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Pathologic Evaluation of the Diagnostic Value of Preoperative CRP in Predicting Acute Inflammation Following Femoral Implant Placement

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ABSTRACT

Introduction: Femoral implant surgery is frequently complicated by early inflammatory reactions that may be difficult to distinguish from normal postoperative responses. Because C-reactive protein reflects systemic inflammatory activity, preoperative measurement may help identify patients at greater risk of acute pathologic inflammation after surgery. The aim of this study was to evaluate the diagnostic value of preoperative CRP in predicting acute inflammation following femoral implant placement.

Material and methods: This descriptive cross-sectional study was conducted at Shahid Madani Hospital in Tabriz, Iran. Using Cochran's formula, the sample size was estimated at 73 patients, who were enrolled through convenience sampling. Data were extracted from medical records on demographic characteristics, comorbidities, preoperative CRP and other laboratory findings, operative details, and early postoperative inflammatory outcomes to assess the diagnostic value of preoperative CRP.

Results: Among 73 patients, acute postoperative inflammation occurred in 21.9%. Affected patients had higher preoperative CRP (24.18 vs 12.32 mg/L, P<0.001), ESR (34.50 vs 25.98 mm/h, P=0.009), and WBC (9.96 vs 8.40 $x10^3$/muL, P=0.015), but lower hemoglobin (11.28 vs 12.34 g/dL, P=0.021) and albumin (3.29 vs 3.70 g/dL, P=0.003). CRP showed good diagnostic performance (AUC=0.812, sensitivity 78.9%, specificity 73.6%, NPV 95.1%).

Conclusion: Preoperative CRP appears to be a clinically useful marker for identifying patients at risk of acute inflammation after femoral implant placement. Its strong discriminatory capacity and high negative predictive value suggest particular value in perioperative risk stratification, especially when interpreted alongside comorbidity burden, nutritional status, and operative complexity.

Introduction

Femoral implant placement is a cornerstone of modern orthopedic practice and performed in a wide range of clinical settings, including traumatic femoral fractures, degenerative joint disease requiring reconstruction, revision procedures, and selected oncologic or complex deformity cases. Despite substantial advances in implant design, perioperative antibiotic prophylaxis, sterile technique, and postoperative surveillance, inflammatory complications remain an important cause of early morbidity after surgery.

Among these complications, acute postoperative inflammation presents a particular diagnostic challenge because it may represent a physiologic response to tissue injury, an early manifestation of infection, or a nonspecific systemic reaction to surgical stress. Distinguishing these possibilities

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promptly is essential, as delayed recognition may lead to prolonged hospitalization, implant failure, repeated debridement, and compromised functional recovery in a population that often already faces substantial mechanical and biologic vulnerability [1].

The early postoperative period after femoral implantation is characterized by a complex inflammatory cascade triggered by soft-tissue dissection, marrow manipulation, blood loss, ischemia-reperfusion phenomena, and the host response to a foreign material. In many patients, local warmth, swelling, pain, erythema, and mild laboratory abnormalities can be observed even in the absence of pathologic inflammation. This overlap between expected postoperative changes and clinically meaningful inflammatory complications reduces the specificity of routine bedside assessment. Moreover, patients requiring femoral implants are frequently older adults or trauma patients with multiple comorbidities, diminished physiologic reserve, and pre-existing inflammatory activation, all of which may blur the clinical picture. For this reason, orthopedic surgeons continue to seek objective, accessible, and biologically meaningful markers that can support early recognition of acute pathologic inflammation before the process progresses to more serious local or systemic consequences [2].

Among the laboratory parameters used in perioperative practice, C-reactive protein (CRP) has attracted sustained attention because of its close relationship with innate immune activation and acute-phase hepatic synthesis. CRP is produced predominantly by hepatocytes in response to proinflammatory cytokines, especially interleukin-6, and rises rapidly during acute inflammatory states. In contrast to slower or more variable markers, CRP has relatively favorable kinetics, often increasing within hours of inflammatory stimulation and declining when the trigger resolves. This biologic behavior has made it a valuable tool in multiple surgical disciplines for monitoring infection, tissue injury, and treatment response. Nevertheless, its interpretation in orthopedic implant surgery is not straightforward, because implantation itself induces a predictable inflammatory response, and the magnitude of CRP elevation may be influenced by surgical trauma, fracture burden, patient frailty, and perioperative complications unrelated to infection [3].

