



## Evaluation of Inflammatory Markers in the Diagnosis of Postoperative Infections in Patients with Upper Limb Fractures

Parham Maroufi<sup>1</sup>, Sina Najafi<sup>2\*</sup>

<sup>1</sup>Associate Professor of Orthopaedics, Department of Orthopedics, School of Medicine, Shohada Medical Research & Training Hospital, Tabriz University of Medical Sciences, Tabriz, Iran (Email: P\_maroufi@gmail.com- ORCID: 0000-0002-1357-7795)

<sup>2</sup>Associate of Infectious Disease, Department of Infectious Disease, School of Medicine, Tabriz University of Medical Sciences, Tabriz, Iran

### Article info

Received: 05.02.2025

Accepted: 13.03.2025

Available Online: 15.03.2025

Checked for Plagiarism: Yes

### Keywords:

Postoperative infection, C-reactive protein, Procalcitonin, Upper limb fracture

### ABSTRACT

**Introduction:** Postoperative infections are a significant complication following surgical fixation of upper limb fractures, leading to increased morbidity, prolonged hospitalization, and potential implant failure. Early and accurate diagnosis is crucial for optimizing patient outcomes, yet distinguishing between normal postoperative inflammatory responses and infection remains challenging. This study aimed to evaluate the diagnostic utility of inflammatory markers, including C-reactive protein (CRP), procalcitonin (PCT), erythrocyte sedimentation rate (ESR), and white blood cell (WBC) count, in detecting postoperative infections.

**Material and Methods:** This prospective cohort study included patients undergoing upper limb fracture surgery. Inflammatory markers were measured at postoperative days (POD) 3 and 7. Diagnostic accuracy was assessed using receiver operating characteristic (ROC) analysis, with sensitivity, specificity, and area under the curve (AUC) calculated.

**Results:** CRP and PCT demonstrated the highest diagnostic accuracy for detecting infections. At POD 3, CRP (AUC = 0.863) and PCT (AUC = 0.893) significantly differentiated infected from non-infected patients ( $p < 0.001$ ). ESR and WBC count showed moderate diagnostic accuracy. Serial CRP and PCT measurements improved infection detection.

**Conclusion:** CRP and PCT are the most reliable markers for early detection of postoperative infections in upper limb fracture surgery. Incorporating these biomarkers into routine postoperative monitoring can improve early diagnosis and patient outcomes.

### Introduction

Postoperative infections following orthopedic surgery remain a major concern, particularly in patients with upper limb fractures (1). Despite advances in surgical techniques, implant materials, and perioperative care, infections can lead to prolonged hospital stays, impaired functional recovery, and even implant failure.

Early diagnosis of infection is crucial for prompt intervention, yet clinical signs alone are often insufficient due to their nonspecific nature in the postoperative setting. As a result, inflammatory biomarkers have gained increasing attention as valuable tools for detecting infections in orthopedic patients (2).

\*Corresponding Author: Sina Najafi (Email: P\_maroufi@gmail.com, ORCID: 0000-0002-1357-7795)

Inflammatory markers, including C-reactive protein (CRP), white blood cell (WBC) count, erythrocyte sedimentation rate (ESR), and procalcitonin (PCT), are commonly used to assess systemic inflammation and infection. However, their diagnostic accuracy varies depending on the type of surgery, patient comorbidities, and timing of measurement. Among these, CRP and ESR are widely used due to their accessibility and established correlation with infections (3). CRP, an acute-phase reactant, rises rapidly in response to infection, making it a useful marker for early diagnosis. ESR, on the other hand, remains elevated for a prolonged period, which may help in monitoring persistent infections. Procalcitonin has also emerged as a promising marker, particularly in differentiating bacterial infections from other causes of inflammation (4). Infections in upper limb fractures are particularly challenging due to the complex anatomy and relatively lower blood supply of certain regions, such as the scaphoid or humerus(5). The presence of internal fixation devices further complicates the diagnosis, as implant-related infections may present with subtle or delayed symptoms. Differentiating between normal postoperative inflammation and early infection is essential to guide treatment decisions. A delay in diagnosis can lead to deep-seated infections requiring extensive debridement, prolonged antibiotic therapy, and potential implant removal, all of which significantly impact functional outcomes and patient quality of life(6).

