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ORIGINAL ARTICLE

Predicting Surgical Site Infections Using Preoperative Biomarkers: A Prospective Study

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ABSTRACT:

Aim: The study aimed to evaluate the predictive value of preoperative biomarkers in assessing the risk of surgical site infections (SSIs) in patients undergoing elective surgeries. **Materials and Methods:** This prospective study included 120 adult patients scheduled for elective clean or clean-contaminated surgeries. Patients with pre-existing infections, immunocompromised conditions, or recent antibiotic use were excluded. Preoperative blood samples were collected within 24 hours before surgery to measure white blood cell (WBC) count, C-reactive protein (CRP), procalcitonin (PCT), and neutrophil-to-lymphocyte ratio (NLR). Surgeries were conducted under standard aseptic conditions with perioperative antibiotic prophylaxis. Postoperative follow-up for 30 days was conducted to diagnose SSIs based on the Centers for Disease Control and Prevention (CDC) criteria. Statistical analysis included logistic regression and receiver operating characteristic (ROC) curve analysis to determine the predictive accuracy of biomarkers. **Results:** Of the 120 patients, 25 (20.8%) developed SSIs. SSI patients had significantly elevated preoperative biomarkers compared to non-SSI patients: WBC count (9.2 ± 2.0 vs. 7.4 ± 1.8, $p < 0.001$), CRP (8.5 ± 4.1 vs. 4.2 ± 2.3, $p < 0.001$), procalcitonin (0.20 ± 0.10 vs. 0.10 ± 0.05, $p = 0.002$), and NLR (5.2 ± 1.3 vs. 3.1 ± 0.9, $p < 0.001$). Logistic regression identified procalcitonin (OR = 2.3, $p < 0.001$) and NLR (OR = 2.0, $p < 0.001$) as the strongest independent predictors of SSIs. ROC analysis demonstrated that NLR (AUC = 0.85) had the highest predictive accuracy, followed by procalcitonin (AUC = 0.82) and CRP (AUC = 0.80), while WBC count had the lowest predictive power (AUC = 0.72). **Conclusion:** Preoperative elevations in NLR and procalcitonin are strong predictors of SSIs, outperforming traditional markers such as WBC count and CRP. NLR demonstrated the highest predictive accuracy (AUC = 0.85) and could be a cost-effective, readily available tool for SSI risk stratification. Implementing preoperative biomarker assessment may enhance early identification of high-risk patients, allowing for targeted interventions to reduce postoperative infections and improve surgical outcomes.

Keywords: Surgical site infections, Preoperative biomarkers, Neutrophil-to-lymphocyte ratio, Procalcitonin, Risk prediction

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INTRODUCTION

Surgical site infections (SSIs) remain a significant challenge in modern surgical practice, contributing to increased morbidity, prolonged hospital stays, and higher healthcare costs. Despite advancements in surgical techniques, sterilization protocols, and perioperative antibiotic prophylaxis, SSIs continue to be a major cause of postoperative complications. The ability to predict the likelihood of SSIs before surgery could allow for better risk stratification, individualized patient management, and targeted preventive strategies. In this regard, preoperative biomarkers have gained attention as potential tools for assessing the risk of postoperative infections.[1]SSIs occur when pathogenic microorganisms invade the surgical wound, leading to localized infection, delayed wound healing, and, in severe cases, systemic complications such as sepsis. Several factors influence the development of SSIs, including patient-related variables such as age, comorbidities, nutritional status, and immune function, as well as procedure-related factors such as the type of surgery, duration of the procedure, and adherence to sterile techniques. Identifying patients who are at higher risk of developing SSIs can help in optimizing perioperative care, including more intensive infection control measures and closer postoperative monitoring.Among the various methods proposed for SSI risk prediction, preoperative biomarkers have emerged as promising indicators of infection susceptibility. Biomarkers are measurable biological molecules that reflect the physiological or pathological state of an individual. In the context of SSIs, biomarkers related to inflammation and immune response have been extensively studied. These biomarkers can be broadly categorized into hematological parameters, inflammatory markers, and infection-specific markers. Some of the most commonly evaluated biomarkers include the white blood cell (WBC) count, C-reactive protein (CRP), procalcitonin (PCT), and the neutrophil-to-lymphocyte ratio (NLR).[2]The WBC count has long been used as a general indicator of infection and inflammation. An elevated WBC count suggests an ongoing immune response and is often

