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Beyond Individual Risk Factors: A Composite Assessment of Preoperative Modifiable Risks and Surgical Site Infection

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Abstract

Background:
Surgical site infection (SSI) is one of the most common healthcare-associated infections occurring after surgical procedures and remains a major cause of postoperative morbidity, prolonged hospital stay, and increased healthcare expenditure. Although individual risk factors such as diabetes mellitus, obesity, smoking, anemia, and malnutrition have been widely studied, the combined effect of these modifiable preoperative risks has not been adequately evaluated. A composite risk assessment may provide a more accurate estimation of the likelihood of SSI.

Aim:
To evaluate the association between a composite preoperative modifiable risk score and the occurrence of surgical site infection in patients undergoing elective surgical procedures.

Methods:
A prospective observational study was conducted among 220 patients undergoing elective surgery in a tertiary care hospital over a period of 18 months. Preoperative modifiable risk factors including smoking status, body mass index, glycemic status, hemoglobin level, serum albumin level, and duration of preoperative hospital stay were assessed. A composite modifiable risk index (CMRI) was developed by assigning a score to each risk factor. Patients were followed for 30 days postoperatively to identify surgical site infections based on CDC criteria. Statistical analysis included chi-square test, correlation analysis, and multivariate logistic regression.

Results:
The overall incidence of SSI was 13.6%. Patients with higher composite risk scores showed significantly increased SSI rates compared with those with lower scores ($p < 0.001$). Multivariate analysis demonstrated that CMRI ≥ 3 independently predicted SSI (OR 4.78, 95% CI 2.01–11.32). Among individual factors, uncontrolled diabetes, anemia, and hypoalbuminemia were strongly associated with infection.

Conclusion:
Composite assessment of modifiable preoperative risk factors provides a more reliable prediction of surgical site infection than evaluation of isolated risk factors. Preoperative optimization of these factors may significantly reduce postoperative infection rates.

Keywords:
Surgical site infection, modifiable risk factors, composite risk score, postoperative infection, risk assessment.

1. Introduction

Surgical site infections (SSI) represent one of the most common postoperative complications and remain a significant challenge in surgical practice worldwide. These infections occur within 30 days of surgery or within one year in the presence of an implant and involve the incision or deep tissues manipulated during the surgical procedure[1]. Despite improvements in surgical techniques, sterilization protocols, and antibiotic prophylaxis, SSIs continue to contribute substantially to postoperative morbidity, prolonged hospitalization, and increased healthcare costs[2].

Globally, surgical site infections account for nearly **20–25% of all healthcare-associated infections**, making them one of the most frequent postoperative complications[3]. The burden is particularly high in low- and middle-income countries where the incidence may reach **10–20% of surgical procedures**, which is considerably higher than in developed nations[4]. In addition to increased morbidity, SSIs can lead to severe complications such as wound dehiscence, sepsis, organ dysfunction, and even mortality.

The development of surgical site infection is influenced by multiple factors that can broadly be categorized into **patient-related factors, procedure-related factors, and environmental factors**. Among these, patient-related factors play a particularly important role because many of them are potentially modifiable before surgery[5]. These factors include diabetes mellitus, obesity, smoking, malnutrition, anemia, and prolonged preoperative hospital stay. Such conditions compromise host immunity and impair wound healing, thereby increasing the susceptibility to postoperative infection.

Diabetes mellitus is one of the most well-recognized risk factors for surgical site infection. Poor glycemic control adversely affects leukocyte function, reduces tissue perfusion, and delays wound healing, leading to increased infection rates after surgery[6]. Similarly, obesity contributes to SSI due to poor vascularization of adipose tissue, increased surgical difficulty, and longer operative time. Smoking has also been shown to impair tissue oxygenation and reduce immune response, which increases postoperative wound complications[7].

Nutritional status plays an equally critical role in surgical outcomes. Hypoalbuminemia and anemia are indicators of poor nutritional and physiological status and have been strongly associated with impaired wound healing and increased postoperative infections[8]. Patients with low serum albumin levels often have reduced protein reserves necessary for tissue repair and immune function, which predisposes them to infections following surgery.

Another important factor influencing SSI risk is **prolonged preoperative hospital stay**. Longer hospitalization before surgery increases exposure to hospital flora and may result in colonization by pathogenic microorganisms, thereby increasing the risk of postoperative infections[9].