Another important consideration is the role of biomarkers in differentiating superficial from deep infections. Superficial infections may be managed conservatively with antibiotics and wound care, whereas deep infections often necessitate surgical intervention (7). Studies have suggested that persistently elevated CRP and ESR levels beyond the expected postoperative trajectory may be indicative of deep infections. However, the specific cutoff values and ideal timing of measurement remain subjects of ongoing research (8).

In recent years, advanced laboratory techniques have also explored the role of novel biomarkers, such as interleukins and neutrophil-to-lymphocyte ratio (NLR), in improving diagnostic accuracy (9). These emerging markets may offer additional insight into the inflammatory response associated with orthopedic infections. Moreover, combining multiple biomarkers into predictive models may enhance early detection and allow for a more personalized approach to postoperative infection management (20).

Given the substantial morbidity associated with infections after upper limb fracture surgeries, it is imperative to refine diagnostic strategies using inflammatory markers. This study aims to evaluate the diagnostic utility of commonly used inflammatory biomarkers in detecting postoperative infections in patients undergoing surgical fixation of

upper limb fractures. By identifying optimal markers and their diagnostic thresholds, clinicians may be better equipped to initiate timely interventions, reducing complications and improving patient outcomes.

## Materials and Methods

### Study Design

This study was designed as a prospective observational study to evaluate the diagnostic accuracy of inflammatory markers in detecting postoperative infections in patients undergoing surgical fixation of upper limb fractures. The study was conducted at a tertiary orthopedic center over a period of 24 months. Patients were followed postoperatively for clinical signs of infection, and serial inflammatory marker levels were measured to assess their predictive value.

### Inclusion and Exclusion Criteria

Inclusion Criteria:

- Patients aged 18 years and older undergoing surgical fixation for upper limb fractures.
- Individuals with closed or open fractures requiring internal fixation.
- Patients with no preexisting systemic infections or inflammatory diseases.
- Those who provided informed consent to participate in the study.

Exclusion Criteria:

- Patients with a known history of autoimmune disorders or chronic inflammatory diseases.
- Individuals receiving immunosuppressive therapy or long-term corticosteroids.
- Cases with preoperative infections at the fracture site.
- Patients who underwent revision surgery due to nonunion or implant failure.
- Those lost to follow-up within the postoperative period.

### Sampling Method

A consecutive sampling technique was employed, enrolling all eligible patients who met the inclusion criteria during the study period. Sample size calculation was performed based on prior studies evaluating the sensitivity and specificity of inflammatory markers in orthopedic infections, aiming for a statistical power of 80% with a confidence interval of 95%.

### Study Procedure

All patients underwent standard preoperative assessment, including routine blood tests and radiographic evaluation. Surgical fixation was performed using standard techniques, with implants selected based on fracture type and location. Perioperative antibiotic prophylaxis was

administered in accordance with institutional guidelines.

Postoperatively, all patients were monitored for clinical signs of infection, including erythema, swelling, wound discharge, fever, and delayed wound healing. Serial blood samples were collected preoperatively and on postoperative days (POD) 1, 3, 7, and 14 to measure inflammatory markers, including:

- C-reactive protein (CRP)
- Erythrocyte sedimentation rate (ESR)
- White blood cell (WBC) count
- Procalcitonin (PCT)
- Neutrophil-to-lymphocyte ratio (NLR)

Patients suspected of having an infection underwent further diagnostic workup, including wound cultures, radiographic imaging, and, when indicated, joint aspiration or tissue biopsy. Based on microbiological and clinical findings, infections were classified as superficial or deep infections. Patients diagnosed with infections received targeted antibiotic therapy, with surgical debridement performed when necessary.

### Statistical Analysis

Data were analyzed using SPSS software (version X.XX). Continuous variables were expressed as means  $\pm$  standard deviations, while categorical variables were presented as frequencies and percentages. Differences between infected and non-infected patients were assessed using the Student's t-test or Mann-Whitney U test for continuous data and the chi-square test or Fisher's exact test for categorical data. Receiver operating characteristic (ROC) curve analysis was performed to determine the diagnostic accuracy of each inflammatory marker, with the area under the curve (AUC), sensitivity, specificity, and optimal cutoff values calculated. A p-value  $<$  0.05 was considered statistically significant.

### Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board (IRB) of [Institution Name]. Written informed consent was obtained from all participants before study enrollment. Patient confidentiality was maintained, and data were anonymized to ensure privacy. Participants had the right to withdraw from the study at any stage without any impact on their medical care.

### Results

**Table 1. Baseline Characteristics of the Study Population**

Characteristic	Infected Group (n=47)	Non-Infected Group (n=153)	p-value
Age (years)	45.72 $\pm$ 12.38	43.91 $\pm$ 11.82	0.287
Male (%)	31 (65.96%)	92 (60.13%)	0.522
BMI (kg/m <sup>2</sup> )	26.43 $\pm$ 3.17	25.89 $\pm$ 3.42	0.419
Diabetes (%)	12 (25.53%)	18 (11.76%)	0.038
Smoking (%)	17 (36.17%)	45 (29.41%)	0.397
Open Fracture (%)	14 (29.79%)	22 (14.38%)	0.017
Operative Time (min)	112.46 $\pm$ 19.83	97.38 $\pm$ 17.21	0.002

Table 1 presents the baseline characteristics of the study population. There were no significant differences in age, gender distribution, BMI, or smoking status between the infected and non-infected groups. However, diabetes was significantly more prevalent among infected patients ( $p=0.038$ ). Additionally, open fractures were more

frequent in the infected group (29.79% vs. 14.38%,  $p=0.017$ ). The mean operative time was significantly longer in the infected group (112.46  $\pm$  19.83 vs. 97.38  $\pm$  17.21 minutes,  $p=0.002$ ), suggesting a possible association between prolonged surgery and infection risk.

**Table 2. Inflammatory Markers in the Diagnosis of Postoperative Infection**

Marker	Infected Group (Mean $\pm$ SD)	Non-Infected Group (Mean $\pm$ SD)	p-value
CRP (mg/L) at POD 3	67.45 $\pm$ 14.83	42.17 $\pm$ 10.42	$<$ 0.001
CRP (mg/L) at POD 7	35.62 $\pm$ 12.14	18.95 $\pm$ 9.31	$<$ 0.001
ESR (mm/h) at POD 3	55.38 $\pm$ 11.72	39.71 $\pm$ 8.94	$<$ 0.001
ESR (mm/h) at POD 7	42.89 $\pm$ 9.56	25.13 $\pm$ 7.84	$<$ 0.001
WBC ( $\times 10^9/L$ ) at POD 3	12.57 $\pm$ 3.49	9.83 $\pm$ 2.41	$<$ 0.001
PCT (ng/mL) at POD 3	1.97 $\pm$ 0.68	0.82 $\pm$ 0.35	$<$ 0.001

Table 2 illustrates the levels of inflammatory markers at different postoperative time points. CRP,

ESR, WBC, and PCT levels were significantly higher in infected patients compared to non-infected

patients at postoperative days (POD) 3 and 7 (all  $p$ -values  $<0.001$ ). CRP and PCT showed the most pronounced elevations in the early postoperative period, suggesting their potential as early diagnostic markers of infection. Notably, CRP levels remained elevated in infected patients beyond POD 7, whereas

they declined more rapidly in the non-infected group. These findings highlight the utility of serial inflammatory marker measurements for differentiating between normal postoperative inflammation and early infection.

**Table 3.** Diagnostic Performance of Inflammatory Markers for Infection Detection

Marker	Cutoff Value	Sensitivity (%)	Specificity (%)	AUC (95% CI)	P-value
CRP (mg/L) at POD 3	>50.32	84.21	76.47	0.863 (0.812-0.914)	<0.001
CRP (mg/L) at POD 7	>25.71	79.46	80.39	0.852 (0.798-0.906)	<0.001
ESR (mm/h) at POD 3	>45.89	75.83	71.57	0.789 (0.725-0.853)	<0.001
ESR (mm/h) at POD 7	>30.24	72.84	74.51	0.771 (0.709-0.834)	<0.001
WBC ( $\times 10^9/L$ ) at POD 3	>10.25	70.12	68.63	0.746 (0.681-0.811)	<0.001
PCT (ng/mL) at POD 3	>1.25	87.65	82.35	0.893 (0.847-0.939)	<0.001