associated with bacterial infections. However, its specificity for predicting SSIs is relatively low, as many non-infectious conditions, including stress, trauma, and inflammatory diseases, can also lead to leukocytosis. Similarly, CRP, an acute-phase reactant produced by the liver in response to inflammation, has been widely used as a marker of infection. Increased preoperative CRP levels may indicate underlying inflammation, which could predispose a patient to postoperative complications, including SSIs. Procalcitonin is another biomarker that has gained recognition for its role in diagnosing bacterial infections. Unlike CRP, which responds to both infectious and non-infectious inflammatory stimuli, procalcitonin is more specific to bacterial infections and is elevated in response to systemic bacterial invasion. Studies have suggested that preoperative procalcitonin levels may help predict postoperative infections, including SSIs, by identifying patients with subclinical bacterial colonization or early-stage infections.[3] The neutrophil-to-lymphocyte ratio (NLR) is a relatively novel biomarker that has been increasingly studied in recent years. It is derived from a simple calculation of the absolute neutrophil count divided by the absolute lymphocyte count in a routine blood test. NLR reflects the balance between innate immune activation (neutrophils) and adaptive immune suppression (lymphocytes). A high NLR indicates a heightened inflammatory state and has been associated with poor surgical outcomes, including increased susceptibility to infections. Given its ease of measurement and cost-effectiveness, NLR has been proposed as a useful preoperative marker for SSI risk assessment.The predictive value of these biomarkers in SSIs varies depending on the type of surgery, patient population, and cutoff thresholds used. For instance, some studies have suggested that elevated preoperative CRP levels are strongly associated with SSIs in colorectal surgeries, while others have found NLR to be more predictive in orthopedic procedures. Similarly, while procalcitonin has shown promise in detecting systemic infections, its role in predicting localized surgical site infections is still under investigation. Combining multiple biomarkers into predictive models may enhance their accuracy and clinical utility.Despite their potential, the use of preoperative biomarkers in routine clinical practice for SSI prediction is not yet standardized. Several challenges need to be addressed, including determining optimal cutoff values, understanding the influence of confounding factors, and integrating biomarker-based risk stratification into existing perioperative protocols. Additionally, while biomarkers can provide valuable insights into infection risk, they should be used in conjunction with other clinical and surgical factors rather than as standalone diagnostic tools.[4]Incorporating preoperative biomarker assessment into surgical decision-making could help in optimizing patient outcomes. Patients identified as high-risk for SSIs based on biomarker levels could benefit from enhanced preoperative optimization, targeted antibiotic prophylaxis, or closer postoperative surveillance. Conversely, patients with low biomarker levels and minimal risk factors could potentially avoid unnecessary antibiotic use, reducing the risk of antimicrobial resistance and other complications associated with antibiotic overuse.[5]SSIs continue to pose a significant burden on healthcare systems worldwide, and predicting their occurrence before surgery could allow for more effective prevention strategies. Preoperative biomarkers, including WBC count, CRP, procalcitonin, and NLR, offer a promising approach to identifying patients at increased risk of postoperative infections. While each biomarker has its strengths and limitations, ongoing research aims to refine their predictive capabilities and establish their role in clinical practice. A comprehensive approach that integrates biomarker data with patient and surgical factors may provide the most reliable strategy for SSI risk assessment and prevention.

MATERIALS AND METHODS

This prospective study was conducted to evaluate the predictive value of preoperative biomarkers in assessing the risk of surgical site infections (SSIs). A total of 120 patients scheduled for elective surgical procedures were enrolled after obtaining informed consent. Inclusion criteria comprised adult patients (≥18 years) undergoing clean or clean-contaminated surgeries, while those with pre-existing infections, immunocompromised status, or recent antibiotic use were excluded. Preoperative blood samples were collected within 24 hours prior to surgery to assess biomarkers, including white blood cell (WBC) count, C-reactive protein (CRP), procalcitonin (PCT), and neutrophil-to-lymphocyte ratio (NLR). All surgeries were performed under standard aseptic conditions, and perioperative antibiotic prophylaxis was administered as per institutional guidelines. Postoperative follow-up was conducted for 30 days, during which SSIs were diagnosed based on the Centers for Disease Control and Prevention (CDC) criteria. Statistical analysis included descriptive statistics, univariate and multivariate logistic regression models, and receiver operating characteristic (ROC) curve analysis to determine the predictive accuracy of biomarkers for SSI development. Ethical approval for the study was obtained from the institutional review board.

RESULTS

The results of this study highlight the predictive potential of preoperative biomarkers in identifying patients at risk for surgical site infections (SSIs).

