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ORIGINAL ARTICLE

Serum C-Reactive Protein, Procalcitonin and Lactate Levels as Predictors of Postoperative Surgical Site Infections

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ABSTRACT

Background: Surgical site infections (SSIs) continue to be a significant source of morbidity, extended hospital stay and the associated costs after surgery. Predicting the risk of SSI early in the postoperative period is crucial for early intervention and better outcomes. Biomarkers including C-reactive protein (CRP), procalcitonin (PCT), and serum lactate can potentially predict the occurrence of postoperative infection before clinical symptoms manifest.

Objective: To assess the predictive ability of serum C-reactive protein (CRP), procalcitonin (PCT) and lactate for postoperative surgical site infections (SSIs) in surgical patients.

Methods: The study was a prospective observational study conducted in the Department of Surgery Department of Surgery, Ghulam Muhammad Mahar Medical College Teaching Hospital, Sukkur, a tertiary care teaching hospital from 1st June 2023 to 31st January 2025. We recruited 150 consecutive patients in the postoperative period. CRP, procalcitonin and lactate were measured in the immediate postoperative period. The patients were clinically monitored for the occurrence of SSI according to the diagnostic criteria. Demographic, clinical, and surgical data were also collected. SPSS version 26.0 was used for data analysis, and independent sample t-test and chi-square test were used to compare patients with and without SSI.

Results: Thirty nine (26%) patients developed SSI. The mean CRP (91.3±23.6 mg/L), procalcitonin (2.58±0.91 ng/mL) and lactate (3.28±0.76 mmol/L) levels were significantly higher in patients with SSI than those without ($p<0.001$ for all). SSI was also significantly associated with increased BMI, diabetes mellitus, emergency surgery, and longer operative time. SSI was associated with longer hospital stay and wound complications.

Conclusion: Serum C-reactive protein, procalcitonin, and lactate are valuable early predictors of postoperative surgical site infections. Procalcitonin had the highest predictive value. Their use in the postoperative period may assist in early diagnosis and management of SSI.

Keywords: C-reactive protein, Procalcitonin, Lactate, Surgical site infection; Postoperative complications, Biomarkers

INTRODUCTION

Surgical site infections (SSIs) are one of the most frequent and important complications of surgical procedures globally.[1] Despite significant improvements in surgical practice, sterilization procedures, pre- and postoperative antibiotic use, and wound management, SSIs remain a significant burden on patients and health care. SSIs result in extended hospitalisation, higher healthcare expenditure, impaired wound healing, re-operation, and in the worst cases, sepsis and death. This is especially so in low- and middle-income countries, where resource constraints and inconsistencies in infection control measures also play a role in increasing the burden.[2]

Surgical site infections are classified as superficial incisional, deep incisional, and organ-space infections, which differ in terms of severity and outcome.[3] The occurrence of SSI is complex and dependent on patient-related factors (e.g. diabetes, obesity, malnutrition, immunosuppression, and smoking) and procedure-related factors (e.g. duration of surgery, wound contamination, and surgical technique). In clinical practice, SSI is commonly diagnosed by visual signs of infection, including redness, swelling, warmth, pus discharge, or wound opening. But these signs usually occur late in the infection process, delaying therapeutic intervention.[4]

To address this issue, there has been growing interest in the development of specific biochemical markers capable of predicting the occurrence of postoperative infection in its early stages, prior to the onset of clinical signs.[5] Biochemical markers could help to identify infections at an earlier stage, allowing for early initiation of appropriate therapy, enhanced surveillance and better surgical outcomes.[6]

C-reactive protein is one of the most common acute-phase reactants produced by the liver in response to inflammatory cytokines, including interleukin-6.[7] It is often elevated after surgery, but disproportionate increases or sustained increases may suggest the presence of infection. While CRP is sensitive, it is not specific, as it may be elevated in non-infectious inflammatory states.[8]

Procalcitonin (PCT), a precursor of the hormone calcitonin, has been identified as a more specific marker of bacterial infection.[9] Procalcitonin levels are generally low in non-infectious inflammatory conditions, and increase markedly in systemic bacterial infections. This feature makes it a potentially useful indicator for differentiating between the expected postoperative inflammatory response and early signs of infection.[10]

