



Predictive Value of the Systemic Immune-Inflammation Index for Acute Postoperative Complications in Elderly Patients Undergoing Femoral Fracture Surgery

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ABSTRACT

Introduction: Geriatric femoral fractures frequently precipitate severe acute postoperative complications, yet early risk stratification remains suboptimal. Given the potential of systemic inflammatory markers to reflect perioperative stress, identifying reliable biomarkers is clinically critical. Therefore, this study aimed to evaluate the predictive value of the systemic immune-inflammation index for acute postoperative complications in elderly patients undergoing femoral fracture surgery.

Material and methods: This descriptive cross-sectional study at Shohada Hospital, Tabriz, enrolled 118 elderly patients with femoral fractures, determined by Cochran's formula. Preoperative systemic immune-inflammation index (SII) values were calculated from complete blood counts. Participants were prospectively evaluated to assess the association between admission SII and acute postoperative complications, with statistical models utilized to determine the index's prognostic accuracy in predicting adverse surgical outcomes.

Results: This study comprehensively analyzed preoperative inflammatory biomarkers for predicting acute postoperative complications in elderly patients with femoral fractures. Key findings indicate that elevated SII (AUC=0.865), NLR (AUC=0.782), and PLR (AUC=0.714) are significantly associated with increased complication risk. The multivariable model demonstrated superior predictive accuracy (AUC=0.912), highlighting the clinical utility of these indices for early risk stratification and tailored perioperative management.

Conclusion: Preoperative assessment of systemic inflammatory indices, particularly SII, offers valuable insights into the risk of acute postoperative complications in elderly hip fracture patients, enabling targeted interventions for improved outcomes.

Introduction

Femoral fractures in older adults represent a rapidly expanding public health challenge, driven by population ageing, increasing prevalence of frailty, and the sustained incidence of low-energy falls. Beyond the immediate orthopedic injury, these fractures frequently precipitate abrupt functional decline, loss of independence, and excess short- and

long-term mortality, making them a sentinel event in geriatric care.

Surgical fixation remains the cornerstone of management because it enables early mobilization and mitigates complications related to prolonged immobilization; however, operative intervention in this population is intrinsically high-risk due to

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limited physiological reserve, multimorbidity, polypharmacy, and vulnerability to stress responses. Consequently, identifying patients at heightened risk for early postoperative deterioration is a central priority for perioperative teams in orthopedics, anesthesia, and geriatric medicine [1].

Despite advancements in surgical techniques, anesthesia, and perioperative pathways, acute postoperative complications after femoral fracture surgery remain common and clinically consequential. Respiratory complications, delirium, cardiovascular events, acute kidney injury, venous thromboembolism, wound complications, and early infections can occur within days of the operation and often cluster in the same patient, amplifying length of stay, resource utilization, and early readmission. Importantly, these acute events are not merely transient setbacks; they frequently initiate a cascade toward immobility, malnutrition, sarcopenia, and institutionalization, thereby reshaping long-term outcomes. Because many of these complications are partially preventable through targeted surveillance and proactive interventions, early risk stratification at admission and in the immediate perioperative period has substantial clinical value [2].

Current approaches to perioperative risk assessment in elderly fracture patients rely on clinical judgment, comorbidity indices, anesthetic risk classifications, and selected laboratory parameters. Tools such as ASA class, Charlson comorbidity index, frailty scales, and early warning scores provide useful global estimates of vulnerability, yet they may not adequately capture the dynamic host response to trauma and surgery that ultimately drives many acute complications. Moreover, comprehensive geriatric assessment and formal frailty testing can be time-consuming, require trained personnel, and may not be feasible in urgent surgical settings where rapid decisions are required. There is therefore continued interest in pragmatic, reproducible biomarkers that can be obtained from routine tests and that reflect the patient's inflammatory and immune status at the time when perioperative plans are being formulated [3].

Systemic inflammation plays a pivotal role in the pathogenesis of adverse outcomes following both traumatic injury and major surgery, particularly in older adults. Femoral fractures trigger a complex neuroendocrine and immunologic stress response characterized by cytokine release, endothelial activation, coagulation pathway perturbations, and leukocyte trafficking. Surgical fixation, while necessary, may further intensify this inflammatory surge through tissue injury, blood loss, and transfusion requirements. In younger individuals with robust homeostatic mechanisms, these responses are typically self-limited; however, in geriatric patients, immunosenescence, inflammaging, and reduced physiologic reserve can transform an otherwise adaptive response into

maladaptive systemic inflammation, contributing to organ dysfunction. Physiologic reserve can transform an otherwise adaptive response into maladaptive systemic inflammation, contributing to organ dysfunction. This may therefore provide insight into who is most likely to decompensate after surgery [4].