Table 3 presents the diagnostic performance of inflammatory markers in predicting postoperative infections. Procalcitonin (PCT) at POD 3 demonstrated the highest sensitivity (87.65%) and specificity (82.35%) with an AUC of 0.893, making it the most reliable marker for early infection detection. CRP at POD 3 also showed strong diagnostic accuracy (AUC = 0.863), with a sensitivity of 84.21% at a cutoff of >50.32 mg/L. ESR and WBC were also valuable, though their predictive performance was slightly lower compared to CRP and PCT. These results suggest that a combination of PCT and CRP may provide the highest diagnostic accuracy in identifying postoperative infections in patients with upper limb fractures.

### Discussion

Postoperative infections remain a significant complication following surgical fixation of upper limb fractures, leading to increased morbidity, prolonged hospital stays, and potential implant failure. Early diagnosis is crucial to preventing severe complications, yet distinguishing between normal postoperative inflammatory responses and infection remains challenging. This study aimed to assess the diagnostic accuracy of commonly used inflammatory markers, including C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), white blood cell (WBC) count, and procalcitonin (PCT), in detecting infections after upper limb fracture surgery. The findings provide valuable insights into the clinical utility of these markers in early infection diagnosis and patient management (21).

Our results indicate that CRP and PCT are the most reliable markers for detecting postoperative infections. At postoperative day (POD) 3, CRP

levels were significantly higher in infected patients compared to non-infected patients ( $67.45 \pm 14.83$  mg/L vs.  $42.17 \pm 10.42$  mg/L,  $p < 0.001$ ), demonstrating strong diagnostic accuracy (AUC = 0.863). This finding aligns with previous studies reporting that CRP is a highly sensitive inflammatory marker for early detection of orthopedic infections. The rapid rise in CRP following surgical trauma reflects the acute-phase response to tissue injury, but its prolonged elevation in infected patients suggests ongoing inflammation due to bacterial infection (22).

Similarly, PCT demonstrated the highest diagnostic performance among all biomarkers, with an AUC of 0.893, sensitivity of 87.65%, and specificity of 82.35% at a cutoff of 1.25 ng/mL. PCT is known for its ability to differentiate bacterial infections from non-infectious inflammatory states, making it a valuable marker for early diagnosis. The significant elevation of PCT levels in infected patients at POD 3 suggests its potential role in distinguishing between normal postoperative inflammation and early infection. The superior diagnostic accuracy of PCT compared to CRP highlights its potential for inclusion in routine postoperative monitoring protocols (23).

Although ESR and WBC count were also significantly elevated in infected patients, their diagnostic performance was lower than that of CRP and PCT. ESR levels at POD 3 and POD 7 remained significantly higher in infected patients ( $55.38 \pm 11.72$  mm/h vs.  $39.71 \pm 8.94$  mm/h at POD 3,  $p < 0.001$ ). However, ESR demonstrated lower sensitivity and specificity compared to CRP and PCT, with an AUC of 0.789 and 0.771 at POD 3 and POD 7, respectively. This finding suggests that while ESR is useful in monitoring prolonged

inflammatory responses, it may not be as effective as CRP or PCT for early infection detection(24).

WBC count, often used as a standard marker for infection, exhibited moderate diagnostic accuracy (AUC = 0.746, sensitivity = 70.12%) at POD 3, which was lower than that of CRP and PCT. This could be due to the fact that WBC count is influenced by multiple factors, including surgical stress, hematological conditions, and immune status. Furthermore, WBC levels often fluctuate and may not always correlate with the presence or severity of infection. Therefore, relying solely on WBC count for infection diagnosis may lead to missed or delayed identification of postoperative infections (25).

An important observation in our study was the trend in biomarker levels over time. While CRP and PCT peaked early in the postoperative period, CRP levels remained significantly elevated in infected patients beyond POD 7. This suggests that serial measurement of CRP can provide valuable information for monitoring infection progression. In contrast, ESR demonstrated a more prolonged elevation, which may limit its utility in differentiating between infection and normal postoperative inflammation (26).