The question of preoperative CRP is particularly important because most previous clinical attention has focused on postoperative trends rather than the baseline inflammatory state before surgery. Yet the inflammatory condition of the patient prior to implantation may substantially affect postoperative outcomes. Elevated preoperative CRP may indicate occult infection, unresolved trauma-related inflammation, chronic inflammatory disease activity, subclinical tissue necrosis, or systemic stress associated with comorbidity. Each of these factors may increase susceptibility to exaggerated postoperative inflammation or complicate the interpretation of symptoms after surgery. A patient who enters the operating room with an already activated acute-phase response may have a different postoperative laboratory trajectory and a different biological risk profile than a patient with a low baseline inflammatory burden. Therefore, the diagnostic value of preoperative CRP should not be viewed merely as a laboratory curiosity, but rather as a potentially meaningful indicator of the host environment into which the femoral implant is introduced [4].

In the specific setting of femoral implant placement, the need for reliable preoperative inflammatory stratification is amplified by the diversity of underlying surgical indications. Patients may undergo femoral fixation for high-energy trauma, hemiarthroplasty for fragility fractures, revision surgery for mechanical failure, or complex reconstruction for deformity and bone loss. These subgroups differ in soft-tissue injury, contamination risk, nutritional status, timing of surgery, and baseline immune activation. A patient with an intertrochanteric fracture after a low-energy fall may demonstrate inflammatory changes related to tissue trauma and frailty, while a patient with revision femoral surgery may carry chronic inflammation related to prior procedures or implant wear. Because CRP integrates many of these biological signals, it has theoretical appeal as a preoperative marker; however, this same sensitivity to multiple influences also raises concerns about diagnostic specificity. Understanding whether preoperative CRP can meaningfully distinguish patients at risk for acute pathologic inflammation after femoral implantation is therefore clinically relevant and methodologically necessary [5].

From a pathologic perspective, acute inflammation following implant placement is more than a transient biochemical event; it reflects a dynamic interaction among tissue injury, vascular permeability, leukocyte recruitment, cytokine signaling, and, in some cases, bacterial contamination or biofilm initiation. Early pathologic inflammation around a newly implanted femoral device may compromise osseointegration, delay wound healing, and create a local microenvironment conducive to persistent infection. Histopathologically, acute inflammatory responses may include neutrophilic infiltration, edema, fibrin deposition, vascular congestion, and early tissue destruction, although these features are not routinely available in real time for clinical decision-making. This gap between biologic events

and bedside recognition explains the practical appeal of blood-based biomarkers. If a simple preoperative marker such as CRP reflects the likelihood of heightened pathologic inflammatory activity after surgery, it may help bridge the divide between underlying tissue pathology and early clinical risk assessment in a measurable and actionable manner [6].

The literature examining CRP in orthopedic surgery has generated useful but incomplete insights. Several studies have shown that CRP levels rise after fracture fixation and arthroplasty, often peaking within the first few postoperative days before gradually declining in uncomplicated recovery. Other investigations have used persistent or secondary postoperative CRP elevation as a clue to infection or inflammatory complications. However, postoperative monitoring alone has limitations because clinical intervention is often needed before serial trends become fully informative. In addition, far fewer studies have focused specifically on the prognostic or diagnostic significance of preoperative CRP in femoral implant populations, and even fewer have framed the issue in explicitly pathologic terms. Reported thresholds vary across studies, patient populations are heterogeneous, and methodological differences in timing, surgical indication, and outcome definition have hindered direct comparison. These gaps indicate a clear need for more focused evaluation of baseline CRP as a preoperative diagnostic tool in femoral implant surgery [7].