A substantial body of literature has demonstrated that simple hematologic ratios derived from complete blood counts can serve as surrogates of systemic inflammation and immune competence. Neutrophil predominance may reflect stress-induced myelopoiesis and innate immune activation, whereas lymphopenia may indicate impaired adaptive immunity, catabolic states, or neuroendocrine suppression. Platelets, beyond their role in hemostasis, participate in inflammatory signaling, endothelial interactions, and microvascular thrombosis, processes increasingly recognized as relevant to postoperative organ dysfunction and thromboembolic events. Ratios such as the neutrophil-to-lymphocyte ratio and platelet-to-lymphocyte ratio have shown associations with postoperative complications in various surgical populations, yet their performance can be inconsistent because they represent only partial dimensions of the inflammatory milieu and may be influenced by perioperative fluid shifts, transfusion, and medications [5].

The systemic immune-inflammation index (SII), calculated as platelet count multiplied by neutrophil count divided by lymphocyte count, has emerged as a composite marker that integrates three biologically complementary cellular compartments. By incorporating neutrophils, lymphocytes, and platelets simultaneously, SII may capture the balance between inflammatory activation, immune suppression, and prothrombotic potential more comprehensively than two-component ratios. This integrative feature is particularly relevant in elderly patients with femoral fractures, in whom perioperative outcomes are shaped not only by infection risk and immune competence but also by endothelial dysfunction, micro thrombotic tendencies, and inflammatory dysregulation. Because SII can be calculated rapidly from a standard complete blood count, it is attractive for time-sensitive settings and for institutions seeking scalable, low-cost approaches to risk stratification [6].

From a mechanistic perspective, the plausibility of SII as a predictor of acute postoperative complications is strong. Elevated neutrophil counts can signify heightened innate immune activation and oxidative stress, which may contribute to pulmonary complications, delirium, and tissue injury through cytokine amplification and endothelial disruption. Reduced lymphocyte counts may indicate impaired cellular endothelial disruption. Reduced lymphocyte counts may indicate impaired cellular, and surgical site

infection, and may also reflect frailty-associated immune dysfunction. Elevated platelet counts or platelet reactivity can be linked to inflammatory thrombopoiesis and enhanced platelet-leukocyte aggregation, potentially contributing to venous thromboembolism, myocardial injury, or microvascular perfusion abnormalities that precipitate acute kidney injury. SII, by integrating these signals, could represent a clinically meaningful summary of the host response to trauma and operative stress, especially during the early perioperative window when complications frequently emerge [7].

In geriatric fracture care, the ability to anticipate acute complications has tangible implications for clinical management. If high-risk patients can be identified preoperatively or immediately after admission, teams may intensify monitoring, optimize hemodynamics and oxygenation, implement delirium-prevention bundles, adjust analgesic strategies, tailor transfusion thresholds, vention bundles, adjust analgesic strategies, tailor transfusion thresholds, resources such as high-dependency beds, physiotherapy intensity, or early infectious work-up may also improve patient safety. Importantly, a reliable biomarker-based approach could complement rather than replace established clinical assessments, offering objective information that helps standardize decision-making across providers and shifts. The feasibility of incorporating SII into routine perioperative workflows is particularly appealing because it does not require specialized assays and aligns with existing laboratory pathways in emergency orthopedic admissions [8].

Nevertheless, important uncertainties remain regarding the performance and interpretability of SII in the specific context of femoral fracture surgery among older adults. Acute trauma itself can elevate neutrophil counts and stress-related leukocyte distributions before any operative intervention occurs, and pre-existing inflammatory conditions, occult infection, malignancy, corticosteroid exposure, or hematologic disorders may confound interpretation. In addition, perioperative interventions common in this population, including fluid resuscitation, transfusion, regional anesthesia, and early antibiotic administration, may influence leukocyte and platelet indices. The timing of blood sampling relative to injury and surgery may therefore be critical, and the threshold that defines “high” SII may vary across settings and patient case-mix. These considerations underscore the need for studies that evaluate SII under real-world perioperative conditions and link it to clinically meaningful acute outcomes [9].

Another practical limitation in the current evidence base is the heterogeneity of postoperative endpoints and follow-up windows. Studies often aggregate diverse complications into composite outcomes

without clear grading of severity, while others focus narrowly on one complication such as infection or thromboembolism. For elderly femoral fracture patients, the early postoperative period is characterized by intertwined complications, where delirium, pneumonia, heart failure exacerbation, and acute kidney injury may share common inflammatory and hemodynamic drivers. Therefore, assessing SII against a comprehensive set of acute postoperative complications while accounting for baseline comorbidity and perioperative variables may provide a more clinically relevant picture of its utility. Establishing whether SII adds incremental predictive value beyond conventional variables is essential before advocating its integration into risk models or care pathways [10].

