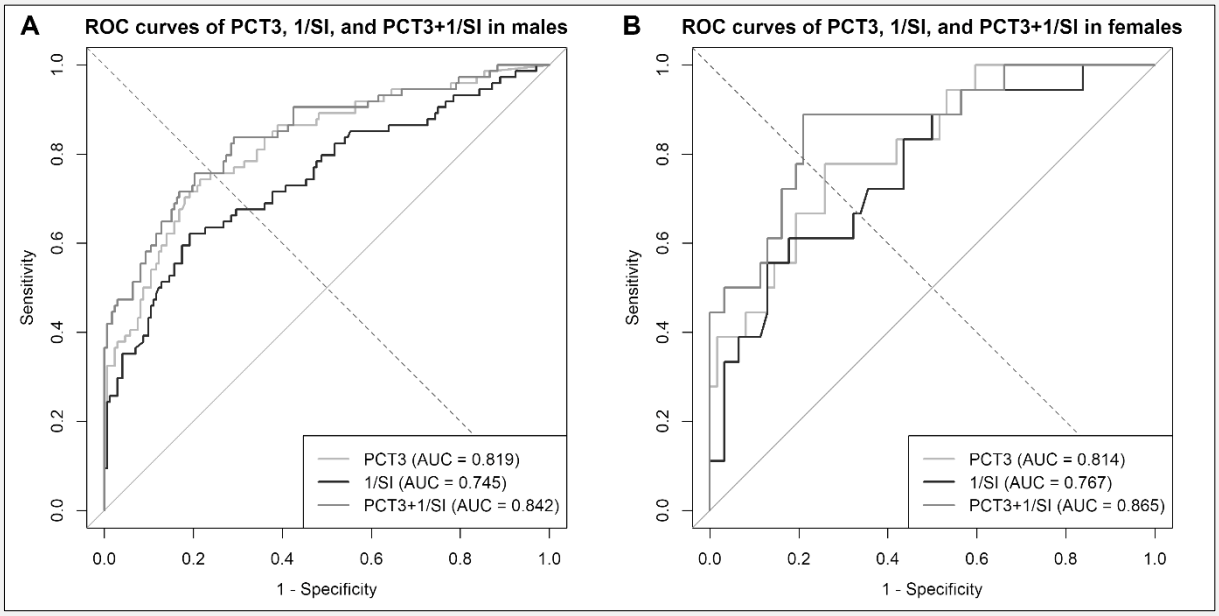


Figure 5. Gender-stratified ROC curves of PCT3, 1/SI, and PCT3 + 1/SI.

A: ROC in males: AUCs = 0.819 (PCT3), 0.745 (1/SI), 0.842 (PCT3 + 1/SI). B: ROC in females: AUCs = 0.814 (PCT3), 0.767 (1/SI), 0.865 (PCT3 + 1/SI).
ROC: receiver operating characteristic, PCT3: procalcitonin on day 3, SI: sarcopenia index, AUC: area under the curve, SI = (Cr/CysC) × 100; 1/SI is unitless; "PCT3 + 1/SI" refers to the logistic probability.

0.819 for PCT3 alone and 0.745 for 1/SI alone) and 0.865 in females (compared to 0.814 for PCT3 alone and 0.767 for 1/SI alone) (see Table 6; Figure 5A, B). DCA demonstrated that the combined model provided positive net benefit across a wide range of threshold probabilities, outperforming both the "treat-all" and "treat-none" strategies (Figure 6A, B). The calibration curves closely approximated the ideal line, and the bias-corrected curves were consistent with the apparent curves (Figure 6C, D), indicating superior discriminative ability, clinical net benefit, and good calibration.

DISCUSSION

This study, conducted in emergency-admitted patients hospitalized with abdominal trauma, demonstrated three key findings. First, among PCT measured on days 1, 3, and 5, Day-3 PCT (PCT3) provided the best discrimination for in-hospital IAI. Second, the sarcopenia index (SI) and its inverse (1/SI) were associated with IAI risk and showed clear gender-related distribution differences. Third, combining PCT3 with 1/SI further improved predictive performance with acceptable calibration and decision-curve-based clinical net benefit. Notably, both markers are minimally invasive and based on routinely available tests (PCT, creatinine, and cystatin C), enabling individualized early risk stratification for IAI by hospital day 3 without additional resource burden.

Previous surgical studies have shown that PCT can identify the risk of IAI early postoperatively and, in some contexts, outperforms CRP. Spoto et al. reported that in continuous monitoring from days 1 - 3 after abdominal surgery, a PCT level < 0.5 ng/mL on day 3 could be used to determine early safe discharge [27]. In pancreatic surgery populations, Giardino et al. also found that elevated PCT on day 3 was associated with complication risk [28]. This study moved the observation window earlier to the initial phase of hospitalization for abdominal trauma and systematically compared PCT on days 1, 3, and 5, demonstrating that PCT3 had the best discriminative power. This finding is consistent with evidence in trauma: PCT often peaks within 24 - 72 hours post-injury and correlates with severe outcomes, providing a pathophysiological basis for its higher diagnostic utility on day 3 [29].