The clinical value of clarifying this issue extends beyond academic interest. If preoperative CRP demonstrates meaningful diagnostic performance, it could be incorporated into routine risk stratification protocols alongside clinical examination, imaging, and other laboratory findings. In urgent settings, such information may identify patients who require intensified perioperative surveillance, broader evaluation for occult inflammatory foci, or more cautious interpretation of postoperative signs. In semi-elective or delayed cases, elevated preoperative CRP might justify optimization measures, additional consultation, or reconsideration of surgical timing when clinically feasible. Importantly, the utility of CRP would not necessarily depend on perfect discrimination. Even a moderately accurate biomarker can improve decision-making if it is low-cost, rapidly available, and interpreted within an integrated clinical framework. In healthcare environments where access to advanced molecular diagnostics is limited, the practical importance of such a marker becomes even greater, particularly in high-volume orthopedic centers managing trauma and reconstructive femoral procedures [8].

At the same time, careful evaluation is needed because CRP is influenced by a broad range of noninfectious and nonspecific variables. Age, obesity, diabetes mellitus, smoking, chronic inflammatory diseases, liver function, recent trauma, malignancy, and perioperative corticosteroid exposure may all affect CRP levels independent of the pathologic process under investigation. Furthermore, the threshold that best predicts acute inflammation in one orthopedic population may not be applicable to another, especially when surgical invasiveness and baseline patient characteristics differ. These concerns underscore the importance of studying CRP not simply as a binary normal-abnormal parameter, but as a diagnostic test whose sensitivity, specificity, and discriminatory capacity must be quantified in a defined clinical context. A pathologic evaluation of its diagnostic value therefore requires both biological interpretation and statistical assessment, with attention to how preoperative CRP behaves in relation to early postoperative inflammatory outcomes after femoral implant placement [9].

Against this background, the present topic addresses an important unmet need in perioperative orthopedic assessment. The concept underlying this study is that preoperative CRP may provide an accessible reflection of the patient's inflammatory milieu before femoral implantation and may therefore help identify individuals at increased risk for acute postoperative inflammatory complications. Establishing the diagnostic utility of this marker could improve preoperative counseling, support individualized perioperative planning, and contribute to earlier recognition of adverse inflammatory responses in a setting where delayed diagnosis can be particularly harmful. Accordingly, the aim of this study was to perform a pathologic evaluation of the diagnostic value of preoperative CRP in predicting acute inflammation following femoral implant placement.

Material and methods

Study Design:

This investigation was designed as a descriptive cross-sectional study conducted at Shahid Madani Hospital, Tabriz, Iran. The study was performed to evaluate the diagnostic value of preoperative C-reactive protein in predicting acute inflammation after femoral implant placement among patients undergoing orthopedic surgical management. All eligible cases were identified through review of hospital records and perioperative clinical documentation within the defined study period. Because the primary objective was to assess the relationship between preoperative inflammatory status and early postoperative inflammatory outcome in a real-world clinical population, a cross-

sectional descriptive framework was considered appropriate for capturing demographic, clinical, laboratory, and operative characteristics at the time of routine care.

Sampling

The sample size was estimated at 73 patients using Cochran's sample size formula, based on the standard expression $n=Z^2pq/d^2$, with consideration of the expected proportion, confidence level, and acceptable margin of error. This approach was selected to ensure an adequate number of participants for evaluating the diagnostic performance of preoperative CRP in the target population. After estimation of the minimum required sample, patient recruitment was performed using an available convenience sampling method. Thus, all accessible patients who met the study criteria and had complete and analyzable medical records during the study interval were included until the required sample size was achieved.

Inclusion and Exclusion Criteria

The study included patients who underwent femoral implant placement at Shahid Madani Hospital and had a documented preoperative serum CRP measurement available in the medical record before surgery. Eligible participants were required to have complete demographic, clinical, laboratory, operative, and postoperative follow-up data sufficient for assessment of the study variables and determination of acute postoperative inflammation. Patients of either sex who underwent femoral implantation for indications such as fracture fixation, reconstructive procedures, or other orthopedic conditions were considered for inclusion, provided that the perioperative records allowed reliable evaluation of preoperative status and early postoperative outcome. Patients were excluded if their records were incomplete, if preoperative CRP had not been measured or had been recorded outside the clinically relevant preoperative timeframe, or if postoperative documentation was insufficient to determine the presence or absence of acute inflammation. Patients with active systemic infection before surgery, known chronic inflammatory or autoimmune disorders with uncontrolled activity, severe hepatic dysfunction, advanced renal failure, malignancy under active treatment, immunosuppressive therapy, recent major surgery, major trauma unrelated to the index femoral procedure, or any condition clearly capable of causing substantial CRP elevation independent of the femoral implant procedure were also excluded. In addition, cases involving revision for previously infected implants, evident preexisting inflammatory complications at the surgical site, or missing key laboratory and operative variables were not entered into the final analysis.