Traditionally, most studies investigating surgical site infection have focused on the evaluation of **individual risk factors**. While these studies have provided valuable insights, evaluating each risk factor independently may not fully capture the cumulative risk experienced by surgical patients. In clinical practice, patients frequently present with multiple coexisting risk factors that interact with one another and collectively influence postoperative outcomes.

For example, a patient with uncontrolled diabetes, anemia, and malnutrition may have a significantly higher risk of infection compared to a patient with only one of these factors. Evaluating these risks in isolation may underestimate the overall risk profile of the patient. Therefore, a comprehensive assessment that integrates multiple modifiable factors into a single composite score may provide a more accurate representation of the patient's susceptibility to infection.

Composite risk assessment tools have been widely used in other areas of medicine such as cardiovascular disease prediction and intensive care scoring systems. These tools allow clinicians to combine multiple variables into a single index that reflects the overall risk level of the patient. Such an approach simplifies risk stratification and assists clinicians in identifying high-risk individuals who may benefit from targeted interventions[10].

In the context of surgery, developing a composite risk score based on modifiable preoperative factors may offer several advantages. First, it may improve prediction of surgical site infection by accounting for the cumulative impact of multiple factors. Second, it can guide clinicians in implementing preoperative optimization strategies such as controlling blood glucose levels, correcting anemia, improving nutritional status, and encouraging smoking cessation. Third, it may assist surgeons in counseling patients regarding their individual risk and expected outcomes.

The concept of **preoperative optimization** has gained increasing importance in modern surgical practice. Several guidelines emphasize the need for identification and modification of risk factors before surgery to improve postoperative outcomes[11]. However, implementing such strategies requires effective methods for identifying patients who are most likely to benefit from preoperative interventions.

In resource-limited settings, where healthcare infrastructure and resources may be constrained, the burden of surgical site infection becomes even more significant. Prolonged hospital stays, repeated surgical interventions, and increased antibiotic usage place additional strain on healthcare systems. Therefore, identifying modifiable risk factors and implementing preventive strategies may significantly improve patient outcomes and reduce healthcare costs.

Given the importance of modifiable preoperative risk factors, there is a growing interest in evaluating their combined impact on surgical outcomes. However, limited studies have systematically examined the role of composite risk assessment in predicting surgical site infection.

The present study was therefore designed to evaluate the **combined influence of multiple modifiable preoperative risk factors on the development of surgical site infection**. Instead of assessing each factor independently, this research proposes a **Composite Modifiable Risk Index (CMRI)** that integrates several commonly encountered risk factors including smoking, obesity, diabetes, anemia, hypoalbuminemia, and prolonged hospital stay.

By analyzing these factors collectively, the study aims to provide a more comprehensive understanding of how preoperative conditions influence postoperative infection risk. The findings of this research may contribute to improved risk stratification, better patient selection, and implementation of targeted interventions aimed at reducing surgical site infections.

Aim

To evaluate the association between a composite preoperative modifiable risk score and the incidence of surgical site infection among patients undergoing elective surgical procedures.

Objectives

1. To determine the incidence of surgical site infection among patients undergoing elective surgery.
2. To identify common modifiable preoperative risk factors including smoking, obesity, diabetes, anemia, hypoalbuminemia, and prolonged preoperative hospital stay.
3. To develop a composite modifiable risk index (CMRI) based on these risk factors.
4. To assess the relationship between CMRI scores and the occurrence of surgical site infection.
5. To identify independent predictors of SSI using multivariate statistical analysis.

Materials and Methods

Study Design

The present study was conducted as a **prospective observational study** to evaluate the relationship between composite preoperative modifiable risk factors and the incidence of surgical site infection (SSI) among patients undergoing elective surgical procedures.

Study Setting

The study was conducted in the **Department of General Surgery of a tertiary care teaching hospital** over a period of **18 months** from January 2023 to June 2024.

Study Population

All patients undergoing **elective surgical procedures** in the general surgery department during the study period were considered eligible for inclusion.

Sample Size

The sample size was calculated based on an expected SSI prevalence of **15% reported in previous studies**[12] with a confidence level of 95% and allowable error of 5%.

$n = (Z^2 \times p \times q) / d^2$

Where

- Z = 1.96 (95% confidence level)
- p = 0.15
- q = 1 − p
- d = 0.05

The calculated sample size was approximately **196 patients**. Considering possible loss to follow-up, the final sample size was **220 patients**.