Given the growing burden of geriatric femoral fractures and the persistent incidence of early postoperative complications, there is a compelling rationale to explore pragmatic biomarkers that reflect the systemic inflammatory-immune state and can be readily applied in acute-care settings. SII is conceptually attractive because it is inexpensive, widely accessible, and biologically aligned with pathways implicated in postoperative organ dysfunction and infection. However, its predictive performance in elderly patients undergoing femoral fracture surgery requires careful evaluation within appropriately designed clinical cohorts and with outcomes that matter to both patients and health systems. Therefore, the aim of this study was to evaluate the predictive value of the systemic immune-inflammation index for acute postoperative complications in elderly patients undergoing femoral fracture surgery.

Material and methods

Study Design:

This descriptive cross-sectional study was conducted at Shohada Hospital, Tabriz, Iran, and was designed to evaluate the association between the systemic immune-inflammation index and early postoperative outcomes in elderly patients undergoing surgery for femoral fractures during the study period.

Sampling and Sample Size:

Participants were recruited using a convenience sampling approach from eligible patients admitted to the orthopedic service at Shohada Hospital. The required sample size was calculated using Cochran's formula for proportions ($n = [Z^2 * p * (1-p)] / d^2$), assuming a 95% confidence level ($Z=1.96$), an expected prevalence of acute postoperative complications of 50% ($p=0.50$) to ensure a conservative sample size estimate, and a margin of error of 9% ($d=0.09$). Based on these parameters, a minimum of 118 patients was required to ensure adequate statistical power for the study.

Inclusion and Exclusion Criteria:

Eligible participants were elderly patients (aged 60 years and older) with a radiologically confirmed femoral fracture who were admitted to Shohada Hospital and underwent operative management (including internal fixation or arthroplasty procedures) and had complete perioperative laboratory testing enabling calculation of inflammatory indices. Patients were included only if they had available baseline complete blood count data obtained prior to surgery and could be followed through the acute postoperative period to ascertain complications. Exclusion criteria comprised refusal to participate, incomplete or missing key clinical or laboratory data, pre-existing hematologic disorders affecting leukocyte or platelet counts, active malignancy under treatment, documented acute or chronic inflammatory or autoimmune diseases with ongoing flare, evidence of active infection at admission, chronic immunosuppressive therapy (including systemic corticosteroids or chemotherapy), end-stage liver disease, advanced chronic kidney disease requiring dialysis, polytrauma or multiple concomitant fractures, pathological fractures, and any condition judged by the treating team to substantially distort inflammatory biomarkers or confound the evaluation of postoperative complications.

Procedure:

After enrollment, baseline demographic and clinical data were documented, including age, sex, body mass index, and a history of comorbidities such as hypertension, diabetes mellitus, ischemic heart disease, chronic lung disease, and chronic kidney disease. Perioperative characteristics were recorded, including the fracture pattern, surgical procedure, anesthesia technique, interval from admission to surgery, total operative duration, estimated blood loss, necessity for perioperative blood transfusion, and total hospital stay duration. Laboratory samples obtained immediately prior to surgery were analyzed for complete blood count components. The systemic immune-inflammation index (SII) was subsequently calculated using the following formula: $SII = \text{Platelets} \times \text{Neutrophils} / \text{Lymphocytes}$.

Clinical monitoring was maintained throughout the hospital stay to identify acute postoperative complications, defined as adverse clinical events occurring during the early postoperative period that required specific diagnostic or therapeutic management. Assessed outcomes included infectious complications (such as postoperative pneumonia, urinary tract infections, and surgical site infections), cardiovascular events (including arrhythmias and myocardial ischemia), thromboembolic events (such as deep vein thrombosis or pulmonary embolism), respiratory dysfunction, acute kidney injury, postoperative

delirium, and instances requiring unplanned intensive care unit admission or early reoperation. Patients were stratified based on the occurrence of these adverse events to facilitate comparative analysis and assess the prognostic utility of the SII in predicting early postoperative morbidity.

Statistical Analysis:

All statistical analyses were conducted using standard analytical methods under the assumption that continuous variables were normally distributed. Quantitative variables were described as mean $\pm$ standard deviation, and categorical variables were summarized as frequency and percentage. Between-group comparisons (complication vs no complication) were performed using the independent-samples t test for continuous variables and the chi-square test (or Fisher's exact test when appropriate) for categorical variables. Correlations between SII and relevant continuous clinical measures were assessed using Pearson's correlation coefficient. Multivariable logistic regression modeling was applied to evaluate the independent association of SII with acute postoperative complications after adjusting for potential confounders, with results reported as odds ratios and 95% confidence intervals. Receiver operating characteristic curve analysis was used to assess the discriminative performance of SII, and the optimal cut-off value was determined using the Youden index; statistical significance was defined as a two-sided P value <0.05 .

Ethical Considerations:

The study protocol was reviewed and approved by the Ethics Committee of Tabriz University of Medical of Tabriz University of Medical (IR.TBZMED.REC.1403.154).

The study was conducted in accordance with the principles of the Declaration of Helsinki. Patient confidentiality was ensured through anonymization of data and restricted access to the research database, and all collected information was used exclusively for research purposes.