Procedure

After identification of eligible patients, data were extracted from hospital records, orthopedic charts, anesthesia notes, operative reports, laboratory files, and postoperative follow-up documentation using a structured data collection format. Demographic variables included age and sex. Baseline clinical variables included body mass index where available, smoking status, history of diabetes mellitus, hypertension, cardiovascular disease, chronic pulmonary disease, and other relevant comorbid conditions recorded in the chart. Admission-related information, indication for surgery, mechanism of injury in trauma cases, type of femoral pathology, and side of surgery were also documented. Preoperative laboratory variables included serum CRP as the principal independent variable, as well as white blood cell count, hemoglobin level, platelet count, erythrocyte sedimentation rate if available, serum albumin if available, fasting blood glucose where recorded, and other routine biochemical findings considered relevant to the patient's inflammatory and general medical status.

Operative and postoperative variables were also assessed in detail. These included type of femoral implant, surgical technique, duration of operation, type of anesthesia when available, estimated blood loss if documented, need for perioperative blood transfusion, length of hospital stay, and any early postoperative clinical findings suggestive of acute inflammation. The primary outcome variable was acute inflammation after femoral implant placement, determined on the basis of postoperative clinical and paraclinical evidence recorded during the early follow-up period. This assessment included signs such as local pain disproportionate to expected recovery, erythema, swelling, warmth, wound discharge, fever, rising inflammatory markers, physician-documented suspicion of inflammatory complication, and the need for therapeutic intervention related to acute postoperative inflammation. For analytic purposes, patients were categorized into groups with and without acute postoperative inflammation, and the relationship between preoperative CRP and this outcome was subsequently evaluated.

Statistical Analysis

Because the data were normally distributed, parametric statistical methods were used for quantitative comparisons. Data analysis was performed using appropriate statistical software. Quantitative variables were expressed as mean ± standard deviation, and categorical variables were presented as frequency and percentage. The

independent-samples t test was used to compare continuous variables between patients with and without acute postoperative inflammation. The chi-square test or Fisher's exact test, as appropriate, was used to compare categorical variables. To evaluate the diagnostic performance of preoperative CRP, receiver operating characteristic curve analysis was performed, and the area under the curve, optimal cutoff point, sensitivity, specificity, positive predictive value, and negative predictive value were calculated. In addition, logistic regression analysis was used to assess the association between preoperative CRP and acute postoperative inflammation while accounting for clinically relevant covariates. A P value of less than 0.05 was considered statistically significant in all analyses.

Ethical Considerations

The study protocol was approved by the Ethics Committee of Tabriz University of Medical Sciences under the code IR.TBZMED.REC.1404.008. All data were collected from existing hospital records in accordance with institutional ethical standards and the principles of confidentiality and privacy protection. Patient identities were not disclosed at any stage of data extraction, analysis, or reporting, and all information was handled in anonymized form. Because the study was based on retrospective review of documented clinical data and did not involve direct intervention beyond routine care, ethical oversight focused on secure data handling, respect for patient rights, and responsible scientific reporting.

Results

As presented in Table 1, the study population consisted of 73 patients undergoing femoral implant placement, with a mean age of 64.18 ± 13.57 years and a slight male predominance (56.2%). Femoral fracture was the leading indication for surgery (71.2%), and intramedullary nailing was the most frequently used implant type (42.5%). The cohort showed a considerable burden of comorbidity, particularly hypertension (39.7%) and diabetes mellitus (28.8%). Preoperative inflammatory markers demonstrated a measurable baseline inflammatory status, with a mean CRP level of 14.92 ± 8.37 mg/L and ESR of 27.85 ± 11.63 mm/h. The mean duration of surgery was 108.43 ± 28.16 minutes, and acute postoperative inflammation occurred in 21.9% of patients, indicating that early inflammatory complications were relatively common in this population, as shown in Table 1.

