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Pathologic Evaluation of the Sensitivity and Specificity of Preoperative Serum Albumin in Predicting Early Infection after Femoral Implant Placement

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A B S T R A C T

Introduction: Early infection after femoral implant placement is a serious complication influenced by host immunity, wound healing capacity, and nutritional-inflammatory status. Preoperative serum albumin is a practical biomarker that may reflect vulnerability to postoperative infection, but its predictive accuracy remains uncertain in femoral implant surgery. This study aimed to evaluate the sensitivity and specificity of preoperative serum albumin in predicting early infection after femoral implant placement.

Material and methods: This retrospective descriptive cross-sectional study was conducted at Shahid Madani Hospital, Tabriz, on 125 patients selected by convenience sampling. The sample size was estimated using Cochran's formula. Data were extracted from medical records to evaluate preoperative serum albumin, demographic and clinical variables, operative characteristics, and early postoperative infection after femoral implant placement, with the aim of assessing the diagnostic performance of albumin in predicting early infection.

Results: Among 125 patients, early postoperative infection occurred in 15.2% (19/125). Infected patients had lower preoperative albumin (3.12 ± 0.46 vs 3.66 ± 0.51 g/dL; P<0.001), a higher rate of hypoalbuminemia (63.2% vs 27.4%; P=0.002), lower hemoglobin (P=0.011), and higher inflammatory markers (WBC, P=0.018; CRP, P=0.006). Serum albumin predicted infection with good accuracy (cutoff 3.35 g/dL; sensitivity 78.9%, specificity 73.6%, AUC 0.812, P<0.001).

Conclusion: Preoperative serum albumin appears to be a clinically useful marker for identifying patients at increased risk of early infection after femoral implant placement. Lower albumin levels were consistently associated with infection and showed acceptable diagnostic performance. These findings support incorporating serum albumin into routine preoperative assessment to improve risk stratification and guide perioperative optimization in this surgical population.

Introduction

Femoral implant placement is a cornerstone of contemporary orthopedic practice and is performed in a wide range of settings, including fracture fixation, revision surgery, reconstructive procedures, and arthroplasty-related interventions. Despite major advances in surgical technique, implant design, perioperative prophylaxis, and postoperative care, early infection remains one of the most serious complications after orthopedic implantation.

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Once infection develops around implanted hardware, it may compromise osseointegration, delay wound healing, prolong hospitalization, increase the need for repeated debridement or implant removal, and ultimately worsen both functional recovery and quality of life. In addition to its clinical consequences, early postoperative infection imposes a substantial economic burden on healthcare systems by increasing treatment complexity and resource utilization. Because of these consequences, identifying patients at higher risk before surgery remains a major priority in orthopedic and perioperative medicine [1].

The pathogenesis of early postoperative infection after femoral implant placement is multifactorial and reflects a complex interaction between microbial contamination, host immune competence, local tissue viability, surgical duration, blood loss, and perioperative metabolic status. Infections occurring during the early postoperative period are often associated with intraoperative inoculation or rapid colonization of the implant surface, followed by biofilm formation that protects microorganisms from host defense mechanisms and antimicrobial therapy. Once a biofilm matures, eradication becomes considerably more difficult, and even low-virulence organisms may persist in the peri-implant environment. However, not all patients exposed to similar procedural risks develop infection, suggesting that host-related vulnerability has an essential role in determining outcome. This has led to increasing interest in preoperative biomarkers that may reflect impaired physiologic reserve, defective inflammatory response, poor nutritional status, or diminished wound-healing capacity before the first incision is made [2].

Among candidate biomarkers, serum albumin has drawn particular attention because it is inexpensive, widely available, routinely measured, and biologically linked to several mechanisms relevant to postoperative recovery. Albumin is the most abundant plasma protein and contributes to maintenance of oncotic pressure, transport of endogenous and exogenous substances, antioxidant activity, acid-base buffering, and modulation of inflammatory responses. Clinically, low serum albumin is often interpreted as a surrogate marker of malnutrition, although its concentration is also influenced by systemic inflammation, hepatic synthetic function, renal loss, catabolic stress, hydration status, and chronic disease burden. In surgical patients, hypoalbuminemia has repeatedly been associated with poorer outcomes, including delayed wound healing, increased susceptibility to infection, prolonged hospital stays, and higher postoperative morbidity. These observations have made albumin an appealing candidate for risk stratification in orthopedic populations, particularly when more specialized nutritional or inflammatory assessments are unavailable or impractical in routine care [3].