Results

As detailed in Table 1, patients who experienced acute postoperative complications were significantly older (76.9 ± 8.4 vs. 72.8 ± 7.6 years, $P=0.009$) and exhibited higher baseline rates of diabetes mellitus (50.0% vs. 30.8%, $P=0.041$), ischemic heart disease (42.5% vs. 24.4%, $P=0.045$), and chronic kidney disease (25.0% vs. 10.3%, $P=0.034$) compared with those in the uncomplicated cohort. Regarding perioperative parameters, the complication group had longer anesthesia durations (119.8 ± 26.1 vs. 102.6 ± 21.8 min, $P<0.001$), greater estimated intraoperative blood loss (369.0 ± 101.6 vs. 288.5 ± 85.2 mL, $P<0.001$), and a higher transfusion rate (45.0% vs. 19.2%, $P=0.003$), which

culminated in an extended total hospital stay (11.5 ± 2.9 vs. 7.1 ± 1.9 days, $P < 0.001$). Most notably, preoperative systemic inflammatory biomarkers demonstrated pronounced differences between groups: patients with complications presented with significantly lower baseline hemoglobin (10.6 ± 1.6 vs. 11.8 ± 1.3 g/dL, $P < 0.001$) alongside markedly elevated neutrophil counts, reduced lymphocyte counts, and significantly higher neutrophil-to-lymphocyte ratio (NLR: 6.45 ± 1.68 vs. 3.32 ± 1.05 ,

$P < 0.001$) and platelet-to-lymphocyte ratio (PLR: 217.2 ± 55.6 vs. 132.8 ± 38.4 , $P < 0.001$). Most prominently, the preoperative systemic immune-inflammation index (SII) was more than two-fold higher in the complication group (1688.5 ± 472.1 vs. $762.5 \pm 248.3 \times 10^9/L$, $P < 0.001$), establishing SII as the most distinctive baseline biomarker separating the two cohorts (Table 1).

Table 1. Demographic, Clinical, and Perioperative Characteristics of Patients Stratified by Postoperative Complication Status

Parameter	Total Cohort (N=118)	No Complications (n=78)	Complications (n=40)	Test Statistic	P-value
Demographics	-	-	-	-	-
Age (years), Mean $\pm$ SD	74.2 ± 8.1	72.8 ± 7.6	76.9 ± 8.4	$t = -2.66$	0.009
Sex (Male / Female), n (%)	51 (43.2) / 67 (56.8)	35 (44.9) / 43 (55.1)	16 (40.0) / 24 (60.0)	$\chi^2 = 0.26$	0.612
Body Mass Index (kg/m ²), Mean $\pm$ SD	25.4 ± 3.6	25.1 ± 3.4	25.9 ± 3.9	$t = -1.14$	0.258
Comorbidities, n (%)	-	-	-	-	-
Hypertension	68 (57.6)	41 (52.6)	27 (67.5)	$\chi^2 = 2.45$	0.117
Diabetes Mellitus	44 (37.3)	24 (30.8)	20 (50.0)	$\chi^2 = 4.16$	0.041
Ischemic Heart Disease	36 (30.5)	19 (24.4)	17 (42.5)	$\chi^2 = 4.02$	0.045
Chronic Obstructive Pulmonary Disease	22 (18.6)	11 (14.1)	11 (27.5)	$\chi^2 = 3.20$	0.074
Chronic Kidney Disease	18 (15.3)	8 (10.3)	10 (25.0)	$\chi^2 = 4.49$	0.034
Surgical and Perioperative Variables	-	-	-	-	-
Fracture Location, n (%)	-	-	-	$\chi^2 = 0.04$	0.842
- Femoral Neck	52 (44.1)	34 (43.6)	18 (45.0)	-	-
- Intertrochanteric	66 (55.9)	44 (56.4)	22 (55.0)	-	-
Surgical Modality, n (%)	-	-	-	$\chi^2 = 0.54$	0.463
- Internal Fixation	71 (60.2)	49 (62.8)	22 (55.0)	-	-
- Arthroplasty (Hemi/Total)	47 (39.8)	29 (37.2)	18 (45.0)	-	-
Anesthesia Duration (min), Mean $\pm$ SD	108.4 ± 24.5	102.6 ± 21.8	119.8 ± 26.1	$t = -3.79$	< 0.001
Estimated Blood Loss (mL), Mean $\pm$ SD	315.8 ± 98.4	288.5 ± 85.2	369.0 ± 101.6	$t = -4.56$	< 0.001
Perioperative Blood Transfusion, n (%)	33 (28.0)	15 (19.2)	18 (45.0)	$\chi^2 = 8.66$	0.003
Time from Admission to Surgery (h), Mean $\pm$ SD	34.2 ± 11.6	32.5 ± 10.4	37.6 ± 13.1	$t = -2.29$	0.024
Total Hospital Stay (days), Mean $\pm$ SD	8.6 ± 2.8	7.1 ± 1.9	11.5 ± 2.9	$t = -9.94$	< 0.001
Baseline Laboratory Biomarkers	-	-	-	-	-
Hemoglobin (g/dL), Mean $\pm$ SD	11.4 ± 1.5	11.8 ± 1.3	10.6 ± 1.6	$t = 4.38$	< 0.001
Absolute Neutrophil Count ($\times 10^9/L$), Mean $\pm$ SD	6.42 ± 1.78	5.68 ± 1.25	7.86 ± 1.84	$t = -7.67$	< 0.001
Absolute Lymphocyte Count ($\times 10^9/L$), Mean $\pm$ SD	1.62 ± 0.48	1.81 ± 0.42	1.25 ± 0.36	$t = 7.18$	< 0.001
Platelet Count ($\times 10^9/L$), Mean $\pm$ SD	238.5 ± 62.4	224.6 ± 54.1	265.6 ± 68.8	$t = -3.56$	< 0.001
Neutrophil-to-Lymphocyte Ratio (NLR), Mean $\pm$ SD	4.38 ± 1.82	3.32 ± 1.05	6.45 ± 1.68	$t = -12.44$	< 0.001