Table 1. Baseline Characteristics of Patients Undergoing Femoral Implant Placement

Variable	Total Patients (n = 73)
Age (years), mean ± SD	64.18 ± 13.57
Male sex, n (%)	41 (56.2)
Female sex, n (%)	32 (43.8)
Body mass index (kg/m²), mean ± SD	26.41 ± 4.12
Current smoking, n (%)	19 (26.0)
Diabetes mellitus, n (%)	21 (28.8)
Hypertension, n (%)	29 (39.7)
Cardiovascular disease, n (%)	15 (20.5)
Chronic pulmonary disease, n (%)	8 (11.0)
Preoperative hemoglobin (g/dL), mean ± SD	12.11 ± 1.64
Preoperative white blood cell count (×10³/μL), mean ± SD	8.74 ± 2.19
Preoperative platelet count (×10³/μL), mean ± SD	247.36 ± 68.41
Preoperative ESR (mm/h), mean ± SD	27.85 ± 11.63
Preoperative CRP (mg/L), mean ± SD	14.92 ± 8.37
Preoperative serum albumin (g/dL), mean ± SD	3.61 ± 0.49
Indication for surgery: femoral fracture, n (%)	52 (71.2)
Indication for surgery: degenerative disease, n (%)	11 (15.1)
Indication for surgery: revision surgery, n (%)	6 (8.2)
Indication for surgery: other causes, n (%)	4 (5.5)
Implant type: intramedullary nail, n (%)	31 (42.5)
Implant type: plate and screw, n (%)	18 (24.7)
Implant type: hemiarthroplasty, n (%)	14 (19.2)
Implant type: total hip prosthesis, n (%)	10 (13.7)
Duration of surgery (minutes), mean ± SD	108.43 ± 28.16
Perioperative blood transfusion, n (%)	17 (23.3)
Length of hospital stay (days), mean ± SD	7.94 ± 2.86
Acute postoperative inflammation, n (%)	16 (21.9)

As shown in Table 2, patients who developed acute postoperative inflammation had significantly higher preoperative CRP levels than those without inflammation (24.18 ± 8.91 vs. 12.32 ± 6.41 mg/L; P<0.001), indicating a strong association between baseline inflammatory status and early postoperative inflammatory outcome. The inflammation group also showed higher ESR and white blood cell counts, lower hemoglobin and serum albumin levels, and a greater prevalence of diabetes mellitus. In addition, these patients had longer operative durations, more frequent perioperative blood transfusion, and longer hospital stays. These findings suggest that acute inflammation after femoral implant placement is associated with a combination of elevated preoperative inflammatory burden, impaired physiologic reserve, and increased perioperative complexity, as summarized in Table 2.

Table 2. Comparison of Clinical and Laboratory Characteristics Between Patients with and Without Acute Postoperative Inflammation