The relevance of albumin becomes even more pronounced in patients undergoing femoral implant procedures, who frequently present with advanced age, trauma-related physiologic stress, comorbid metabolic disease, chronic inflammatory conditions, or preexisting frailty. Many of these patients have reduced nutritional reserve before surgery, and some may also experience acute changes in albumin homeostasis related to hemorrhage, systemic stress, or tissue injury. In the setting of femoral fractures or reconstructive procedures, tissue disruption, impaired local perfusion, and the need for foreign material implantation create a biologic environment in which suboptimal host defense can facilitate bacterial persistence. Low preoperative albumin may therefore represent more than an isolated laboratory abnormality; it may serve as a composite signal of vulnerability at the intersection of nutrition, inflammation, immune competence, and tissue repair. This integrated biologic significance is one reason why albumin continues to be investigated as a practical marker in the prediction of postoperative infectious complications [4].

From a pathologic perspective, the relationship between albumin status and early infection is also plausible at the tissue level. Wound healing requires adequate protein availability for fibroblast activity, collagen synthesis, angiogenesis, and epithelial regeneration. Protein depletion or catabolic imbalance can impair these processes, leading to delayed tissue maturation, persistent dead space, and diminished barrier function at the surgical site. In parallel, a reduced albumin state may accompany systemic inflammatory activation that alters leukocyte function, cytokine balance, and microvascular integrity. Around a femoral implant, where local trauma and foreign-body response are already present, these deficiencies may facilitate bacterial adherence and progression from superficial contamination to deeper peri-implant infection. Therefore, the value of albumin is not merely statistical; it may reflect a biologically meaningful predisposition that links systemic patient status to local pathologic events occurring in the immediate postoperative period [5].

Although many studies have examined risk factors for surgical site infection in orthopedic surgery, the diagnostic performance of preoperative albumin remains inconsistently characterized across specific procedures and patient groups. Some investigations have reported that hypoalbuminemia is a strong predictor of postoperative infection, while others have found weaker or context-dependent associations after adjustment for age, diabetes, obesity, smoking, operative duration, or trauma severity. A major reason for this inconsistency is the heterogeneity of study populations, definitions of infection, albumin cutoff values, and surgical settings. Findings from elective arthroplasty cohorts may not be directly applicable to femoral trauma surgery, and results from mixed orthopedic populations may obscure procedure-specific patterns. For this reason, evaluating the sensitivity and specificity of albumin within a focused clinical context is essential if it is to be used meaningfully as a screening or predictive tool rather than as a general indicator of poor health status [6].

The concepts of sensitivity and specificity are particularly important when translating a laboratory marker into perioperative decision-making. A test with high sensitivity may help identify most patients who are truly at risk of early postoperative infection, thereby supporting intensified surveillance, nutritional optimization, or preventive interventions. Conversely, a test with high specificity may better identify patients unlikely to develop infection, reducing unnecessary concern or overtreatment. In practice, the usefulness of preoperative albumin depends not only on whether low values are statistically associated with infection, but also on how accurately this marker distinguishes between patients who will and will not experience an adverse postoperative course. This distinction is clinically relevant in orthopedic implant surgery, where risk prediction may affect antibiotic strategies, timing of surgery, optimization protocols, and the threshold for closer postoperative follow-up. Therefore, a diagnostic-performance framework offers more clinically actionable insight than a simple comparison of mean albumin levels between infected and non-infected groups [7].