Mechanistically, PCT on admission or the first postoperative day is susceptible to influence from sterile inflammation and tissue stress, limiting its specificity

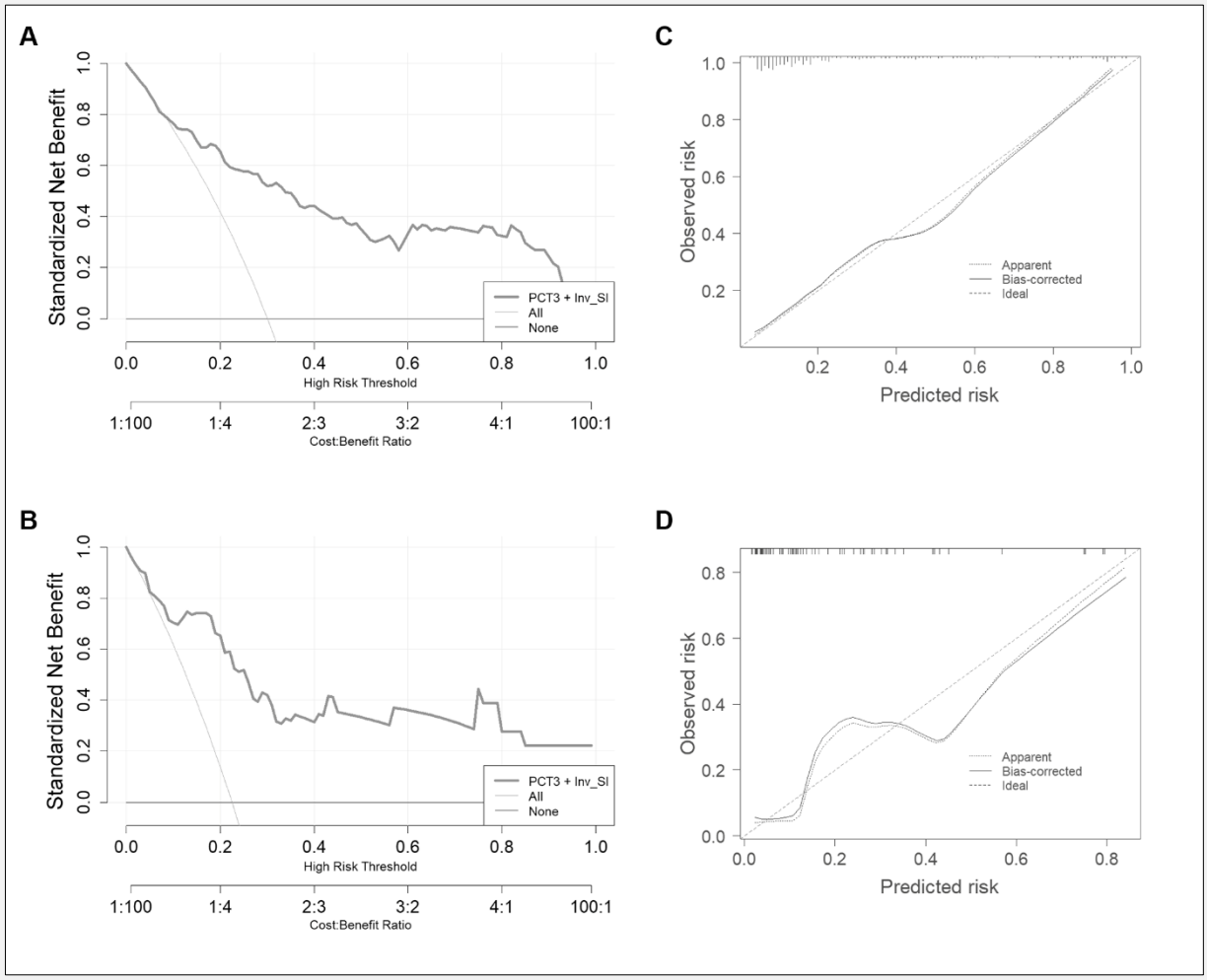


Figure 6. DCA and calibration of the gender-stratified PCT3 + 1/SI model.

A: DCA in males: standardized net benefit across threshold probabilities for the PCT3 + 1/SI model versus "treat all" and "treat none"; the model yields positive net benefit over a wide range of thresholds. B: DCA in females: the PCT3 + 1/SI model shows consistent net benefit across broad thresholds relative to "treat all/none". C: Calibration in males: "Apparent", "Bias-corrected" (bootstrap-corrected), and "Ideal" lines; rug marks indicate case distribution. The model demonstrates good agreement between predicted and observed risks. D: Calibration in females: "Apparent", "Bias-corrected", and "Ideal" lines, indicating acceptable calibration.
PCT3: procalcitonin on day 3, SI: sarcopenia index. DCA: decision curve analysis.

[29]; by day 5, antimicrobial and source control interventions may dilute the differences between infected and non-infected cases [30]; in contrast, day 3 represents a window where initial inflammation subsides and infectious signals emerge, making it more suitable for identifying IAI [27].