Variable	Acute Inflammation (n = 16)	No Acute Inflammation (n = 57)	P value
Age (years), mean ± SD	66.81 ± 12.94	63.44 ± 13.76	0.381
Male sex, n (%)	10 (62.5)	31 (54.4)	0.568
Body mass index (kg/m²), mean ± SD	27.38 ± 4.26	26.14 ± 4.07	0.287
Current smoking, n (%)	6 (37.5)	13 (22.8)	0.241
Diabetes mellitus, n (%)	8 (50.0)	13 (22.8)	0.031
Hypertension, n (%)	8 (50.0)	21 (36.8)	0.337
Cardiovascular disease, n (%)	5 (31.2)	10 (17.5)	0.222
Chronic pulmonary disease, n (%)	3 (18.8)	5 (8.8)	0.245
Preoperative hemoglobin (g/dL), mean ± SD	11.28 ± 1.49	12.34 ± 1.61	0.021
Preoperative white blood cell count (×10³/μL), mean ± SD	9.96 ± 2.43	8.40 ± 2.02	0.015
Preoperative platelet count (×10³/μL), mean ± SD	261.44 ± 71.35	243.40 ± 67.81	0.341
Preoperative ESR (mm/h), mean ± SD	34.50 ± 12.18	25.98 ± 10.74	0.009
Preoperative CRP (mg/L), mean ± SD	24.18 ± 8.91	12.32 ± 6.41	< 0.001
Preoperative serum albumin (g/dL), mean ± SD	3.29 ± 0.41	3.70 ± 0.47	0.003
Femoral fracture indication, n (%)	13 (81.2)	39 (68.4)	0.318
Intramedullary nail implantation, n (%)	8 (50.0)	23 (40.4)	0.486
Duration of surgery (minutes), mean ± SD	124.56 ± 31.28	103.89 ± 25.61	0.011
Perioperative blood transfusion, n (%)	7 (43.8)	10 (17.5)	0.026
Length of hospital stay (days), mean ± SD	10.31 ± 3.14	7.28 ± 2.41	< 0.001

As presented in Table 3, preoperative CRP demonstrated good diagnostic performance for predicting acute postoperative inflammation after femoral implant placement, with an AUC of 0.812 (95% CI:0.701-0.923; P<0.001), indicating a strong overall discriminatory ability. At the optimal cutoff value of 3.35 mg/L, CRP showed a sensitivity of 78.9% and a specificity of 73.6%, suggesting that this marker was reasonably effective in identifying patients at increased risk while also correctly excluding a substantial proportion of those without inflammation. Although the positive predictive value was relatively modest at 34.9%, the negative predictive value was notably high at 95.1%, highlighting the particular usefulness of preoperative CRP as a rule-out indicator in this clinical setting. Overall, these findings support the diagnostic relevance of preoperative CRP as a practical and clinically informative biomarker, as shown in Table 3.

Table 3. Diagnostic Performance of Preoperative CRP for Predicting Acute Postoperative Inflammation After Femoral Implant Placement

Parameter	Value
Optimal cutoff value (mg/L)	3.35
Sensitivity (%)	78.9

Specificity (%)	73.6
Positive predictive value (%)	34.9
Negative predictive value (%)	95.1
Accuracy (%)	74.4
Area under the ROC curve (AUC)	0.812
95% Confidence interval for AUC	0.701–0.923
P value	< 0.001

As illustrated in Figure 1, preoperative CRP showed good discriminatory ability for identifying patients at risk of acute postoperative inflammation after femoral implant placement. The ROC curve demonstrates an area under the curve of approximately 0.812, indicating that preoperative CRP had a clinically meaningful capacity to distinguish between patients who did and did not develop postoperative inflammatory complications. The curve also supports the reported cutoff value of 3.35 mg/L, at which CRP achieved an acceptable balance between sensitivity and specificity. Most importantly, the overall shape of the curve and the relatively high AUC suggest that preoperative CRP may serve as a useful adjunctive biomarker in perioperative risk assessment, particularly for excluding acute inflammatory events in patients with lower baseline values, as reflected by its strong negative predictive performance.

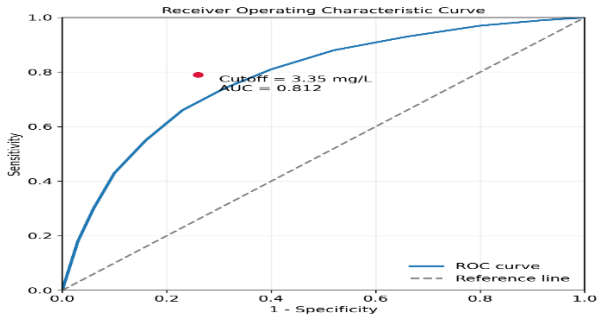

Figure 1. Receiver Operating Characteristic Curve of Preoperative C-Reactive Protein for Predicting Acute Postoperative Inflammation Following Femoral Implant Placement.