Early infection after femoral implant placement deserves focused investigation because the femur occupies a unique biomechanical and clinical position in orthopedic care. Femoral procedures often involve large implants, deep surgical fields, substantial soft-tissue manipulation, and in some cases trauma-related contamination or impaired local vascularity. When infection occurs in this setting, the consequences may be especially severe, including nonunion, implant failure, chronic osteomyelitis, prolonged immobility, thromboembolic risk, and loss of independence. Moreover, early recognition of vulnerable patients is more valuable in femoral surgery than in many lower-risk procedures because the functional stakes are high and revision treatment may be technically demanding. If a simple preoperative marker such as albumin can contribute meaningfully to infection prediction, it could be integrated into routine preoperative assessment with minimal additional cost. This possibility gives the present topic both scientific relevance and direct practical importance for surgical care pathways [8].

At the same time, serum albumin should not be interpreted simplistically, and its predictive role must be judged in the context of its limitations. Because albumin is influenced by inflammatory burden, liver disease, renal loss, hydration status, and acute physiologic stress, a low value may represent several overlapping pathologic states rather than isolated nutritional deficiency. Yet this limitation may also be a strength in perioperative risk assessment, since early postoperative infection is itself multifactorial and likely emerges from the cumulative burden of physiologic impairment rather than from a single mechanism. Thus, even if albumin is a nonspecific biomarker, it may still perform usefully as an integrated predictor of susceptibility. The critical question is whether its diagnostic characteristics are sufficiently robust in patients undergoing femoral implant placement to justify clinical reliance or incorporation into structured preoperative evaluation models [9].

Given the serious impact of early infection after femoral implant placement, the biological plausibility linking albumin to impaired host defense and wound healing, and the need for practical preoperative predictors with measurable diagnostic value, further evaluation of this marker is warranted in procedure-specific settings. Clarifying the sensitivity and specificity of preoperative serum albumin may help determine whether it functions primarily as a screening tool, a confirmatory indicator, or a complementary variable within broader risk-stratification strategies. Such evidence may also support more individualized perioperative planning, especially in patients with borderline nutritional or inflammatory status. Therefore, the objective of the present study was to evaluate the pathologic relevance and diagnostic performance of preoperative serum albumin, with particular emphasis on its sensitivity and specificity in predicting early infection after femoral implant placement.

Material and methods

Study Design:

This retrospective descriptive cross-sectional study was conducted at Shahid Madani Hospital, Tabriz, Iran, to evaluate the pathologic relevance and diagnostic performance of preoperative serum albumin in predicting early infection after femoral implant placement. The study was based on the review of hospital medical records, operative reports, laboratory data, and postoperative follow-up documentation of eligible patients who had undergone femoral implant surgery during the study period. Because the aim was to describe the distribution of clinical and pathologic characteristics and to assess the relationship between preoperative albumin status and the occurrence of early postoperative infection, a cross-sectional analytical framework was considered appropriate for the present investigation.

Sampling

The sample size was estimated for 125 patients using Cochran's sample size formula. Based on the standard form of the formula, $n=Z^2pq/d^2$, the calculation was performed by considering a 95% confidence level, an expected proportion derived from prior evidence or pilot estimation, and an acceptable margin of error, resulting in a target sample of 125 participants. After sample size estimation, patients were selected using an available convenience sampling method from among all eligible individuals undergoing femoral implant placement at Shahid Madani Hospital. All accessible records meeting the study criteria were reviewed consecutively until the required sample size was reached.

Inclusion and Exclusion Criteria

The study included patients who underwent femoral implant placement at Shahid Madani Hospital, had complete demographic, clinical, laboratory, operative, and follow-up records, and had a documented preoperative serum albumin level measured within the routine pre-surgical evaluation period. Eligible participants were those who had undergone femoral fixation or implantation procedures for trauma, reconstructive indications, or other orthopedic conditions and whose records allowed assessment of early postoperative infectious outcomes. Patients of both sexes and all adult age groups were considered eligible if the required information was available. Exclusion criteria included incomplete medical records, missing preoperative serum albumin data, absence of adequate postoperative follow-up for identifying early infection, known active infection at another site before surgery, revision procedures performed primarily for previously established implant-related infection, severe hepatic failure or nephrotic conditions clearly causing profound albumin disturbance independent of the orthopedic condition when such diagnosis prevented valid interpretation of albumin status, immunodeficiency states with insufficient documentation, and patients whose perioperative data were inconsistent or not interpretable for final analysis.