PCT primarily reflects the activity and current burden of infection and can guide antibiotic therapy [31]; SI, as an indicator of baseline host constitution and metabolic/muscle reserve, is linked to immune capacity and tissue repair ability [32]. Their complementary dimensions of information explain the improved performance when combined. Previous studies have shown that low SI indicates inadequate muscle mass and nutritional-metabolic vulnerability, associated with increased infection risk and adverse outcomes [33-35]; in abdominal trauma populations, low SI has also been identified as an independent risk factor for IAI with acceptable predictive performance [36]. Furthermore, a clear biological basis exists for gender differences: males generally have higher SI than females [37,38]; whereas the predictive efficacy of PCT3 showed no significant gender-based

variation, demonstrating stable performance in both male and female patients [36,39]. Given the gender-related distribution differences in SI, using uniform thresholds or weights could introduce systematic bias; previous recommendations also suggest using gender-specific cutoffs (e.g., approximately 81.4 for males and 57.9 for females) [36]. In this study, we implemented gender-stratified modeling and provided corresponding nomograms, which may enhance bedside interpretability, applicability, and fairness.

From a clinical perspective, obtaining both PCT and SI on hospital day 3 enables an effective IAI risk screening without incurring additional costs. Using the gender-specific nomograms, PCT3 and 1/SI can be translated into individualized risk probabilities, assisting decisions on whether to initiate early repeat imaging or perform abdominal assessment, optimize antibiotic strategies and monitoring plans, while avoiding repeated CT scans and empirical medication in low-risk patients, thereby improving resource utilization efficiency. The improvement in AUC with the combined model, though modest, was accompanied by more stable performance in decision and calibration curves, suggesting tangible gains for clinical decision-making. The two-indicator model based on PCT3 and 1/SI is simple, easily generalizable, performs robustly across male and female patients, and has potential for cross-institutional transferability.

Strengths of this study include its focus on a clearly defined and clinically relevant abdominal trauma population, the systematic comparison of PCT at multiple time points after admission with identification of day-3 as the optimal assessment window, and the use of two simple, routinely available serological markers (PCT3 and 1/SI) that can be readily applied at the bedside. Methodologically, we developed parsimonious models with gender-stratified nomograms and comprehensively evaluated their performance in terms of discrimination, calibration, and decision-curve-based clinical usefulness. Using 1/SI unified the direction of risk association and facilitated interpretation of thresholds, which may further support practical implementation.

Several limitations should be acknowledged. First, this was a single-center study, and although the final sample size and number of IAI events met conventional methodological requirements, the overall cohort - particularly the female subgroup - remains relatively modest, which may limit generalizability. Second, SI is an indirect surrogate of muscle mass and may be influenced by mild fluctuations in renal function, which could introduce misclassification. Third, only internal validation was performed, and the modeling strategy was not tested in external populations. Future work should therefore include multicenter, prospective external validation and potential recalibration of the model, as well as evaluation of its impact on decision-making efficiency, imaging and antimicrobial use, and patient outcomes in different clinical and resource settings.

In summary, PCT3 was the strongest single predictor, and its combination with 1/SI enabled early, minimally invasive prediction of in-hospital IAI by day-3, with acceptable calibration and clinical net benefit. This simple model based on routinely available markers shows promise as a practical early risk stratification tool for hospitalized abdominal trauma patients; however, multicenter prospective validation is required before widespread implementation.

CONCLUSION

In this single-center cohort (n = 326), PCT3 demonstrated the best discriminatory performance for IAI among the three measured time points (days 1, 3, and 5), establishing day 3 as the subsequent baseline time point. Significant gender differences were observed in SI, while no significant gender-based differences were found in PCT3 levels or IAI prevalence. Within each gender group, the distribution of SI showed consistent and significant differences between IAI and non-IAI patients. Gender-stratified regression analysis revealed that PCT3 was a common independent predictor in both male and female patients, while SI demonstrated an inverse association with IAI. The combined model incorporating PCT3 and 1/SI achieved the highest AUC in both male and female subgroups, demonstrated stable net benefit in DCA, and showed good calibration. Gender-specific nomograms derived from these models enable bedside individualized IAI risk estimation with potential clinical utility.

In summary, PCT3 emerged as the strongest single predictor, while its combination with SI further enhanced the discriminatory and clinical decision-making value for IAI. External validation and contextual assessment in multicenter, prospective cohorts are required to evaluate generalizability and implementation outcomes.

Declaration of Generative AI in Scientific Writing:
The authors have no conflicts of interest to declare.

Availability of Data and Materials:
The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

Ethics Approval:
The present study was approved by the Ethics Committee of Chongqing Hospital of Jiangsu Provincial People's Hospital and written informed consent was provided by all patients prior to the study start. All procedures were performed in accordance with the ethical standards of the Institutional Review Board and The Declaration of Helsinki, and its later amendments or comparable ethical standards.

Declaration of Interest:
None of the authors have any commercial or other association that might pose a conflict of interest.

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