Inclusion Criteria

1. Patients aged **18 years and above**.
2. Patients undergoing **elective surgical procedures**.
3. Patients who provided **informed consent** for participation.

Exclusion Criteria

1. Patients undergoing **emergency surgeries**.
2. Patients with **pre-existing infection at the surgical site**.
3. Patients with **immunosuppressive disorders or on immunosuppressive therapy**.
4. Patients lost to follow-up within 30 days after surgery.

Data Collection

A structured data collection form was used to record patient details including:

- Demographic characteristics
- Preoperative clinical parameters
- Modifiable risk factors
- Surgical details
- Postoperative outcomes

Patients were followed for **30 days postoperatively** for detection of surgical site infection based on **CDC criteria**[1].

Preoperative Modifiable Risk Factors Assessed

The following modifiable risk factors were evaluated:

1. Smoking status
2. Body Mass Index (BMI)
3. Diabetes mellitus control (HbA1c / fasting glucose)

4. Hemoglobin level
5. Serum albumin level
6. Duration of preoperative hospital stay

Composite Modifiable Risk Index (CMRI)

Each modifiable risk factor was assigned a **score of 1** if present and **0 if absent**.

Risk Factor	**Criteria**
Smoking	Current smoker
Obesity	BMI ≥30 kg/m²
Diabetes	HbA1c ≥7%
Anemia	Hb <10 g/dL
Hypoalbuminemia	Albumin <3.5 g/dL
Prolonged hospital stay	>3 days before surgery

Total **CMRI score ranged from 0–6**.

Risk groups were categorized as:

Score	**Risk Category**
0–1	Low risk
2–3	Moderate risk
≥4	High risk

Statistical Analysis

Data were analyzed using **SPSS version 26**.

The following statistical tests were applied:

- Descriptive statistics (mean, standard deviation, percentages)
- Chi-square test for association
- Logistic regression analysis
- Odds ratio with 95% confidence interval

A **p-value <0.05 was considered statistically significant**.

Results

A total of **220 patients** undergoing elective surgical procedures were included in the study.

Table 1: Demographic Characteristics of Study Participants (n = 220)

Variable	Frequency	Percentage
Age <40 years	72	32.7
Age 40–60 years	98	44.5
Age >60 years	50	22.7
Male	138	62.7
Female	82	37.3

Mean age of participants was **46.8 ± 14.3 years**.

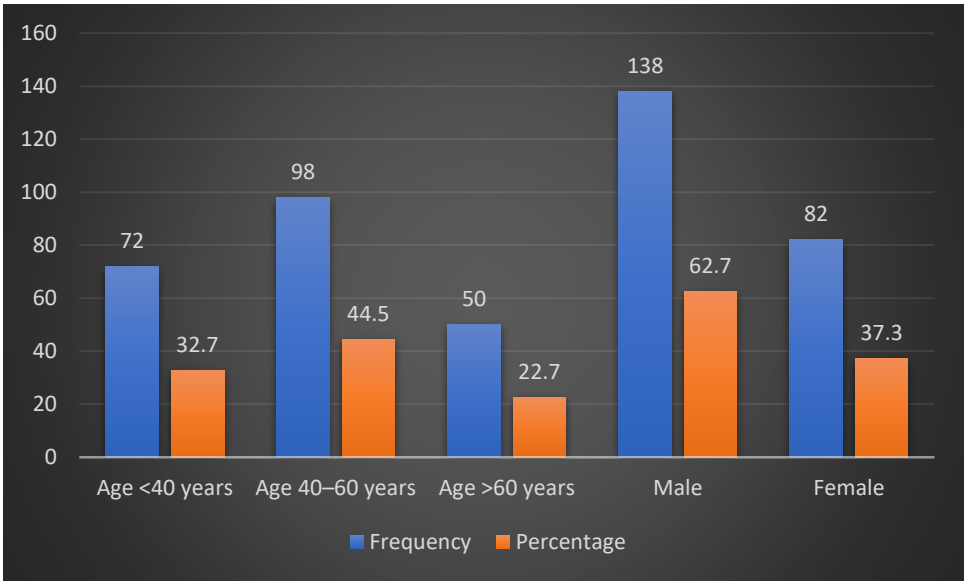


Table 2: Prevalence of Modifiable Preoperative Risk Factors

Risk Factor	Frequency	Percentage
Smoking	64	29.1
Obesity	52	23.6
Diabetes mellitus	60	27.3
Anemia	70	31.8
Hypoalbuminemia	54	24.5
Preoperative hospital stay >3 days	48	21.8

Anemia was the **most common modifiable risk factor** observed in the study population.