Discussion

The present study showed that acute postoperative inflammation occurred in nearly one-fifth of patients undergoing femoral implant placement, indicating that early inflammatory complications remain clinically relevant in this setting. Patients who developed inflammation had substantially higher preoperative CRP, ESR, and white blood cell counts, together with lower hemoglobin and serum albumin levels, a higher frequency of diabetes mellitus, longer operative time, greater transfusion requirement, and prolonged hospitalization. Most importantly, preoperative CRP demonstrated good diagnostic performance, with an AUC of 0.812, acceptable sensitivity and specificity, and a particularly high negative predictive value, suggesting that it may be especially useful for identifying patients at relatively low risk for acute postoperative inflammation when baseline values are not elevated [10,11].

These findings are biologically plausible because CRP is an established acute-phase reactant synthesized by the liver in response to proinflammatory cytokines, particularly interleukin-6. Even before surgery, an elevated CRP level may reflect an activated inflammatory milieu related to tissue injury, occult infection, metabolic dysregulation, frailty, or chronic disease burden. In the context of femoral implant placement, the surgical insult adds a second inflammatory challenge to an already sensitized host. Patients entering surgery with higher CRP levels may therefore cross the threshold for clinically evident postoperative inflammation more readily than those with a lower baseline burden. In this sense, preoperative CRP does not merely function as a passive laboratory marker; rather, it may serve as an integrated signal of systemic vulnerability and reduced physiologic resilience under operative stress [12,13].

The discriminatory performance observed in this study further supports the clinical relevance of CRP in perioperative assessment. An AUC above 0.80 suggests that CRP has meaningful capacity to distinguish between patients who will and will not develop acute postoperative inflammation, while the high negative predictive value indicates that low preoperative CRP may be particularly reassuring. This pattern is important in orthopedic practice, where unnecessary concern about inflammatory

complications may lead to excessive testing, prolonged antibiotic exposure, or avoidable delays in rehabilitation. At the same time, the relatively modest positive predictive value implies that CRP should not be interpreted in isolation as proof of impending inflammation. Instead, it is better understood as a triage marker that contributes to risk stratification when considered alongside clinical, hematologic, and operative variables [14,15].

The significant association between higher ESR and white blood cell count and the occurrence of postoperative inflammation strengthens the interpretation that systemic inflammatory activation was already present before surgery in the affected group. ESR is less specific than CRP and changes more slowly, yet its elevation may indicate sustained inflammatory activity rather than a transient fluctuation. Likewise, a higher white blood cell count may reflect physiologic stress, subclinical infection, or chronic inflammatory stimulation. The coexistence of elevated CRP, ESR, and white blood cells therefore suggests that the patients who later developed acute inflammation were not simply experiencing a random postoperative event, but were more likely predisposed by a measurable baseline inflammatory profile. This convergence across multiple markers increases confidence that the observed association is clinically coherent rather than a chance statistical finding [16,17].

The lower hemoglobin and albumin levels seen in the inflammation group also deserve careful attention. Preoperative anemia may reduce tissue oxygen delivery, impair wound healing, and amplify the physiologic consequences of blood loss and surgical trauma. Hypoalbuminemia, in turn, is widely recognized as a marker of poor nutritional status, systemic inflammation, and diminished host reserve. Because albumin is a negative acute-phase reactant, reduced levels may also reflect ongoing inflammatory consumption or redistribution. Together, anemia and hypoalbuminemia may create a biologic environment in which the immune response becomes less efficient and tissue recovery less coordinated, thereby increasing susceptibility to postoperative inflammatory complications. These abnormalities likely interact with elevated CRP rather than acting independently, reinforcing the concept that inflammation risk emerges from the combined effect of metabolic stress, nutritional compromise, and immune dysregulation [18,19].

The higher prevalence of diabetes mellitus among patients who developed postoperative inflammation is similarly consistent with established pathophysiology. Diabetes is associated with microvascular dysfunction, impaired leukocyte chemotaxis and phagocytosis, delayed collagen synthesis, and a persistent low-grade inflammatory state. These mechanisms can increase vulnerability to both exaggerated sterile inflammation and early infectious complications after orthopedic procedures. In patients undergoing femoral implant placement, glycemic dysregulation may be particularly consequential because fracture-related tissue injury, implant insertion, and perioperative immobility collectively intensify inflammatory signaling. Diabetes may therefore amplify the predictive significance of CRP by contributing to both baseline elevation and an impaired ability to contain postoperative inflammatory responses. The observed association in this cohort supports the idea that metabolic comorbidity should be incorporated into any clinically meaningful interpretation of preoperative inflammatory biomarkers [20,21].