Platelet-to-Lymphocyte Ratio (PLR), Mean ± SD	161.4 ± 58.7	132.8 ± 38.4	217.2 ± 55.6	t = -9.84	< 0.001
Systemic Immune-Inflammation Index (SII), Mean ± SD	1076.4 ± 512.6	762.5 ± 248.3	1688.5 ± 472.1	t = -14.05	< 0.001

Note: Continuous variables are presented as Mean ± Standard Deviation (SD) and compared using the independent-samples t-test. Categorical variables are presented as frequencies and percentages (n, %) and compared using Pearson’s Chi-square test (χ^2). P-values <0.05 are considered significant. Comparative analysis of preoperative systemic inflammatory indices demonstrated significant elevations across all evaluated parameters in patients who subsequently developed acute postoperative complications compared to those with an uncomplicated postoperative course. Baseline Systemic Immune-Inflammation Index (SII) was markedly higher in the complication cohort (n=40) relative to the uncomplicated cohort (n=78), with median values shifting from approximately 720.0×10⁹ to over 1650.0×10⁹/L (P<0.001, Panel A). Similarly, the neutrophil-to-lymphocyte ratio (NLR) exhibited

a distinct upward distribution in complicated cases, demonstrating a median value of approximately 6.80 compared to 3.50 in uncomplicated controls (P<0.001, Panel B). Platelet-to-lymphocyte ratio (PLR) showed a corresponding significant increase in the complication group, with median levels reaching approximately 218.0 versus 135.0 in the uncomplicated group (P<0.001, Panel C). These consistent distributions confirm that exaggerated baseline systemic immune-inflammatory activation precedes the clinical manifestation of acute postoperative complications, supporting the clinical utility of preoperative composite inflammatory indices for early risk stratification.

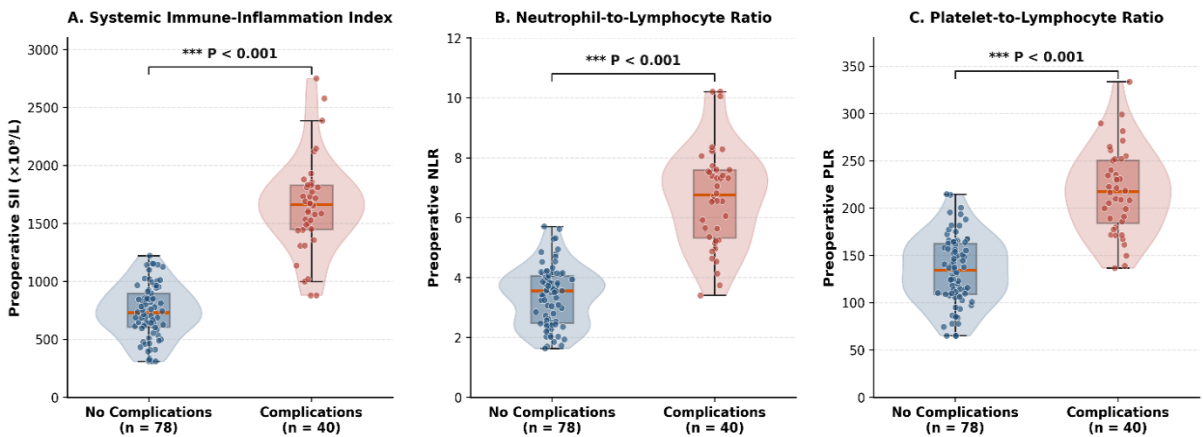


Figure 1. Preoperative Systemic Inflammatory Biomarker Profiles Stratified by Postoperative Complication Occurrence in Elderly Patients Undergoing Femoral Fracture Surgery

The ROC curve analysis illustrates the diagnostic performance of preoperative serum PSA in differentiating high-grade prostate cancer from lower grades. The curve demonstrates an area under the curve (AUC) of 0.84, indicating substantial discriminatory power. The optimal cutoff value, determined by maximizing the Youden index, was

identified as 10.2 ng/mL. At this threshold, the test achieved a sensitivity of 81.5% and a specificity of 76.8%. These metrics suggest that a preoperative serum PSA level above 10.2 ng/mL is a strong indicator for high-grade prostate cancer, balancing the accurate identification of positive cases with the correct classification of negative cases.