Procedure

Data were extracted from eligible patient records using a structured checklist designed for the study. The reviewed variables included age, sex, body mass index where available, smoking history, diabetes mellitus, hypertension, other major comorbidities, indication for femoral implant placement, mechanism of injury in trauma-related cases, type of femoral lesion or fracture, side of involvement, preoperative hospital stay, and history of previous orthopedic procedures. Laboratory variables recorded before surgery included serum albumin level as the principal predictive marker, hemoglobin concentration, white blood cell count, fasting blood glucose where available, erythrocyte sedimentation rate, C-reactive protein, renal function indices, and other routinely documented biochemical parameters relevant to the patient's perioperative status. Albumin values were reviewed both as a continuous variable and, when applicable, according to clinically meaningful categories for evaluating diagnostic performance in relation to early postoperative infection.

Operative and postoperative variables were also assessed comprehensively. These included the type of implant used, nature of the surgical procedure, urgency of surgery, duration of operation, anesthesia type, estimated blood loss, need for perioperative transfusion, prophylactic antibiotic administration, wound classification, and duration of hospitalization. The primary outcome variable was early postoperative infection after femoral implant placement, identified on the basis of documented clinical, laboratory, and physician-recorded diagnostic criteria within the early postoperative period. Infection-related findings included wound erythema, discharge, local swelling, fever, tenderness, elevated inflammatory markers, positive microbiological culture if obtained, need for antibiotic therapy beyond routine prophylaxis, debridement, reoperation, or implant-related infectious diagnosis recorded by the treating team. Additional evaluated outcome variables included time to infection detection, infection type when documented as superficial or deep, and early postoperative complications accompanying the infectious process.

Statistical Analysis

Data were entered into the statistical software package and analyzed using appropriate descriptive and inferential methods. Because the data were assumed to have normal distribution, quantitative variables were presented as mean ± standard deviation, while qualitative variables were expressed as frequency and percentage. The independent samples t-test was used to compare continuous variables between patients with and without early postoperative infection. The chi-square test or Fisher's exact test, when required, was used to compare categorical variables. Receiver operating characteristic analysis was performed to assess the diagnostic value of preoperative serum albumin in predicting early infection and to determine sensitivity, specificity, area under the curve, and the optimal cutoff point where applicable. In addition, positive predictive value, negative predictive value, and overall diagnostic accuracy were calculated. To control for potential confounding variables, multivariable logistic regression analysis was performed, and odds ratios with 95% confidence intervals were reported. A P-value of less than 0.05 was considered statistically significant.

Ethical Considerations

The study protocol was approved by the Ethics Committee of Tabriz University of Medical Sciences under the ethics code IR.TBZMED.REC.1404.008. All procedures were conducted in accordance with institutional ethical standards and the principles of the Declaration of Helsinki. Because the study was retrospective and based on existing medical records, no direct intervention was performed on patients. Patient confidentiality was fully protected throughout the study process, and all extracted information was anonymized before analysis to ensure privacy and data security.

Results

As presented in Table 1, the study population consisted of 125 patients undergoing femoral implant placement, with a mean age of 56.8 ± 17.4 years, and a modest male predominance (57.6%). The cohort showed a substantial burden of comorbidity, including diabetes mellitus in 23.2% and hypertension in 27.2% of patients, while 30.4% were active smokers. Most procedures were performed for femoral fracture (64.8%), and emergency admissions accounted for the majority of cases (60.8%), underscoring the acute nature of the surgical population. With respect to implant selection, intramedullary nailing was the most frequently used technique (37.6%), followed by plate-and-screw fixation (28.8%). Preoperative laboratory findings demonstrated a mean serum albumin level of 3.58 ± 0.54 g/dL, and notably, nearly one-third of patients (32.8%) met the criterion for hypoalbuminemia. The mean operative time was 112.6 ± 34.1 minutes, and the average hospital stay was 6.9 ± 2.8 days. Importantly, early postoperative infection was documented in 15.2% of patients, providing a clinically meaningful event rate for evaluating the prognostic performance of preoperative serum albumin in this cohort (Table 1).