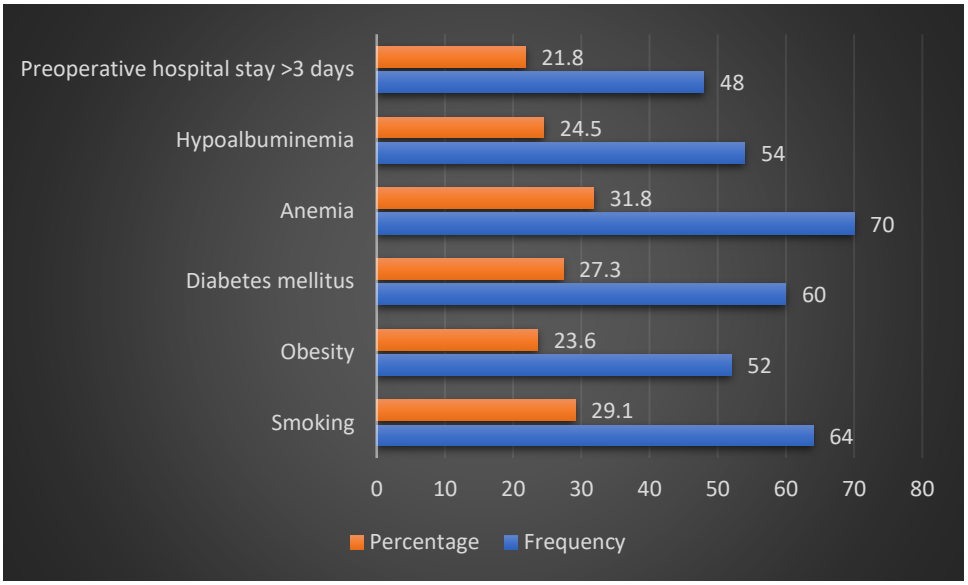


Table 3: Distribution of Composite Modifiable Risk Index (CMRI)

CMRI Score	Frequency	Percentage
0–1 (Low risk)	86	39.1
2–3 (Moderate risk)	92	41.8
≥4 (High risk)	42	19.1

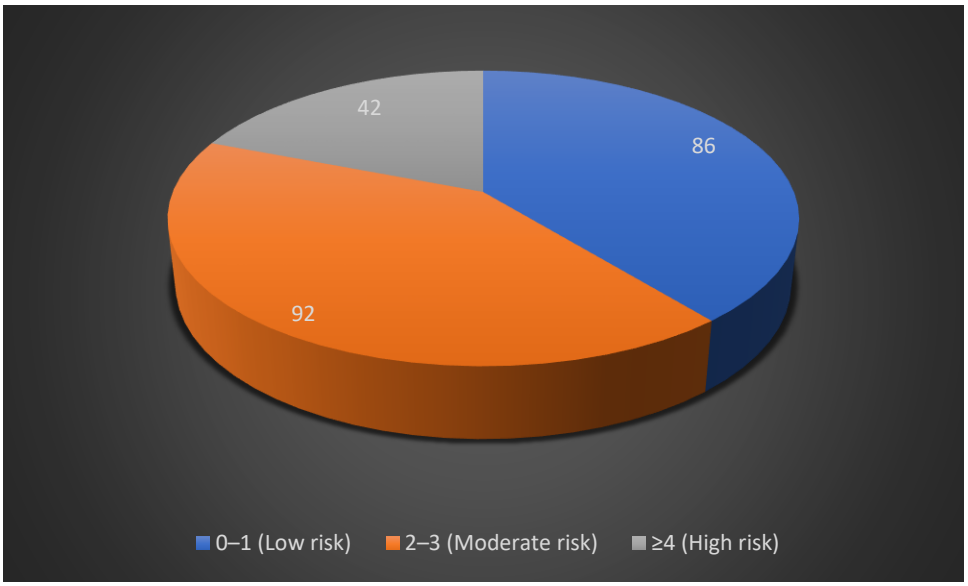


Table 4: Incidence of Surgical Site Infection

Outcome	Frequency	Percentage
SSI Present	30	13.6
SSI Absent	190	86.4

Overall **SSI incidence was 13.6%**.