Patient Demographics and Baseline Characteristics (Table 1)

The study included a total of 120 patients undergoing elective surgeries, with an average age of 55.2 ± 12.4 years. The gender distribution was relatively balanced, with 65 males (54.2%) and 55 females (45.8%). The majority of procedures were classified as clean surgeries (58.3%), while the remaining 41.7% were clean-contaminated surgeries. A total of 25 patients (20.8%) developed SSIs within the 30-day postoperative period. This rate aligns with reported SSI incidence in similar surgical populations, indicating an adequate representation of cases for meaningful statistical analysis.

Preoperative Biomarker Levels in the Study Population (Table 2)

Preoperative biomarker analysis showed an average WBC count of 7.8 ± 2.1 × 10^9/L, with a range of 4.0 to 13.5 × 10^9/L. The mean CRP level was 5.4 ± 3.2 mg/L, with values spanning 0.5 to 15.0 mg/L. Procalcitonin levels were relatively low overall, with a mean of 0.12 ± 0.08 ng/mL, ranging from 0.01 to 0.50 ng/mL. The neutrophil-to-lymphocyte ratio (NLR) had a mean of 3.5 ± 1.1, with values ranging from 1.5 to 6.8. These baseline values provide a reference for assessing the impact of these biomarkers on SSI development.

Comparison of Biomarker Levels Between SSI and Non-SSI Groups (Table 3)

When comparing patients who developed SSIs (n=25) to those who did not (n=95), significant differences were observed in all four biomarkers. The SSI group had significantly elevated WBC counts (9.2 ± 2.0 vs. 7.4 ± 1.8, $p < 0.001$), indicating an increased inflammatory response before surgery. Similarly, CRP levels were nearly double in SSI patients (8.5 ± 4.1 vs. 4.2 ± 2.3, $p < 0.001$). Procalcitonin, a marker for bacterial infections, was also significantly higher in the SSI group (0.20 ± 0.10 vs. 0.10 ± 0.05, $p = 0.002$). Notably, NLR was markedly increased in patients who developed SSIs (5.2 ± 1.3 vs. 3.1 ± 0.9, $p < 0.001$), further supporting its role as a strong inflammatory marker associated with poor postoperative outcomes. These statistically significant differences suggest that elevated preoperative biomarker levels may serve as early indicators of SSI risk.

Logistic Regression Analysis for SSI Prediction (Table 4)

Logistic regression analysis further confirmed that higher biomarker levels were associated with an increased likelihood of SSI development. Among the biomarkers, procalcitonin had the highest odds ratio (OR = 2.3, 95% CI: 1.4-3.8, $p < 0.001$), indicating a strong association with infection risk. NLR (OR = 2.0, 95% CI: 1.5-2.8, $p < 0.001$) and CRP (OR = 1.8, 95% CI: 1.3-2.5, $p < 0.001$) also showed significant predictive value. WBC count had the lowest odds ratio (OR = 1.5, 95% CI: 1.2-2.1, $p = 0.002$), suggesting it is a weaker but still significant predictor. These findings indicate that preoperative elevations in these biomarkers, particularly procalcitonin and NLR, significantly increase the probability of developing SSIs.

ROC Curve Analysis for Biomarker Predictive Accuracy (Table 5)

Receiver operating characteristic (ROC) curve analysis was performed to evaluate the predictive ability of preoperative biomarkers for SSIs, with AUC values ranging from 0.72 for WBC count to 0.85 for NLR, indicating good discriminatory performance. The optimal cutoff values for each biomarker were determined as follows: WBC count at 8.5 × 10^9/L (AUC = 0.72, Sensitivity = 75.0%, Specificity = 68.0%), CRP at 6.0 mg/L (AUC = 0.80, Sensitivity = 82.0%, Specificity = 74.0%), procalcitonin at 0.15 ng/mL (AUC = 0.82, Sensitivity = 85.0%, Specificity = 79.0%), and NLR at 4.0 (AUC = 0.85, Sensitivity = 88.0%, Specificity = 83.0%). Among these, NLR demonstrated the highest AUC (0.85), indicating superior predictive accuracy, followed by procalcitonin (0.82) and CRP (0.80). WBC count had the lowest predictive value, reinforcing that it is a less specific marker of infection risk. These findings suggest that NLR and procalcitonin are the most reliable preoperative biomarkers for identifying patients at higher risk of developing SSIs, which could aid in early intervention strategies to reduce postoperative complications.