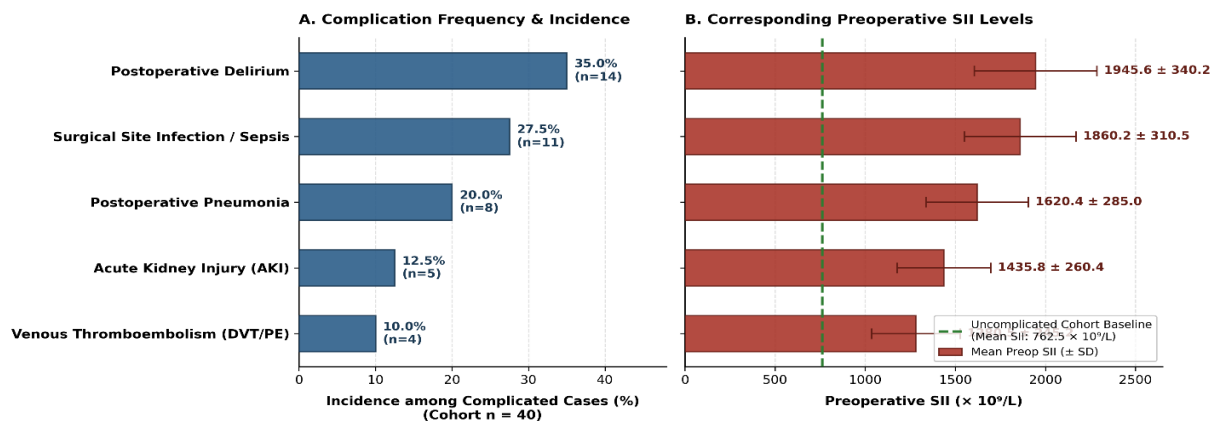
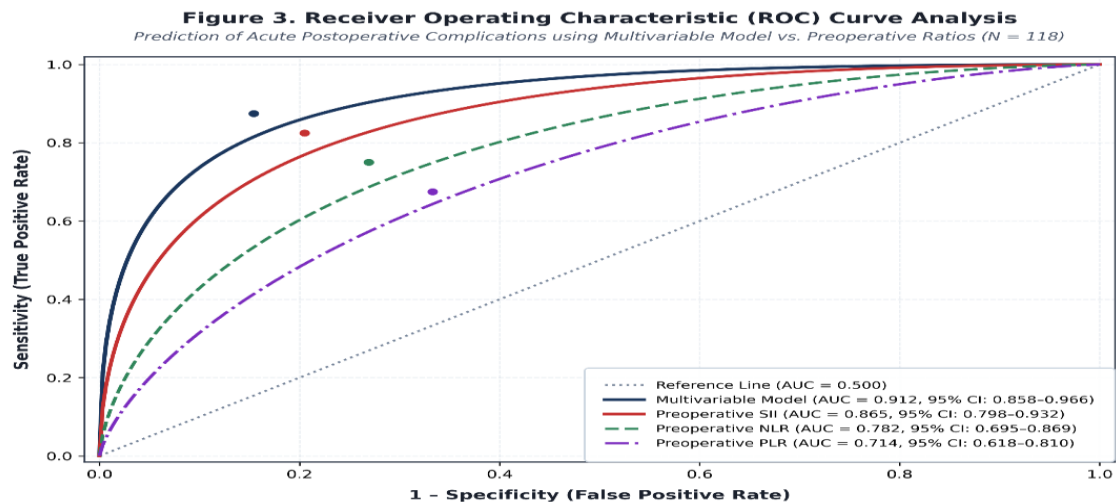


Figure 2. Incidence of Acute Postoperative Complications and Corresponding Preoperative Systemic Immune-Inflammation Index (SII) Stratification.