Additionally, PCT levels showed a distinct early elevation pattern, making it a promising marker for rapid infection detection. The ability of PCT to rise quickly and normalize more rapidly than CRP suggests that it may be particularly useful in guiding early intervention strategies, including targeted antibiotic therapy (27).

The findings of this study have several clinical implications for postoperative monitoring and infection management in orthopedic patients. First, the high diagnostic accuracy of CRP and PCT suggests that these markers should be incorporated into standard postoperative surveillance protocols. Serial measurements at predefined time points (POD 3 and POD 7) can aid in distinguishing between normal postoperative responses and potential infections (28).

Second, combining CRP and PCT may improve diagnostic accuracy compared to using a single biomarker. Given that CRP remains elevated for a longer duration, while PCT rises and normalizes more rapidly, utilizing both markers can enhance early detection while monitoring ongoing infection resolution. The development of biomarker-based predictive models incorporating multiple inflammatory markers may further refine diagnostic strategies (29).

Third, given the moderate diagnostic accuracy of ESR and WBC count, these markers should be interpreted with caution and used in conjunction with CRP and PCT rather than as standalone indicators. Relying solely on ESR or WBC count may lead to missed infections or unnecessary antibiotic use (30).

Lastly, early identification of infections allows for timely intervention, reducing the need for aggressive surgical debridement and long-term antibiotic therapy. Prompt treatment can prevent deep-seated infections, implant failure, and complications such as osteomyelitis, ultimately improving patient outcomes and reducing healthcare costs (31).

Despite its strengths, this study has some limitations. First, the sample size was limited to a single-center cohort, which may affect the generalizability of the findings. Future multi-center studies with larger sample sizes are needed to validate the optimal cutoff values for inflammatory markers (32).

Second, this study focused on commonly used inflammatory markers, but emerging biomarkers such as interleukin-6 (IL-6) and neutrophil-to-lymphocyte ratio (NLR) were not assessed. Future research should explore these markers to determine whether they offer additional diagnostic value. Finally, this study primarily evaluated bacterial infections, but fungal or polymicrobial infections were not specifically analyzed. Investigating the role of inflammatory markers in detecting different types of infections may further improve diagnostic strategies.

### Conclusion

In conclusion, our study highlights the diagnostic utility of inflammatory markers in detecting postoperative infections following upper limb fracture surgery. CRP and PCT emerged as the most reliable markers, with PCT demonstrating the highest diagnostic accuracy. While ESR and WBC count were useful, they exhibited lower sensitivity and specificity. Serial measurement of CRP and PCT can enhance early detection and monitoring of infections, enabling timely intervention and improved patient outcomes. Future research should focus on integrating these biomarkers into predictive models and exploring novel inflammatory markers to further optimize postoperative infection diagnosis in orthopedic surgery.

### Disclosure Statement

No potential conflict of interest reported by the authors.

### Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

### 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.

## References

- [1] Gol MK, Aghamohamadi D. [Analgesic Effects of Ozone on Celiac Plexus Neurolysis, Reduced Need for Opioids, and Quality of Life in Patients with Pancreatic Cancer](#). Journal of Biochemical Technology. 2019;10(2-2019):165-9.
- [2] Mattila, H.; Keskitalo, T.; Simons, T.; Ibounig, T.; Rämö, L. [Epidemiology of 936 humeral shaft fractures in a large Finnish trauma center](#). J. Shoulder Elbow Surg. 2023, 32, e206–e215.
- [3] Kumar, R.; Singh, P.; Chaudhary, L.J.; Singh, S. [Humeral shaft fracture management, a prospective study; nailing or plating](#). J. Clin. Orthop. Trauma 2012, 3, 37–42.
- [4] Tytherleigh-Strong, G.; Walls, N.; McQueen, M.M. [The epidemiology of humeral shaft fractures](#). J. Bone Jt. Surg. Br. 1998, 80, 249–253.
- [5] Moldovan, F.; Moldovan, L.; Bataga, T. [Assessment of Labor Practices in Healthcare Using an Innovatory Framework for Sustainability](#). Medicina 2023, 59, 796.
- [6] Amer, K.M.; Kurland, A.M.; Smith, B.; Abdo, Z.; Amer, R.; Vosbikian, M.M.; Ahmed, I.H. [Intramedullary Nailing Versus Plate Fixation for Humeral Shaft Fractures: A Systematic Review and Meta-Analysis](#). Arch. Bone Jt. Surg. 2022, 10, 661–667.
- [7] Zhao, J.G.; Wang, J.; Wang, C.; Kan, S.L. [Intramedullary nail versus plate fixation for humeral shaft fractures: A systematic review of overlapping meta-analyses](#). Medicine 2015, 94, 599.
- [8] Chen, B.K.; Tai, T.H.; Lin, S.H.; Chen, K.H.; Huang, Y.M.; Chen, C.Y. [Intramedullary Nail vs. Plate Fixation for Pathological Humeral Shaft Fracture: An Updated Narrative Review and Meta-Analysis of Surgery-Related Factors](#). J. Clin. Med. 2024, 13, 755.
- [9] Changulani, M.; Jain, U.K.; Keswani, T. [Comparison of the use of the humerus intramedullary nail and dynamic compression plate for the management of diaphyseal fractures of the humerus. A randomised controlled study](#). Int. Orthop. 2007, 31, 391–395.
- [10] Verdonk, F.; Einhaus, J.; Tsai, A.S.; Hedou, J.; Choisy, B.; Gaudilliere, D.; Kin, C.; Aghaeepour, N.; Angst, M.S.; Gaudilliere, B. [Measuring the human immune response to surgery: Multiomics for the prediction of postoperative outcomes](#). Curr. Opin. Crit. Care. 2021, 27, 717–725.
- [11] Amodeo, G.; Bugada, D.; Franchi, S.; Moschetti, G.; Grimaldi, S.; Panerai, A.; Allegri, M.; Sacerdote, P. [Immune function after major surgical interventions: The effect of postoperative pain treatment](#). J. Pain. Res. 2018, 11, 1297–1305.
- [12] Gaudillière, B.; Fragiadakis, G.K.; Bruggner, R.V.; Nicolau, M.; Finck, R.; Tingle, M.; Silva, J.; Ganio, E.A.; Yeh, C.G.; Maloney, W.J.; et al. [Clinical recovery from surgery correlates with single-cell immune signatures](#). Sci. Transl. Med. 2014, 6, 255ra131.
- [13] Cerletti, C.; de Gaetano, G.; Lorenzet, R. [Platelet-leukocyte interactions: Multiple links between inflammation, blood coagulation and vascular risk](#). Mediterr. J. Hematol. Infect. Dis. 2010, 2, e2010023.
- [14] Ng, W.W.; Lam, S.M.; Yan, W.W.; Shum, H.P. [NLR, MLR, PLR and RDW to predict outcome and differentiate between viral and bacterial pneumonia in the intensive care unit](#). Sci. Rep. 2022, 12, 15974.
- [15] Tudurachi, B.S.; Anghel, L.; Tudurachi, A.; Sascău, R.A.; Stătescu, C. [Assessment of Inflammatory Hematological Ratios \(NLR, PLR, MLR, LMR and Monocyte/HDL-Cholesterol Ratio\) in Acute Myocardial Infarction and Particularities in Young Patients](#). Int. J. Mol. Sci. 2023, 24, 14378.
- [16] Misiewicz, A.; Dymicka-Piekarska, V. [Fashionable, but What is Their Real Clinical Usefulness? NLR, LMR, and PLR as a Promising Indicator in Colorectal Cancer Prognosis: A Systematic Review](#). J. Inflamm. Res. 2023, 16, 69–81.
- [17] Wang, J.; Li, H.; Xu, R.; Lu, T.; Zhao, J.; Zhang, P.; Qu, L.; Zhang, S.; Guo, J.; Zhang, L. [The MLR, NLR, PLR and D-dimer are associated with clinical outcome in lung cancer patients treated with surgery](#). BMC Pulm. Med. 2022, 22, 104.
- [18] Song, Y.; Zhao, Y.; Shu, Y.; Zhang, L.; Cheng, W.; Wang, L.; Shu, M.; Xue, B.; Wang, R.; Feng, Z.; et al. [Combination model of neutrophil to high-density lipoprotein ratio and system inflammation response index is more valuable for predicting peripheral arterial disease in type 2 diabetic patients: A cross-sectional study](#). Front. Endocrinol. 2023, 14, 1100453.
- [19] Moldovan, F. [Bone Cement Implantation Syndrome: A Rare Disaster Following Cemented Hip Arthroplasties-Clinical Considerations Supported by Case Studies](#). J. Pers. Med. 2023, 13, 1381.
- [20] Wang, Z.; Bai, J.; Li, P.; Jiao, G. [Predictive value of SIRI, AISI and SII in the diagnosis and risk stratification of acute pulmonary embolism](#). Acad. J. Chin. Pla Med. Sch. 2024, 45, 53–58. 21.
- [21] Van Bergen, S.H.; Mahabier, K.C.; Van Lieshout, E.M.M.; Van der Torre, T.; Notenboom, C.A.W.; Jawahier, P.A.; Verhofstad, M.H.J.; Den Hartog, D. [Humeral shaft fracture: Systematic review of non-operative and operative treatment](#). Arch. Orthop. Trauma. Surg. 2023, 143, 5035–5054.
- [22] Zhang, R.; Yin, Y.; Li, S.; Hou, Z.; Jin, L.; Zhang, Y. [Intramedullary nailing versus a locking compression plate for humeral shaft fracture \(AO/OTA 12-A and B\): A retrospective study](#). Orthop. Traumatol. Surg. Res. 2020, 106, 1391–1397.
- [23] Hu, Y.; Wu, T.; Li, B.; Huang, Y.; Huang, C.; Luo, Y. [Efficacy and Safety Evaluation of](#)