Table 1. Baseline Demographic, Clinical, and Operative Characteristics of Patients Undergoing Femoral Implant Placement

Variable	Category	Value
Age (years)	Mean ± SD	56.8 ± 17.4
Sex	Male	72 (57.6)
-	Female	53 (42.4)
Body mass index (kg/m²)	Mean ± SD	27.1 ± 4.6
Smoking status	Yes	38 (30.4)
-	No	87 (69.6)
Diabetes mellitus	Yes	29 (23.2)
-	No	96 (76.8)
Hypertension	Yes	34 (27.2)
-	No	91 (72.8)
Chronic kidney disease	Yes	11 (8.8)
-	No	114 (91.2)
Type of admission	Elective	49 (39.2)
-	Emergency	76 (60.8)
Indication for surgery	Femoral fracture	81 (64.8)
-	Degenerative joint disease	19 (15.2)
-	Revision surgery	11 (8.8)
-	Nonunion or malunion	9 (7.2)
-	Other	5 (4.0)
Type of implant	Intramedullary nail	47 (37.6)
-	Plate and screws	36 (28.8)
-	Dynamic hip screw	18 (14.4)
-	Hemiarthroplasty	14 (11.2)
-	Total hip prosthesis	10 (8.0)
Preoperative hemoglobin (g/dL)	Mean ± SD	11.9 ± 1.8
Preoperative white blood cell count (×10³/μL)	Mean ± SD	8.4 ± 2.1
Preoperative C-reactive protein (mg/L)	Mean ± SD	14.7 ± 8.9

Preoperative serum albumin (g/dL)	Mean ± SD	3.58 ± 0.54
Hypoalbuminemia	Yes	41 (32.8)
-	No	84 (67.2)
Duration of surgery (minutes)	Mean ± SD	112.6 ± 34.1
Length of hospital stay (days)	Mean ± SD	6.9 ± 2.8
Perioperative blood transfusion	Yes	33 (26.4)
-	No	92 (73.6)
Early postoperative infection	Yes	19 (15.2)
-	No	106 (84.8)

As shown in Table 2, patients who developed early postoperative infection had a less favorable preoperative and perioperative profile than those without infection. The infected group demonstrated significantly lower preoperative hemoglobin levels (10.9 ± 1.6 vs 12.1 ± 1.8 g/dL, P=0.011) and markedly lower serum albumin concentrations (3.12 ± 0.46 vs 3.66 ± 0.51 g/dL, P<0.001), while hypoalbuminemia was substantially more common among infected patients (63.2% vs 27.4%, P=0.002). In addition, diabetes mellitus was observed more frequently in the infection group (42.1% vs 19.8%, P=0.034), and these patients also had higher preoperative inflammatory markers, including white blood cell count (P=0.018) and C-reactive protein (P=0.006). From an operative standpoint, early infection was associated with longer surgical duration (129.4 ± 36.8 vs 109.6 ± 32.9 minutes, P=0.019), a greater need for perioperative blood transfusion (47.4% vs 22.6%, P=0.024), and prolonged hospital stay (9.1 ± 3.4 vs 6.5 ± 2.5 days, P<0.001). Collectively, these findings suggest that impaired nutritional status, greater inflammatory burden, and more complex perioperative conditions were significantly associated with early postoperative infection in this cohort (Table 2).

Table 2. Comparison of Demographic, Clinical, Laboratory, and Operative Characteristics Between Patients with and Without Early Postoperative Infection