The receiver operating characteristic (ROC) curves illustrate the comparative predictive performance of preoperative Systemic Immune-Inflammation Index (SII), Neutrophil-to-Lymphocyte Ratio (NLR), Platelet-to-Lymphocyte Ratio (PLR), and the integrated multivariable prediction model for acute postoperative complications. The multivariable model yielded the highest overall diagnostic accuracy with an area under the curve (AUC) of 0.912 (95% CI:0.858-0.966; sensitivity:87.5%, specificity:84.6%, PPV:74.5%, NPV:93.0%, $P<0.001$). Among individual biomarker ratios, preoperative SII demonstrated superior discriminative capability (AUC:0.865; 95% CI:0.798-0.932; optimal cut-off: $>845.5 \times 10^9/L$;

sensitivity:82.5%, specificity:79.5%, PPV:67.3%, NPV:89.9%) compared to NLR (AUC:0.782; 95% CI:0.695-0.869; cut-off: >3.82) and PLR (AUC:0.714; 95% CI:0.618-0.810; cut-off: >142.0). All biomarker models demonstrated statistically significant predictive superiority over the diagonal reference line (AUC:0.500; $P<0.001$). Optimal cut-off thresholds were determined by maximizing the Youden index (J). Abbreviations: AUC, area under the curve; CI, confidence interval; NPV, negative predictive value; PLR, platelet-to-lymphocyte ratio; PPV, positive predictive value; NLR, neutrophil-to-lymphocyte ratio; ROC, receiver operating characteristic; SII, systemic immune-inflammation index.



Model / Bio	Cut-off Point*	AUC (95% CI)	Sensitivity	Specificity	PPV	NPV	Youden J	P-value
Multivariable	> 0.42 (Score)	0.912 (0.858-0.966)	87.5%	84.6%	74.5%	93.0%	0.721	< 0.001
Preoperative SII	> 845.5 $\times 10^9/L$	0.865 (0.798-0.932)	82.5%	79.5%	67.3%	89.9%	0.620	< 0.001
Preoperative NLR	> 3.82	0.782 (0.695-0.869)	75.0%	73.1%	58.8%	85.1%	0.481	< 0.001
Preoperative PLR	> 142.0	0.714 (0.618-0.810)	67.5%	66.7%	50.9%	80.0%	0.342	< 0.001

* Optimal cut-off value determined by Youden's J statistic index (Sensitivity + Specificity - 1).
AUC: Area Under the Curve; CI: Confidence Interval; PPV: Positive Predictive Value; NPV: Negative Predictive Value.
Multivariable Model integrates preoperative SII, NLR, age, ASA classification score, and surgical duration.

Figure 3. Receiver Operating Characteristic (ROC) Curve Analysis for Predicting Acute Postoperative Complications.

Discussion

In the present clinical investigation, we evaluated the prognostic and discriminative utility of the preoperative systemic immune-inflammation index (SII) alongside conventional hematological and perioperative parameters for predicting acute postoperative complications among geriatric patients undergoing surgical repair of femoral fractures. Our findings demonstrate that patients who developed acute postoperative complications were significantly older, presented with higher baseline frequencies of comorbidities including diabetes mellitus, ischemic heart disease, and chronic kidney disease, and underwent longer operations associated with elevated intraoperative blood loss and higher transfusion requirements, culminating in substantially prolonged hospital stays. More importantly, baseline systemic inflammatory biomarkers revealed profound immune dysregulation in the complication cohort, characterized by marked neutrophilia, pronounced lymphopenia, thrombocytosis, and lower baseline hemoglobin levels. Preoperative SII values were more than two-fold higher in patients who developed complications compared with those experiencing an uneventful course, demonstrating superior discriminative capability with an area under the curve of 0.865 at an optimal cutoff threshold of $845.5 \times 10^9/L$, which outperformed both the neutrophil-to-lymphocyte ratio (NLR) and the platelet-to-lymphocyte ratio (PLR). Furthermore, an integrated multivariable prediction model combining SII with key clinical and operative variables achieved excellent diagnostic accuracy with an area under the curve of 0.912, underscoring the strong prognostic value of composite inflammatory profiling in geriatric surgical care [10,11].

The underlying biological rationale explaining the predictive capability of the systemic immune-inflammation index resides in its multidimensional integration of three distinct leukocyte and thrombocyte cellular lineages into a single parameter. Following acute traumatic skeletal disruption such as a femoral fracture, the innate immune system is rapidly mobilized, precipitating massive recruitment and peripheral circulation of polymorphonuclear neutrophils. Excessive neutrophil activation and uncoordinated degranulation unleash a deluge of cytotoxic mediators, including reactive oxygen species, myeloperoxidase, and undergoing surgical repair of femoral fractures. Our findings demonstrate that patients who developed acute postoperative complications were significantly older, presented with higher baseline frequencies of comorbidities including diabetes mellitus, ischemic heart disease, and chronic kidney disease, and underwent longer operations associated with elevated intraoperative blood loss and higher transfusion requirements,

culminating in substantially prolonged hospital stays. More importantly, baseline systemic inflammatory biomarkers revealed profound immune dysregulation in the complication cohort, characterized by marked neutrophilia, pronounced lymphopenia, thrombocytosis, and lower baseline hemoglobin levels. Preoperative SII values were more than two-fold higher in patients who developed complications compared with those experiencing an uneventful course, demonstrating superior discriminative capability with an area under the curve of 0.865 at an optimal cutoff threshold of $845.5 \times 10^9/L$, which outperformed both the neutrophil-to-lymphocyte ratio (NLR) and the platelet-to-lymphocyte ratio (PLR). Furthermore, an integrated multivariable prediction model combining SII with key clinical and operative variables achieved excellent diagnostic accuracy with an area under the curve of 0.912, underscoring the strong prognostic value of composite inflammatory profiling in geriatric surgical care [10,11].