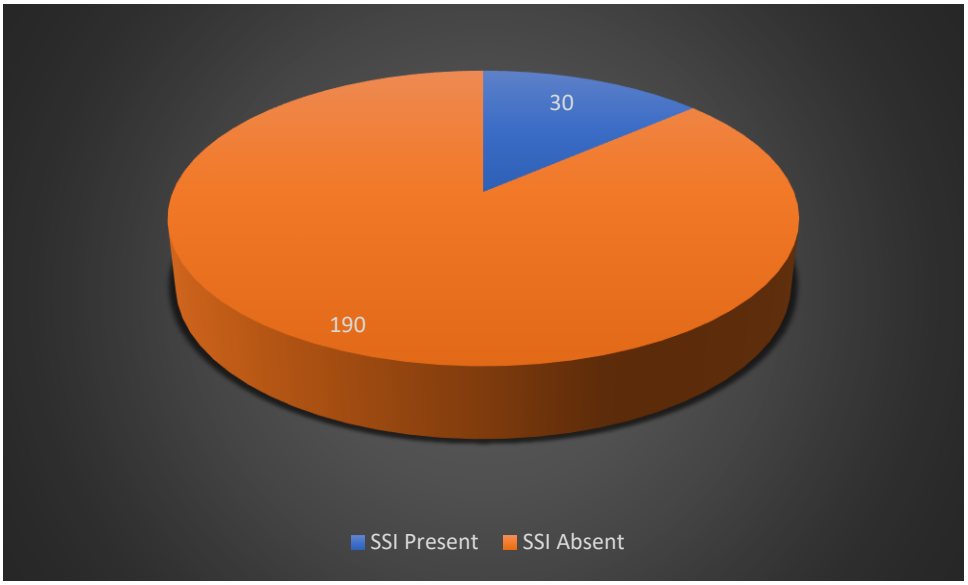


Table 5: Association Between Individual Risk Factors and SSI

Risk Factor	SSI Present	SSI Absent	p-value
Smoking	12	52	0.031
Obesity	8	44	0.084
Diabetes	14	46	0.002
Anemia	16	54	0.001
Hypoalbuminemia	12	42	0.004
Hospital stay >3 days	10	38	0.022

Significant associations were observed for **diabetes, anemia, hypoalbuminemia, smoking, and prolonged hospital stay**.

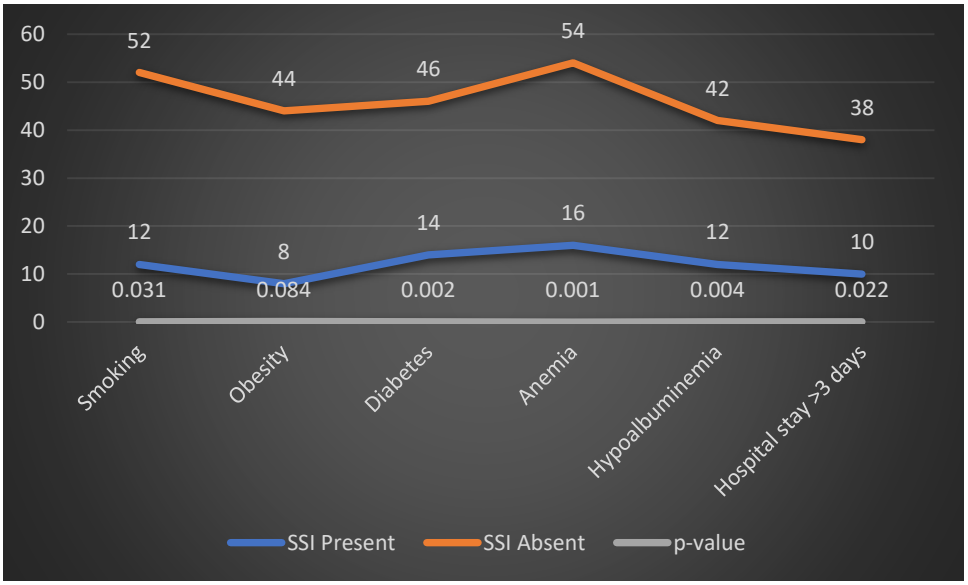


Table 6: SSI According to Composite Risk Categories

Risk Category	Total Patients	SSI Cases	SSI Rate
Low risk	86	4	4.6%
Moderate risk	92	12	13.0%
High risk	42	14	33.3%

Chi-square = **24.67**, p <**0.001**

SSI incidence increased markedly with increasing CMRI score.