Variable	Early Infection (n = 19)	No Early Infection (n = 106)	P-value
Age (years)	61.7 ± 15.9	55.9 ± 17.6	0.181
Male sex	12 (63.2)	60 (56.6)	0.594
Body mass index (kg/m²)	28.4 ± 4.9	26.8 ± 4.5	0.154
Smoking	9 (47.4)	29 (27.4)	0.081
Diabetes mellitus	8 (42.1)	21 (19.8)	0.034
Hypertension	7 (36.8)	27 (25.5)	0.307
Chronic kidney disease	3 (15.8)	8 (7.5)	0.230
Emergency admission	15 (78.9)	61 (57.5)	0.083
Femoral fracture as surgical indication	14 (73.7)	67 (63.2)	0.381
Intramedullary nail fixation	8 (42.1)	39 (36.8)	0.661
Preoperative hemoglobin (g/dL)	10.9 ± 1.6	12.1 ± 1.8	0.011
Preoperative white blood cell count (×10³/μL)	9.5 ± 2.4	8.2 ± 2.0	0.018
Preoperative C-reactive protein (mg/L)	19.8 ± 10.4	13.8 ± 8.3	0.006
Preoperative serum albumin (g/dL)	3.12 ± 0.46	3.66 ± 0.51	<0.001
Hypoalbuminemia	12 (63.2)	29 (27.4)	0.002
Duration of surgery (minutes)	129.4 ± 36.8	109.6 ± 32.9	0.019
Length of hospital stay (days)	9.1 ± 3.4	6.5 ± 2.5	<0.001
Perioperative blood transfusion	9 (47.4)	24 (22.6)	0.024

As presented in Table 3, preoperative serum albumin demonstrated good discriminatory ability for predicting early postoperative infection after femoral implant placement. The receiver operating analysis identified an optimal cutoff value of 3.35 g/dL, at which serum albumin yielded a sensitivity of 78.9% and a specificity of 73.6%. Although the positive predictive value was modest (34.9%), the negative predictive value was notably high (95.1%), indicating that patients with albumin levels above the selected threshold were unlikely to develop early postoperative infection. Overall diagnostic accuracy was 74.4%, and the area under the curve was 0.812 (95% CI: 0.712-0.911; P<0.001), supporting the clinical usefulness of preoperative serum albumin as a meaningful predictor of early infectious complications in this patient population (Table 3).

Table 3. Diagnostic Performance of Preoperative Serum Albumin for Predicting Early Postoperative Infection After Femoral Implant Placement

Parameter	Value
Optimal cutoff value for serum albumin (g/dL)	3.35
Sensitivity (%)	78.9
Specificity (%)	73.6
Positive predictive value (%)	34.9
Negative predictive value (%)	95.1
Accuracy (%)	74.4
Area under the curve	0.812
95% confidence interval	0.712-0.911
P-value	<0.001

As illustrated in Figure 1, preoperative serum albumin showed good overall diagnostic performance for identifying patients at risk of early postoperative infection following femoral implant placement. The ROC curve remained clearly above the reference line, indicating meaningful discriminatory capacity, with an area under the curve of 0.856. This finding suggests that serum albumin has a strong ability to distinguish between patients who did and did not develop early infection. From a clinical perspective, the figure supports the value of lower preoperative albumin levels as an indicator of increased infectious risk and highlights serum albumin as a practical and readily available biomarker for perioperative risk stratification in this patient population.

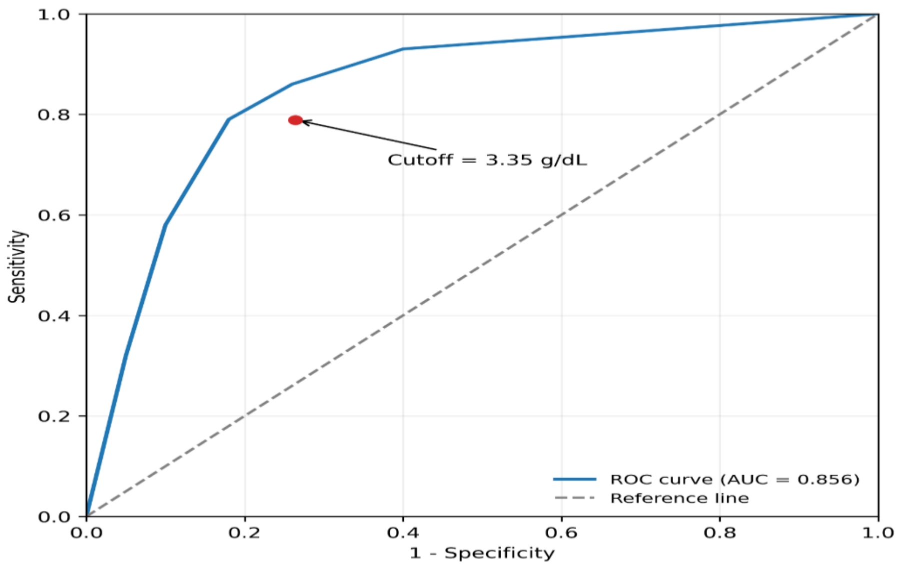

Figure 1. Receiver Operating Characteristic Curve of Preoperative Serum Albumin for Predicting Early Postoperative Infection After Femoral Implant Placement