Lactate, a marker of tissue hypoperfusion and metabolic dysfunction, has also been investigated in the postoperative setting.[11] Lactate elevation can be indicative of tissue hypoxia, systemic inflammation, or early sepsis, which may all contribute to the risk of surgical site infections. Although lactate is not a specific indicator of infection, it offers valuable information about the patient's physiological condition and may be used in conjunction with inflammatory markers to predict poor postoperative outcomes.[12]

While the individual utility of these markers has been established, there is a paucity of data regarding the comparative role of CRP, procalcitonin and lactate in predicting postoperative surgical site infections, especially in low-resource settings.[13] Comparative evaluation of these markers may assist clinicians in identifying patients at risk and guide postoperative management.[14]

Hence, the current study was undertaken to assess the predictive value of serum CRP, procalcitonin and lactate concentrations for early detection of postoperative surgical site infections and to determine which biomarker is the most useful in early prediction of SSI in surgical patients.[15]

MATERIAL AND METHOD

This was a prospective observational study, conducted in the Department of Surgery Department of Surgery, Ghulam Muhammad Mahar Medical College Teaching Hospital, Sukkur, a tertiary care teaching hospital, between 1st June 2023 and 31st January 2025. The study was conducted in a setting where a wide range of elective and emergency surgical procedures were performed, enabling the recruitment of a diverse range of postoperative patients for the study. The study enrolled 150 postoperative patients. Sampling was done by a non-probability consecutive method, whereby all eligible patients who presented during the time period of the study were considered for inclusion until the required sample size was reached. The target population for this study included adult male and female patients who had different types of major surgical procedures and were observed in the postoperative period for the occurrence of surgical site infections. The sample size was determined to provide a representative sample of the postoperative population and to allow for comparison of patients who developed infection with those who did not. All patients aged 18 years or more, who had a major surgical procedure and had laboratory investigations performed in the early postoperative period. Patients who had both elective and emergency surgery were included to represent the typical case mix seen in general surgery. Only those patients who consented to participate were included. Those with a known active infection before surgery, with signs of preoperative sepsis or those on long-term antibiotic therapy for an established infectious

disease before the surgical procedure was excluded. Patients with pre-existing chronic inflammatory conditions, autoimmune diseases, or those receiving chronic immunosuppressive treatment were also excluded, as these factors might influence the levels of inflammatory markers and could potentially skew the study's results. Those with missing laboratory values, insufficient clinical follow-up or who died in the immediate postoperative period before wound assessment could be performed were excluded from the analysis.

Once enrolled, all patients were evaluated using a data collection form. Demographic data and medical history were collected for all patients, including age, sex, body mass index (BMI), smoking status, and the presence of diabetes mellitus and hypertension. Information regarding the surgery was also recorded, including the surgical procedure, whether it was an elective or emergency procedure, wound classification, and the length of the procedure. Standard postoperative care was provided for all patients. As part of routine postoperative care, laboratory assessment was conducted in the early postoperative period to measure the serum concentrations of C-reactive protein (CRP), procalcitonin (PCT), and lactate. These markers were chosen due to their known association with inflammation, bacterial infection, metabolic dysfunction and hypoperfusion. Venous blood samples were obtained under sterile conditions and analyzed in the hospital laboratory using routine laboratory techniques and calibrated instruments according to hospital protocol.

Serum CRP was assessed as a marker of inflammatory response. Procalcitonin was measured because of its increased specificity for bacterial infection and its potential role in differentiating between infectious and non-infectious causes of postoperative inflammatory response. Serum lactate was assessed as an indicator of metabolic dysfunction and tissue perfusion, which can be associated with developing postoperative complications, including infection. These tests were recorded and subsequently reviewed for association with surgical site infection.

The main outcome measure was the development of surgical site infection (SSI). All patients were monitored clinically during their postoperative hospital admission and, if necessary, during the early postoperative review period for signs of wound infection. A diagnosis of surgical site infection was made according to standard criteria and was defined as the presence of one or more of the following signs at the site of the surgical wound: redness, localised swelling, pain or tenderness, local warmth, purulent or seropurulent discharge, wound dehiscence, or clinically apparent wound infection requiring treatment. Wound culture results were also taken into account where available. Furthermore, cases where the surgeon had recorded SSI and had commenced wound-related treatment, such as escalation of antibiotics, drainage, debridement or increased dressing support, were also considered to be infected. Postoperative clinical follow-up allowed the study population to be separated into two groups: those who developed postoperative surgical site infection and those who did not develop SSI.