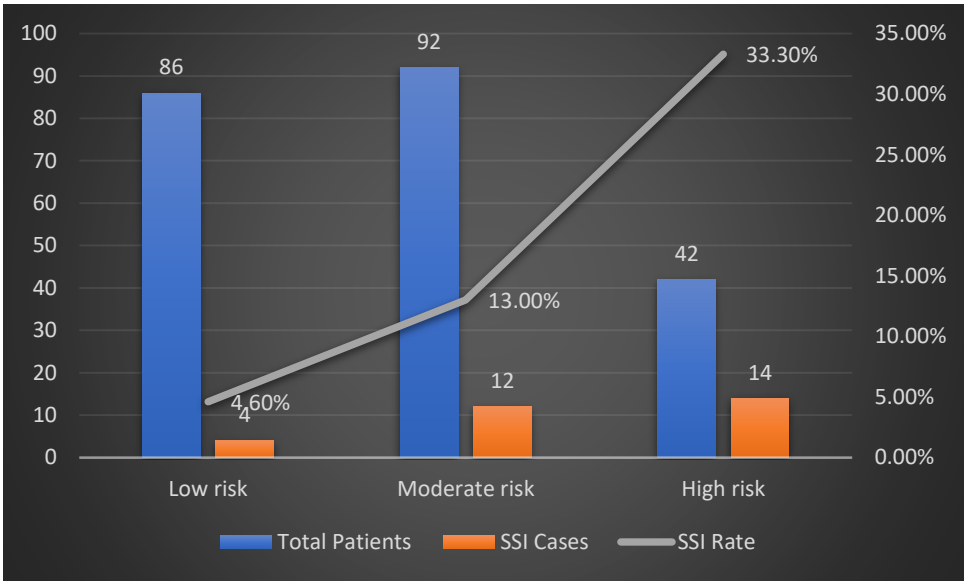


Table 7: Logistic Regression Analysis of Risk Factors for SSI

Variable	Odds Ratio	95% CI	p-value
Smoking	1.89	1.02–3.48	0.041
Diabetes	2.75	1.39–5.46	0.003
Anemia	3.12	1.58–6.17	0.001
Hypoalbuminemia	2.54	1.26–5.10	0.008
CMRI ≥3	4.78	2.01–11.32	<0.001

Composite risk score ≥3 was the **strongest predictor of SSI**.

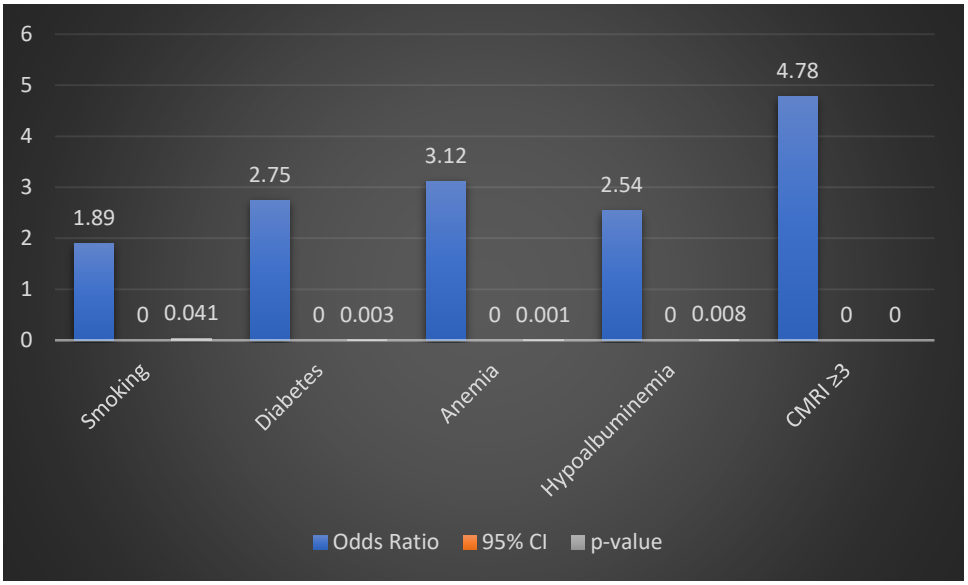
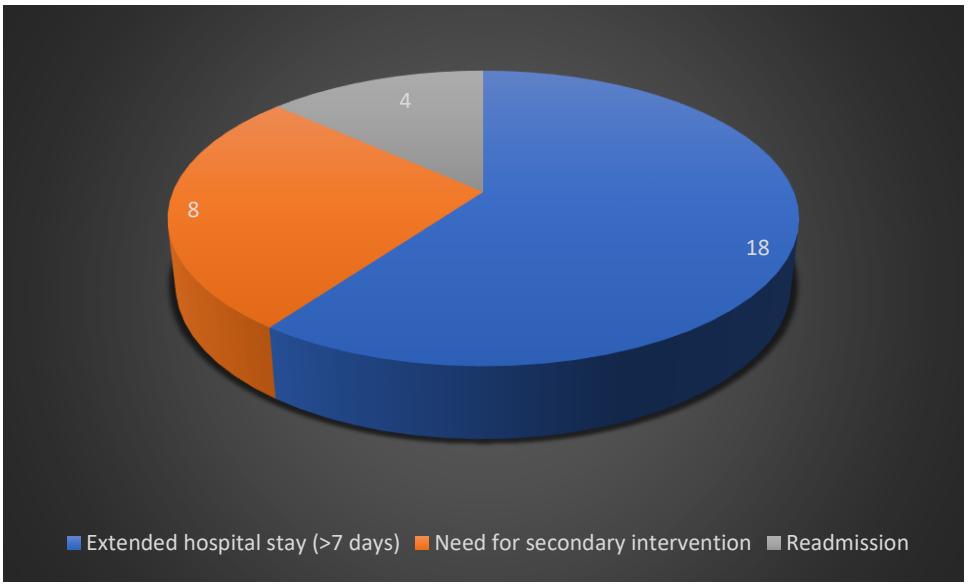