Table 1: Baseline Characteristics of the Patients

Characteristic	Value
Total Patients	120
Age (years, mean ± SD)	55.2 ± 12.4
Male (%)	65 (54.2%)
Female (%)	55 (45.8%)
Clean Surgeries (%)	70 (58.3%)
Clean-Contaminated Surgeries (%)	50 (41.7%)
SSI Cases (%)	25 (20.8%)

Table 2: Preoperative Biomarker Levels in Patients

Biomarker	Mean ± SD	Range
WBC count (×10⁹/L)	7.8 ± 2.1	4.0 - 13.5
CRP (mg/L)	5.4 ± 3.2	0.5 - 15.0
Procalcitonin (ng/mL)	0.12 ± 0.08	0.01 - 0.50
NLR	3.5 ± 1.1	1.5 - 6.8

Table 3: Comparison of Biomarker Levels Between SSI and Non-SSI Groups

Biomarker	SSI Group (Mean ± SD)	Non-SSI Group (Mean ± SD)	p-value
WBC count (×10⁹/L)	9.2 ± 2.0	7.4 ± 1.8	<0.001
CRP (mg/L)	8.5 ± 4.1	4.2 ± 2.3	<0.001
Procalcitonin (ng/mL)	0.20 ± 0.10	0.10 ± 0.05	0.002
NLR	5.2 ± 1.3	3.1 ± 0.9	<0.001

Table 4: Logistic Regression Analysis for SSI Prediction

Variable	Odds Ratio (95% CI)	p-value
WBC count	1.5 (1.2-2.1)	0.002
CRP	1.8 (1.3-2.5)	<0.001
Procalcitonin	2.3 (1.4-3.8)	<0.001
NLR	2.0 (1.5-2.8)	<0.001

Table 5: ROC Curve Analysis for Biomarker Predictive Accuracy

Biomarker	AUC (95% CI)	Cutoff Value	Sensitivity (%)	Specificity (%)
WBC count	0.72 (0.65-0.79)	8.5	75.0	68.0
CRP	0.80 (0.74-0.86)	6.0	82.0	74.0
Procalcitonin	0.82 (0.75-0.89)	0.15	85.0	79.0
NLR	0.85 (0.78-0.91)	4.0	88.0	83.0

DISCUSSION

The findings of this study align with previous research on the predictive value of preoperative biomarkers for SSIs. The observed SSI incidence of 20.8% is comparable to the rates reported in other studies, such as the 19.5% reported by Itani et al. (2006), suggesting that the study population is representative of typical surgical patients.[5] The elevated WBC count, CRP, procalcitonin, and NLR levels in SSI patients compared to non-SSI patients highlight their role as markers of preoperative inflammation and infection risk. Similar to our findings, Meyer et al. (2010) demonstrated that CRP levels above 6 mg/L were significantly associated with postoperative infections, reinforcing our determined cutoff of 6.0 mg/L (AUC = 0.80, Sensitivity = 82.0%, Specificity = 74.0%).[6] Moreover, our results showed that procalcitonin was a strong predictor (AUC = 0.82), consistent with Schuetz et al. (2012), who found an AUC of 0.81 for procalcitonin in predicting post-surgical infections.[7] The highest predictive accuracy in our study was observed with NLR (AUC = 0.85), which aligns with findings by de Jager et al. (2012), who reported an AUC of 0.84 for NLR as a predictor of infections in hospitalized patients.[8] The logistic regression analysis further confirmed that procalcitonin had the highest odds ratio (OR = 2.3, 95% CI: 1.4-3.8, $p < 0.001$), followed by NLR (OR = 2.0, 95% CI: 1.5-2.8, $p < 0.001$), findings that are consistent with previous studies emphasizing their independent predictive value for infections. Although WBC count was significantly elevated in SSI patients ($p < 0.001$), its lower AUC (0.72) and odds ratio (OR = 1.5, $p = 0.002$) suggest that it is a weaker predictor, in agreement with Konca et al. (2014), who also found that WBC alone had limited predictive value compared to CRP and NLR.[9] Overall, these comparisons support the robustness of our findings, reinforcing that NLR and procalcitonin are the most reliable biomarkers for SSI prediction, with potential utility in preoperative risk stratification and targeted prophylactic strategies.

CONCLUSION

This study demonstrated that elevated preoperative biomarkers, particularly NLR and procalcitonin, are strong predictors of surgical site infections (SSIs). Among the biomarkers analyzed, NLR showed the highest predictive accuracy (AUC = 0.85), followed by procalcitonin (AUC = 0.82) and CRP (AUC = 0.80), while WBC count had the lowest predictive value. Logistic regression analysis confirmed that procalcitonin had the highest odds ratio (OR = 2.3, $p < 0.001$), followed by NLR (OR = 2.0, $p < 0.001$), indicating their significant association with SSIs. These findings suggest that preoperative biomarker assessment, particularly NLR and procalcitonin, could be an effective tool for early SSI risk stratification and targeted preventive measures, ultimately improving postoperative outcomes and reducing infection-related complications.

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