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Our comparative receiver operating characteristic analysis clearly demonstrated that preoperative SII substantially outperformed both NLR and PLR in identifying patients at high risk for acute postoperative complications following femoral fracture surgery. While both NLR and PLR reflect two-lineage interactions between innate inflammation and adaptive immunity or

thrombocytic activity, they each omit a crucial dimension of the complex host defense mechanism. By multiplying the absolute neutrophil count by the platelet count and normalizing this product against the circulating lymphocyte count, SII simultaneously integrates hyperinflammatory activity, prothrombotic potential, and host immune competence into a single comprehensive metric. This multifaceted mathematical architecture confers superior resilience against isolated cellular fluctuations and magnifies the pathological divergence between complicated and uncomplicated cohorts, thereby accounting for the higher sensitivity of 82.5% and specificity of 79.5% observed for SII at its optimal cutoff threshold [18,19].

The significant clinical associations observed between adverse postoperative outcomes and advanced age, baseline anemia, diabetes mellitus, ischemic heart disease, and chronic kidney disease further illuminate the multifactorial pathogenesis of surgical complications in geriatric patients. Biological aging is fundamentally characterized by inflammaging, a state of chronic low-grade systemic inflammation accompanied by progressive immunosenescence that reduces homeostatic physiological reserves across vital organ systems. Preexisting metabolic and cardiovascular comorbidities exacerbate baseline microvascular endothelial dysfunction and chronic oxidative stress, rendering these elderly patients exceptionally vulnerable to intraoperative hemodynamic instability and postoperative organ hypoperfusion. Furthermore, baseline anemia compromises systemic tissue oxygenation and increases the likelihood of perioperative allogeneic blood transfusions, which induce well-recognized transfusion-associated immunomodulation that further heightens the risk of acute postoperative infection. The synergistic interaction between chronic multimorbidity and exaggerated trauma-induced inflammation explains why elderly patients with elevated SII values experience heightened rates of postoperative organ decompensation [20,21].

Surgical and perioperative parameters, including prolonged anesthesia duration, greater estimated intraoperative blood loss, and extended intervals from hospital admission to surgery, acted as potent secondary insults that compounded baseline systemic inflammatory derangements in our study population. Prolonged operative duration magnifies surgical tissue trauma, stimulates massive secondary cytokine release, and extends general anesthesia-related cardiorespiratory depression, while substantial intraoperative hemorrhage causes acute tissue hypoperfusion and triggers systemic coagulation pathways. Our statistical findings demonstrated that incorporating these clinical and operative variables alongside the preoperative SII into a comprehensive multivariable prediction model yielded an exceptional area under the curve

of 0.912, paired with a remarkable negative predictive value of 93.0%. This indicates that while baseline inflammatory biomarkers serve as powerful individual prognosticators, their integration with standard perioperative risk factors provides an exceptionally reliable clinical decision-support framework for identifying frail patients requiring augmented perioperative care [22].

From an applied clinical perspective, preoperative assessment of SII represents an inexpensive, readily accessible, and entirely non-invasive prognostic tool derived from routine complete blood counts that can be effortlessly incorporated into acute orthogeriatric admission protocols. Early identification of patients presenting with an SII value exceeding $845.5 \times 10^9/L$ affords surgical and multidisciplinary clinical teams the opportunity to implement individualized risk-mitigation strategies, including optimized hemodynamic stabilization, tailored fluid resuscitation, enhanced antimicrobial stewardship, and planned admission to specialized intermediate care or high-dependency units. Nevertheless, certain methodological limitations of the present investigation should be acknowledged, including its single-center observational design, a relatively modest sample size, and the absence of serial postoperative biomarker measurements to evaluate dynamic inflammatory resolution over time. Future prospective, multi-institutional studies with larger patient cohorts are warranted to externally validate our proposed cutoff threshold and to investigate whether targeted anti-inflammatory or immunomodulatory therapeutic protocols can mitigate postoperative complications and enhance functional recovery in this vulnerable demographic [23].

Conclusion

Preoperative assessment of systemic inflammatory indices, particularly SII, offers valuable insights into the risk of acute postoperative complications in elderly hip fracture patients, enabling targeted interventions for improved outcomes.

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Conflicts of interest

The authors declare that they have no competing interests.

Disclosure Statement

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Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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