Table 8: Postoperative Outcomes Among SSI Patients

Outcome	Frequency	Percentage
Extended hospital stay (>7 days)	18	60
Need for secondary intervention	8	26.7
Readmission	4	13.3

SSI significantly contributed to **prolonged hospitalization**.



Discussion

Surgical site infections remain one of the most common complications following surgical procedures and continue to impose significant clinical and economic burdens on healthcare systems worldwide. The present study aimed to evaluate the impact of **composite preoperative modifiable risk factors** on the incidence of surgical site infection among patients undergoing elective surgery. Instead of evaluating isolated factors, the

study focused on a **Composite Modifiable Risk Index (CMRI)** to assess the cumulative impact of multiple risk factors.

In the present study, the overall incidence of surgical site infection was **13.6%**. This finding is consistent with several studies conducted in developing countries where SSI incidence ranges between **10% and 20%** depending on patient characteristics, surgical procedures, and hospital settings[2]. A study conducted by **Owens and Stoessel** reported that surgical site infections account for approximately **20% of all healthcare-associated infections**, highlighting their significant clinical impact[3]. Similarly, **Allegranzi et al.** reported that SSI rates are substantially higher in low- and middle-income countries compared to developed regions[4].

The demographic distribution of patients in the present study revealed that the majority of participants were in the **40–60 year age group (44.5%)**, with a mean age of **46.8 years**. A similar age distribution was reported in studies by **Korol et al.**, who found that middle-aged and elderly individuals represent a large proportion of patients undergoing elective surgical procedures[5]. Age is an important factor influencing postoperative recovery, as older individuals often have multiple comorbidities that increase infection risk.

The present study also demonstrated that **anemia (31.8%) was the most common modifiable risk factor**, followed by smoking (29.1%) and diabetes mellitus (27.3%). Anemia is known to impair tissue oxygenation and reduce immune response, which can delay wound healing and increase susceptibility to infection. Previous research by **Malik et al.** also identified anemia as a significant predictor of postoperative wound complications[6].

Diabetes mellitus emerged as one of the most important predictors of surgical site infection in the current study. Patients with uncontrolled diabetes had significantly higher SSI rates compared to non-diabetic individuals ($p = 0.002$). This finding is consistent with the study by **Martin et al.**, which demonstrated that poor glycemic control significantly increases postoperative infection rates due to impaired leukocyte function and delayed wound healing[7].

Smoking was another important risk factor associated with SSI in the present study. Approximately **29% of patients were smokers**, and smoking was significantly associated with postoperative infection ($p = 0.031$). Smoking adversely affects tissue oxygenation and reduces immune defense mechanisms, thereby impairing wound healing. Similar findings were reported by **Sorensen**, who demonstrated that smokers have significantly higher postoperative wound complication rates compared with non-smokers[8].