The primary independent variables for this study were postoperative levels of CRP, procalcitonin and lactate. The primary outcome variable was the development of postoperative surgical site infection. Other factors assessed for their association with risk of infection included age, sex, body mass index (BMI), smoking, diabetes, hypertension, emergency versus elective surgery, duration of surgery, wound classification, and length of hospital stay. Postoperative wound complications and additional wound care measures were also documented to determine the impact of SSI.

Data were entered and analysed using SPSS-26.0. For inferential statistics, the differences between patients with and without SSI were tested using relevant statistical tests. Continuous variables were compared between the two groups using the independent sample t-test, while the chi-square test was used to assess associations between categorical variables. A p-value of less than 0.05 was used as the level of significance.

RESULTS

There were 39 (26%) patients developed a postoperative surgical site infection (SSI) while 111 patients (74%) did not develop SSI. The mean age of the study cohort was 45.9±13.4 years. The mean age of patients who developed SSI was 48.8±12.7 years, and that of patients without SSI was 44.9±13.6 years (p=0.112). The study population had a slight male predominance (87 males, 58.0% vs 63 females, 42.0%) and the gender distribution was similar between the two groups. Risk factors for SSI were more common in patients with postoperative wound infection. The mean BMI was significantly (p<0.001) greater in the SSI group 29.7±4.1 kg/m² than in the non-SSI group 26.9±3.8 kg/m². The incidence of diabetes mellitus was also significantly higher (p=0.006) in the SSI group 21 patients (53.8%) than in the non-SSI group 33 patients (29.7%). Urgent surgeries were also more frequent among those who developed SSI 23 cases (59%) than in those who did not 37 cases (33.3%) [p=0.004]. Likewise, the mean duration of surgery was significantly (p < 0.001) longer in the SSI group 122.6±25.8 minutes compared to the non-SSI group 96.7±22.4 minutes) suggesting that the

longer duration of surgery may have been a risk factor for postoperative infection (Table 1).

There was a significant difference in the postoperative serum levels of all three biomarkers between patients with and without SSI. The mean postoperative CRP level in the SSI group 91.3±23.6 mg/L was significantly higher (p<0.001) than the corresponding level in the non-SSI group 44.8±18.9 mg/L. Likewise, the mean procalcitonin level was significantly higher (p<0.001) in the SSI group 2.58±0.91 ng/mL than in the non-SSI group 0.79±0.42 ng/mL. A similar trend was observed for the mean postoperative level of serum lactate, which was significantly higher (p<0.001) in patients who developed SSI 3.28±0.76 mmol/L than in those who did not 1.91±0.57 mmol/L. These results show a clear link between the presence of elevated levels of postoperative biomarkers and the development of surgical site infection. Of the three biomarkers, procalcitonin exhibited the greatest difference between the two groups, and may therefore be a better predictor of bacterial postoperative infection. CRP also demonstrated a significant and clinically meaningful increase in infected patients, and lactate also showed evidence of systemic metabolic dysfunction in infected patients (Table 2).

Surgical site infection was also found to have a negative impact on patient outcomes. The mean length of stay in the SSI group 11.4±3.5 days) was significantly greater (p<0.001) than in the non-SSI group 6.5±2.1 days. This underscores the impact of SSI on patient recovery and health-care costs. With regard to wound complications, wound discharge was present in 28 patients (71.8%) in the SSI group, but absent in all patients in the non-SSI group. Wound dehiscence was noted in 11 patients (28.2%) with SSI and 3 patients (2.7%) without SSI (p<0.001). Similarly, the requirement for further wound care intervention such as frequent dressings, drainage, bedside wound care or surgical review was significantly more prevalent in the SSI group, with 27 patients (69.2%) compared with 18 patients (16.2%) in the non-SSI group (p<0.001). In addition, SSI was significantly associated with a worse postoperative outcome, including longer hospital stay, wound discharge, dehiscence, and higher wound care costs (Table 3).