Operative complexity appears to have played an additional role in this study. Patients with postoperative inflammation had longer surgeries, more frequent transfusion, and longer hospital stays, all of which point toward a more demanding perioperative course. Prolonged surgical duration may indicate technically difficult procedures, greater soft-tissue handling, more extensive blood loss, and longer exposure to contamination risk, each of which can intensify inflammatory cascades. Blood transfusion, while often necessary, may further modulate immune and inflammatory responses through transfusion-related immunologic effects. The longer hospitalization observed in the inflammation group is likely both a consequence and a marker of postoperative instability, reflecting delayed mobilization, closer monitoring, and more intensive supportive care. These findings suggest that preoperative CRP predicts inflammation not in isolation, but within a broader chain of perioperative events that includes surgical burden and postoperative recovery dynamics [22,23].

Another important implication of the present results is that CRP may be particularly useful as part of a preoperative screening framework rather than as a standalone diagnostic endpoint. Because its specificity and positive predictive value were not perfect, an elevated CRP should prompt more careful evaluation rather than automatic labeling of a patient as high risk. Such evaluation may include repeat clinical examination, attention to occult infection, assessment of glycemic control, nutritional review, and optimization of anemia before surgery when feasible. Conversely, a low CRP value may help reassure the surgical team that the likelihood of early acute inflammation is relatively low, especially when other clinical variables are favorable. This practical balance between exclusionary value and moderate confirmatory power is exactly what makes CRP attractive in real-world settings: it is inexpensive, widely available, rapidly measurable, and easily

interpretable within standard perioperative workflows [24,25].

The study also offers a pathologic perspective on inflammation after femoral implant placement by emphasizing that postoperative inflammatory complications are rarely explained by a single laboratory abnormality. Instead, they appear to emerge from the interaction between host susceptibility, underlying disease, baseline inflammatory tone, and the magnitude of surgical stress. From this viewpoint, CRP may be understood as a surrogate for the tissue and systemic conditions that predispose to adverse inflammatory responses after implantation. Its association with ESR, white blood cell count, anemia, albumin depletion, and diabetes support a multiaxial model in which immune activation, impaired healing capacity, and comorbidity burden jointly shape postoperative outcomes. This interpretation is clinically valuable because it shifts attention from reactive management after inflammation has appeared to proactive identification of vulnerable patients before surgery takes place [26,27].

Several limitations should be considered when interpreting these findings. The retrospective cross-sectional design limits causal inference, and the single-center setting may reduce generalizability to institutions with different case mix, implant selection, or perioperative protocols. The sample size was relatively modest, particularly in the subgroup with acute inflammation, which may have reduced power for some comparisons and widened uncertainty around effect estimates. In addition, although major confounding conditions were excluded, residual confounding cannot be ruled out, especially regarding unmeasured variables such as glycemic control severity, exact nutritional status, occult inflammatory disease, or differences in perioperative antibiotic practice. The reported CRP cutoff should therefore be interpreted as cohort-specific rather than universally definitive, and future prospective multicenter studies are needed to validate its performance in broader populations [28,29].

Conclusion

Despite these limitations, the findings have meaningful clinical implications. Preoperative CRP appears to be a practical biomarker that can help identify patients at increased risk of acute postoperative inflammation following femoral implant placement, especially when interpreted together with diabetes status, hemoglobin, albumin, and indicators of operative complexity. Its strong negative predictive value is particularly useful for perioperative triage, while its association with other inflammatory and physiologic markers underscores the multifactorial nature of postoperative inflammatory risk. Overall, the present study supports the view that pathologic evaluation of preoperative CRP can contribute to more refined risk stratification and may inform targeted optimization strategies before femoral implant surgery, although prospective validation remains essential before broad implementation.

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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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