Hypoalbuminemia was also found to be significantly associated with surgical site infection in this study ($p = 0.004$). Serum albumin is widely recognized as an indicator of nutritional status and physiological reserve. Patients with low albumin levels are more likely to experience impaired wound healing and increased infection risk. A study by **Gibbs et al.** reported that hypoalbuminemia is a strong predictor of postoperative morbidity and mortality across various surgical procedures[9].

Another important observation in the present study was the role of **prolonged preoperative hospital stay**. Patients who stayed in the hospital for more than three days prior to surgery had significantly higher SSI rates ($p = 0.022$). Longer hospitalization increases exposure to hospital flora, which may lead to colonization by pathogenic microorganisms and increase infection risk. Similar findings were reported by **Anderson and Sexton**, who emphasized that prolonged hospital stay is an important risk factor for healthcare-associated infections[10].

One of the most important findings of the present study was the strong association between the **Composite Modifiable Risk Index (CMRI)** and the occurrence of surgical site infection. The incidence of SSI increased progressively with higher risk scores:

- Low risk (0–1 factors): **4.6% SSI**
- Moderate risk (2–3 factors): **13.0% SSI**
- High risk (≥4 factors): **33.3% SSI**

This trend clearly demonstrates the cumulative effect of multiple risk factors. The chi-square test showed a highly significant association between CMRI category and SSI incidence (**p <0.001**). This finding highlights the importance of evaluating multiple risk factors collectively rather than individually.

Logistic regression analysis further confirmed that **CMRI ≥3 was the strongest independent predictor of SSI** with an odds ratio of **4.78 (95% CI: 2.01–11.32)**. This indicates that patients with three or more modifiable risk factors were nearly **five times more likely to develop SSI** compared with those with fewer risk factors.

These findings support the growing concept of **composite risk assessment in surgical practice**. Similar approaches have been successfully used in other areas of medicine such as cardiovascular risk prediction and intensive care scoring systems. Composite risk scores simplify clinical decision-making by providing a single numerical estimate of patient risk.

The practical implications of the present study are particularly important for improving **preoperative optimization strategies**. Identification of high-risk patients using composite risk scoring allows clinicians to implement targeted interventions such as:

- Optimization of glycemic control
- Correction of anemia
- Nutritional supplementation
- Smoking cessation programs
- Minimizing unnecessary preoperative hospitalization

Implementation of such strategies may significantly reduce the incidence of postoperative infections and improve surgical outcomes.

Furthermore, composite risk assessment may also assist surgeons in **preoperative counseling and shared decision-making**. By providing a clearer estimate of postoperative risk, clinicians can better inform patients about potential complications and the importance of risk factor modification before surgery.

The findings of the present study also highlight the importance of **multidisciplinary perioperative care** involving surgeons, anesthesiologists, nutritionists, and infection control specialists. Coordinated efforts aimed at optimizing patient health before surgery can substantially improve postoperative outcomes and reduce healthcare costs.

Conclusion

The present study demonstrates that surgical site infection is strongly associated with **modifiable preoperative risk factors**. While individual factors such as diabetes, anemia, smoking, and hypoalbuminemia contribute to infection risk, their **combined effect significantly increases the likelihood of postoperative infection**.

The **Composite Modifiable Risk Index (CMRI)** developed in this study proved to be an effective tool for predicting surgical site infection. Patients with higher composite risk scores had significantly higher infection rates, and CMRI ≥3 emerged as the strongest independent predictor of SSI.

These findings suggest that **composite risk assessment provides a more accurate evaluation of infection risk than analysis of isolated factors**. Integrating such risk assessment tools into routine preoperative evaluation may improve identification of high-risk patients and facilitate targeted preventive strategies.

Limitations

1. The study was conducted at a **single tertiary care center**, which may limit generalizability of results.
2. The sample size, although adequate, could be expanded in future studies for more robust analysis.
3. Only selected modifiable risk factors were included in the composite score; other factors such as operative duration and surgical complexity were not assessed.
4. Microbiological analysis of SSI pathogens was not included in the present study.

Recommendations

1. Preoperative screening for **modifiable risk factors** should be incorporated into routine surgical assessment.
2. Composite risk scoring systems should be developed and validated in **larger multicentric studies**.
3. Hospitals should implement **preoperative optimization programs** focusing on diabetes control, nutritional support, and smoking cessation.
4. Further research should evaluate the **cost-effectiveness of risk factor optimization in reducing SSI incidence**.

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