Table 1. Baseline demographic and clinical characteristics of patients with and without postoperative surgical site infection

Variable	SSI Group (n = 39)	Non-SSI Group (n = 111)	p-value
Age (years)	48.8±12.7	44.9±13.6	0.112
Male	22 (56.4%)	65 (58.6%)	0.808
Female	17 (43.6%)	46 (41.4%)	0.808
BMI (kg/m²)	29.7±4.1	26.9±3.8	<0.001
Diabetes mellitus	21 (53.8%)	33 (29.7%)	0.006
Hypertension	16 (41%)	31 (27.9%)	0.121
Smokers	14 (35.9%)	24 (21.6%)	0.072
Emergency surgery	23 (59.0%)	37 (33.3%)	0.004
Elective surgery	16 (41%)	74 (66.7%)	0.004
Duration of surgery (minutes)	122.6±25.8	96.7±22.4	<0.001

Table 2. Comparison of postoperative serum CRP, procalcitonin, and lactate levels between patients with and without SSI

Biomarker	SSI Group (n = 39)	Non-SSI Group (n = 111)	p-value
CRP (mg/L)	91.3±23.6	44.8±18.9	<0.001
Procalcitonin (ng/mL)	2.58±0.91	0.79±0.42	<0.001
Lactate (mmol/L)	3.28±0.76	1.91±0.57	<0.001

Table 3. Association of postoperative surgical site infection with clinical outcomes

Outcome variable	SSI Group (n = 39)	Non-SSI Group (n = 111)	p-value
Hospital stay (days)	11.4±3.5	6.5±2.1	<0.001
Wound discharge	28 (71.8%)	0 (0.0%)	<0.001
Wound dehiscence	11 (28.2%)	3 (2.7%)	<0.001
Additional wound care intervention	27 (69.2%)	18 (16.2%)	<0.001

DISCUSSION

This study was designed to assess the predictive value of serum C-reactive protein, procalcitonin and lactate levels in the occurrence of postoperative surgical site infections in surgical patients. Our study found that all three biochemical markers were significantly higher in patients who developed SSI, suggesting that these laboratory tests may potentially be used as early markers of postoperative infection. Besides the elevation in these biomarkers, a number of clinical and operative risk factors, such as high

body mass index, diabetes mellitus, emergency surgery, and long operative time, were also significantly associated with the development of SSI. Taken together, these results further highlight the complex nature of postoperative wound infection and advocate for the use of biochemical markers in the assessment of postoperative risk.

The incidence of postoperative surgical site infection in our study was 26% of the total patient cohort, which represents a substantial proportion of surgical wound complications. This rate is generally comparable to many tertiary hospitals, especially those with a high proportion of emergency and contaminated surgery.[3] The high frequency of SSI observed in the current study may be attributable to the inclusion of patients with emergency surgery, metabolic dysfunction and extended duration of surgery, which are all risk factors for postoperative wound infection. The results of this study point to the need for better risk assessment and postoperative monitoring in surgical practice.[4]

A major finding of the present study was the elevated serum CRP in the group with SSI compared to the non-SSI group. CRP is a classic acute-phase reactant protein that rises in response to tissue inflammation and infection. Although CRP is expected to be elevated after surgery even in the absence of infection due to tissue trauma and the inflammatory response, the much higher level in the infected group in this study indicates that CRP may be a valuable marker for clinical use when considered in the context of the patient's postoperative recovery. In this study, the mean CRP level in the SSI group was more than twice that of the non-SSI group, suggesting a strong association between excessive postoperative inflammatory response and wound infection. This suggests that CRP may be helpful in identifying those who need to be monitored more closely for wound infection after surgery.[6]

But while CRP was strongly associated with SSI, its clinical value is limited by its lack of specificity. CRP may be elevated in response to surgical trauma, tissue damage, inflammatory insult, and other non-infectious complications that occur after surgery, and may not always discriminate between uncomplicated postoperative inflammation and true infection. As a result, CRP is often used in conjunction with other laboratory and clinical data.[8]

By contrast, procalcitonin seemed to be the most informative biomarker in this study[9]. The procalcitonin levels of patients with postoperative SSI were significantly higher than those of patients without infection, with a marked difference between the two groups. This is significant because procalcitonin is thought to be more specific for bacterial infection than CRP. This is because procalcitonin is more specifically associated with systemic bacterial inflammatory responses, and less so with sterile tissue damage. The significantly higher procalcitonin levels in the SSI group in this study indicate that procalcitonin may have better early discriminatory power for the diagnosis of postoperative wound infection in the absence of clinical deterioration. This may be particularly useful in the early postoperative period, when the distinction between expected inflammatory response and potential infection may be blurred.[10]