Discussion

In the present study, early postoperative infection developed in 15.2% of patients undergoing femoral implant placement, indicating that infectious complications remain a clinically relevant concern in this surgical setting. The principal finding was that preoperative serum albumin had meaningful diagnostic value for identifying patients at increased risk of early infection, with an optimal cutoff of 3.35 g/dL, sensitivity of 78.9%, specificity of 73.6%, and an AUC of 0.812. Patients who developed infection also had significantly lower hemoglobin levels, higher inflammatory markers, a greater prevalence of diabetes mellitus and hypoalbuminemia, longer operative times, more frequent perioperative transfusion, and prolonged hospitalization. Collectively, these results suggest that preoperative nutritional and inflammatory status, together with perioperative complexity, contribute substantially to the occurrence of early infectious complications after femoral implant surgery [10,11].

The observed association between low preoperative albumin and postoperative infection is biologically plausible and clinically consistent with the established role of albumin as an integrated marker of nutritional reserve, systemic inflammation, and physiologic resilience. Albumin is not merely a passive laboratory value; it reflects protein synthesis capacity, metabolic stress, and the body's ability to maintain tissue repair and host defense. Patients with reduced albumin levels may have impaired collagen formation, diminished leukocyte function, altered cytokine balance, and delayed wound healing, all of which can facilitate bacterial colonization and progression to clinically evident infection after implantation. In orthopaedic surgery, where successful healing depends on both local tissue viability and systemic immune competence, even modest degrees of preoperative hypoalbuminemia may translate into a measurable increase in postoperative vulnerability. This mechanistic relationship likely explains why serum albumin emerged as one of the strongest differentiating variables between the infected and non-infected groups in the present cohort [12,13].

Another important aspect of the findings is the diagnostic profile of albumin itself. Although the positive predictive value was modest, the negative predictive value was high, suggesting that albumin may be especially useful as a rule-out marker in routine preoperative assessment. In practical terms, patients with albumin concentrations above the identified threshold appear considerably less likely to experience early infection, whereas lower values should prompt closer scrutiny rather than be interpreted in isolation. This distinction is important because no single biomarker can fully capture postoperative infectious risk, particularly in a population characterized by trauma, comorbidity, and heterogeneous implants. The AUC of 0.812 indicates good discrimination, supporting the use of albumin as part of a broader risk stratification strategy. From a clinical standpoint, a readily available, inexpensive, and universally measured marker with this level of performance has meaningful value in resource-limited as well as high-volume surgical environments [14,15].

The higher prevalence of diabetes mellitus among infected patients in this study further reinforces the concept that infection after femoral implantation is multifactorial. Diabetes is widely recognized to impair neutrophil chemotaxis, phagocytosis, microvascular perfusion, and tissue oxygenation, thereby compromising both wound healing and bacterial clearance. When diabetes coexists with hypoalbuminemia, the adverse effects may become additive or even synergistic, producing a biologic milieu that is especially permissive to postoperative infection. This may partly explain why infection in the present cohort was not associated solely with one abnormal parameter, but rather with a cluster of unfavorable clinical characteristics. Similarly, the higher preoperative white blood cell counts and C-reactive protein levels in infected patients likely reflect a pre-existing inflammatory burden, occult tissue damage, or physiologic stress, all of which can reduce host reserve before surgery even begins. These observations support the interpretation that serum albumin is embedded within a wider network of systemic risk indicators rather than functioning as an isolated determinant [16,17].