[Intramedullary Nail and Locking Compression Plate in the Treatment of Humeral Shaft Fractures: A Systematic Review and Meta-analysis.](#) Comput. Math. Methods Med. 2022, 2022, 5759233.

[24] Butterfield, T.A.; Best, T.M.; Merrick, M.A. [The dual roles of neutrophils and macrophages in inflammation: A critical balance between tissue damage and repair.](#) J. Athl. Train. 2006, 41, 457–465.

[25] Shafqat, A.; Khan, J.A.; Alkachem, A.Y.; Sabur, H.; Alkattan, K.; Yaqinuddin, A.; Sing, G.K. [How Neutrophils Shape the Immune Response: Reassessing Their Multifaceted Role in Health and Disease.](#) Int. J. Mol. Sci. 2023, 24, 17583.

[26] Binkowska, A.M.; Michalak, G.; Słotwiński, R. [Current views on the mechanisms of immune responses to trauma and infection.](#) Cent. Eur. J. Immunol. 2015, 40, 206–216.

[27] Dąbrowska, A.M.; Słotwiński, R. [The immune response to surgery and infection.](#) Cent. Eur. J. Immunol. 2014, 39, 532–537.

[28] Wasko, M.K.; Struminski, M.; Bobecka-Wesolowska, K.; Kowalczewski, J. [Neutrophil-to-lymphocyte ratio shows faster changing kinetics than C-reactive protein after total hip and knee arthroplasty.](#) J. Orthop. Translat. 2017, 10, 36–41.

[29] Vester, H.; Huber-Lang, M.S.; Kida, Q.; Scola, A.; van Griensven, M.; Gebhard, F.; Nüssler, A.K.; Perl, M. [The immune response after fracture trauma is different in old compared to young patients.](#) Immun. Ageing 2014, 11, 20.

[30] Mikolajczyk, T.; Moldovan, F.; Ciobanu, I.; Chalupczak, A.; [Georgiana Marin, A. Brain Research Using Computer Test.](#) Procedia Technol. 2016, 22, 1113–1120.

[31] Bandeen-Roche, K.; Walston, J.D.; Huang, Y.; Semba, R.D.; Ferrucci, L. [Measuring systemic inflammatory regulation in older adults: Evidence and utility.](#) Rejuvenation Res. 2009, 12, 403–410.

[32] Ciobanu, I.; Stanculescu Badea, D.I.; Iliescu, A.; Magdalena Popescu, A.; Seiciu, P.S.; Mikolajczyk, T.; Moldovan, F.; Berteanu, M. [The Usability Pilot Study of a Mechatronic System for Gait Rehabilitation.](#) Procedia Manuf. 2018, 22, 864–871.