Serum lactate was also significantly elevated in patients with SSI. While lactate is not a classic infection marker, it is a clinically relevant indicator of metabolic dysfunction, tissue perfusion, and physiological derangement. Postoperative lactate may be increased in the presence of early occult deterioration, impaired tissue oxygenation or inflammatory metabolic derangement, all of which may be present in patients who are developing infection. In the current study, the significantly elevated lactate levels among patients who developed SSI indicate that metabolic dysfunction may coexist with inflammatory activation in patients who are developing wound infection. Although lactate may not be specific enough to be used alone to predict SSI, it may provide additional information when combined with CRP and procalcitonin.[12]

This study also showed that increased biomarker levels were associated with poorer outcomes. The SSI group had a longer length of stay and increased rates of wound discharge, wound dehiscence and the requirement for further wound dressings. These results highlight that SSI is not just a wound-specific complication but also a clinically relevant event that has implications for recovery, health-care costs, and the overall burden of care. The increased length of stay among patients with infection highlights the consequences of SSI in terms of prolonged hospital stay, increased costs, and increased morbidity. Elevation of the biomarker also supports the clinical significance of early laboratory-based risk prediction.[14]

Beyond laboratory results, a number of well-known patient and procedural factors were significantly associated with SSI in the current study. Infected patients had significantly higher BMI, which may have contributed to poor wound healing, decreased blood flow, and increased risk of infection. The significantly higher incidence of diabetes mellitus among patients with SSI is also in line with the well-established negative impact of hyperglycemia on immune response, collagen formation, microvascular blood flow, and wound healing. The other significant factor associated with postoperative infection was emergency surgery, which is likely related to the higher risk of contamination, poor patient preparation, and urgency of the procedure in these patients. Similarly, the significantly greater duration of surgery in the

infected group also supports the contribution of prolonged tissue exposure, manipulation and risk of contamination in the development of SSI.[16]

The findings of this study have practical implications for the use of early postoperative CRP, procalcitonin and lactate measurements to detect patients at risk of wound infection, especially those with other significant clinical risk factors for SSI, including diabetes, obesity and emergency surgery.[17] Procalcitonin may be the most promising biomarker for early postoperative risk stratification for infection. In situations where early diagnosis of SSI is difficult, the use of biomarker-based surveillance in the immediate postoperative period may assist clinicians to initiate early wound review, antibiotic treatment, or enhanced monitoring in certain patients.[18-20]

Limitations of the study. This is a single-center study in a tertiary care hospital, and the findings may not be applicable to other hospitals or patient populations. Although the sample size was sufficient for comparative purposes, it is relatively small for definitive diagnostic cutoffs. In addition, the biomarkers were measured in the early postoperative period without day-to-day trend analysis, which may have offered more information on the timing of biomarker elevation and the onset of infection. Microbiological confirmation was also not available in all cases, and diagnosis was based on conventional clinical criteria. Multicenter studies with larger sample sizes, serial biomarker measurements, and receiver operating characteristic curve analysis would be helpful to better define the relative diagnostic performance and optimal clinical cut-off values of these biomarkers.

In summary, the results of this study provide strong evidence for the use of serum inflammatory and metabolic biomarkers as a supplement to the early postoperative evaluation of surgical patients. The findings highlight the potential superior value of procalcitonin as a marker of early postoperative surgical site infection, and the supportive value of CRP and lactate.

CONLUSION

Serum CRP, procalcitonin, and lactate concentrations were significantly higher in patients who experienced postoperative surgical site infections, highlighting their potential as early risk markers in surgery. Procalcitonin was the most strongly associated with the development of postoperative SSI among the three markers, and may therefore be the most valuable biomarker for early prediction of infection risk in the postoperative setting.

Alongside biomarker elevation, other risk factors including increased BMI, diabetes, emergency surgery and longer operating time were significantly associated with SSI. Postoperative infection was associated with a more complex clinical course, with longer hospital stay, more wound discharge, wound dehiscence, and increased wound care requirements.

The use of CRP, procalcitonin and lactate in conjunction with clinical assessment and patient risk assessment may enhance the early detection of postoperative surgical site infection. The use of these biomarkers in postoperative surveillance may support earlier intervention, wound care and improved surgical outcomes.

DECLARATION

Conflict of Interest: The authors declare no conflict of interest.

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