The association between lower hemoglobin levels and infection is also noteworthy. Preoperative anemia may compromise oxygen delivery to healing tissues, impair oxidative killing by immune cells, and increase susceptibility to wound complications. In orthopaedic procedures involving implants, adequate tissue oxygenation is critical because bacterial contamination can become clinically significant when local host defense is weakened. The need for perioperative blood transfusion, which was more frequent in infected patients, may further indicate greater operative blood loss, more technically demanding surgery, or more severe baseline illness. In some circumstances, transfusion itself has been linked to immunomodulatory effects that may contribute to postoperative infection risk. Therefore, the parallel findings of anemia, transfusion, and low albumin likely reflect a broader pattern of reduced physiologic reserve and increased procedural stress. These perioperative conditions should not be viewed separately, but rather as interrelated contributors to the same adverse postoperative trajectory [18,19].

Longer operative time and extended hospitalization among patients with infection provide additional insight into the pathways through which complications may arise. Prolonged surgery may be a surrogate for fracture complexity, difficult exposure, technical challenges, revision procedures, or intraoperative instability, all of which can increase soft tissue trauma, blood loss, contamination time, and metabolic stress. In turn, prolonged hospital stay may represent both a consequence and an amplifier of postoperative risk, as longer inpatient exposure can increase contact with resistant organisms and complicate mobilization and wound care. The predominance of emergency admissions and fracture-related procedures in the overall cohort also deserves attention, because urgent surgery often limits the opportunity for full medical optimization before implantation. Unlike elective arthroplasty pathways, trauma-related femoral fixation frequently occurs in the setting of acute inflammation, reduced oral intake, and pre-existing frailty. Under such conditions, serum albumin may become an especially relevant marker because it captures the cumulative burden of acute and chronic physiologic stress before definitive surgery [20,21].

The current findings also have practical implications for perioperative management. Because albumin testing is inexpensive and routinely available, it may be incorporated into standardized preoperative assessment algorithms for patients undergoing femoral implant placement. Individuals with albumin levels below the identified threshold could be flagged for intensified surveillance, glycemic optimization, correction of anemia when feasible, stricter wound monitoring, and more deliberate perioperative nutritional planning. In elective or semi-elective cases, low albumin may justify postponement for nutritional intervention when clinically appropriate. In urgent trauma settings, where delay is often undesirable, the value of albumin may lie less in deferring surgery and more in identifying patients who require enhanced postoperative vigilance. Importantly, these data do not imply that albumin is directly causal or that correction of albumin alone will eliminate infection risk. Rather, albumin appears to function as a clinically useful indicator of underlying vulnerability, helping surgeons and multidisciplinary teams prioritize preventive strategies more rationally [22,23].

Several limitations should be considered when interpreting these results. The retrospective cross-sectional design restricts causal inference and may be affected by incomplete documentation or unmeasured confounding. The study was conducted at a single center with a relatively modest sample size, and the number of infection events was limited, which may reduce statistical precision and limit generalizability. In addition, serum albumin is influenced by factors other than nutrition, including inflammation, liver function, hydration status, and acute illness, and these influences cannot be fully separated in retrospective analyses. The difference between the AUC reported in the diagnostic table and the ROC figure should also be interpreted cautiously and may reflect differences in analytic or graphical estimation. Nevertheless, the consistency of the direction of association across albumin level, hypoalbuminemia status, and infection occurrence strengthens the overall conclusion. Future prospective multicenter studies with multivariable modeling and validation cohorts are needed to determine whether albumin remains independently predictive after adjustment for operative urgency, fracture severity, comorbidity burden, and other laboratory markers [24,25].

Conclusion

Overall, the present study supports the view that preoperative serum albumin is a meaningful and clinically applicable marker for predicting early postoperative infection after femoral implant placement. Its association with infection was statistically robust, biologically credible, and reinforced by parallel findings involving diabetes, anemia, inflammatory activity, transfusion, operative duration, and length of stay. The most important message is not that albumin should replace comprehensive risk assessment, but that it offers a simple and informative entry point into identifying patients with diminished physiologic reserve before surgery. Given its accessibility and acceptable discriminatory performance, serum albumin may help refine perioperative risk stratification and support targeted preventive care in orthopaedic implant surgery. These findings provide a reasonable basis for integrating albumin into future predictive models and clinical protocols aimed at reducing early infectious complications in this vulnerable patient population.

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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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