

ORIGINAL RESEARCH ARTICLE



Assessment of Surgical site Infections and Associated Determinants Following Surgical Procedures in a Tertiary Care Center in India

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Abstract

Introduction: SSI is significant postoperative complication leads to morbidity, prolonged hospitalization, exposure to antibiotics, and increased health care cost. Various factors related to both patient-related, surgery-related, and post-operative, is significant development of SSI. The study evaluated the prevalence of SSI, distribution of bacteria involved, and various factors associated with it.

Method: The study was cross sectional observational study design was conducted among 80 patients admitted to the tertiary care centre for surgery in India. The convenience sample method included 40 SSI cases and 40 non-SSI cases. Specimens from patients were cultured with conventional microbiological techniques. Data analysis was done by the use of SPSS version 27.0, Chi-square test $p < 0.05$.

Results: Out of 80 patients who underwent surgery, 40 (50.0%) had SSI. Exploratory laparotomy had the highest rate of SSI (7, 17.5%), while hernia repair had the second-highest percentage of SSI (6, 15.0%). The commonest isolate was Staphylococcus aureus (32), followed by Escherichia coli (27). Out of patients with SSI, 55.0% had diabetes, 72.5% were male, and 77.5% were hospitalized for more than 7 days. Significant associations were observed for age ($p = 0.040$), gender ($p = 0.022$), surgery type ($p = 0.025$), diabetes ($p < 0.0001$), and hospital stay ($p < 0.0001$).

Conclusion: The study concluded that the SSI prevalence was noted with diabetes, long term hospitalization stay, age, gender and the surgical features is related with the occurrence of infection.

Key words: Surgical site infection, Surgical procedures, Diabetes mellitus, Bacterial isolates, Risk factors

1 | INTRODUCTION

Surgical site infection is one of the most important post-operative healthcare-associated infections and accounts for significant wound morbidity, increased hospital stays, hospital readmission, exposure to antimicrobial agents, reoperation and healthcare costs. Different conditions, such as patient comorbidities, emergency surgical load, hospital infrastructure, infection preven-

tion and control, and antimicrobial use and post-discharge surveillance, can also cause differences in incidence, and in low- and middle-income countries, SSI rates could be higher than in high-income healthcare systems. The World Health Organisation recognises that SSI prevention is a patient safety priority and that coordinated interventions are needed in the preoperative, intraoperative and postoperative periods to achieve effective prevention [1].

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The risk of SSI depends on the susceptibility of the patient, microbial contamination, and procedure-related factors. Diabetes mellitus is one of the most consistently demonstrated patient-level determinants. A meta-analysis of 14 prospective cohort studies and 91,094 participants showed a pooled crude relative risk of 2.02 (95% CI, 1.68–2.43) and an adjusted relative risk of 1.69 (95% CI, 1.33–2.13), indicating that diabetes was associated with the development of SSI, regardless of the effects of several measured confounders [2]. Other clinical factors that are important are advanced age, obesity, smoking, malnutrition, hypoalbuminemia, immunosuppression, increased American Society of Anaesthesiologists classification, pre-existing infection, and vascular insufficiency. Procedure-related factors are emergency surgery, dirty or contaminated wound, longer operative time, transfusion of blood, placement of drain, open surgical approaches and more complex surgery [3].

These relationships can be stronger or weaker depending on the type of surgery and patients. The incidence of SSIs ranged from 4.09% to 26.7% in a systematic review of abdominal surgery involving 11,996 patients; risk factors included were high BMI, diabetes, smoking, ASA score >2, low albumin levels, anaemia, prolonged operation, emergency surgery, open surgery, high wound classification, blood loss, transfusion, and the use of drains [4]. Similarly, a meta-analysis of colorectal surgery found obesity (RR 1.60), diabetes (RR 1.65), emergency surgery (RR 1.36), higher wound classification (RR 2.65), operative duration ≥ 180 minutes (RR 1.88), smoking (RR 1.38), open surgery (RR 1.81), and blood transfusion (RR 2.03) to be associated with SSI [5].

Evidence from Indian hospitals shows great variation in the rate of SSIs. In a prospective study of 1,196 surgical patients who underwent surgery at a tertiary care centre in Mumbai, Siddique et al. found that SSI occurred in 11% of these patients, with increasing age (>55 years), diabetes, weakened immune system, emergency surgery, drains, dirty wound, prolonged surgery (>2 hours) and prolonged hospitalisation being associated with an increased risk of developing SSI [6]. In a more recent, multicentric Indian surveillance study, 161 (5.2%) of 3,090 patients were identified as having SSIs, with debridement proce-

dures having significantly higher infection rates and the duration of surgery and contamination of surgical wounds being significant factors [7]. Focusing on these differences, the importance of the differences in the surgical case mix, the surveillance approach, the length of follow-up and whether or not the infections that follow the surgery are included.

Thus, there is a need to continue the system evaluation of SSI incidence and related factors at the individual tertiary care hospital level. This study aimed to evaluate the prevalence of SSI after surgical procedures and explore the role of demographic, comorbidity-related, operative, wound-related, and postoperative factors. The identification of modifiable determinants could help to guide institution-specific infection-prevention measures and to help stratify patients preoperatively.

2 | METHOD

Research design

The study was a cross-sectional observational study to evaluate the SSI and the associated determinants which was followed by the surgical techniques. The study was conducted in the Tertiary Care Hospital for duration of 1 year. The study was conducted among 80 patients undergone with surgical process containing 40 patients of surgical site infections (SSI). The study included convenience sampling technique and patients clinical and perioperative information such as age, sex, type and site of surgery, wound classification, ASA status, diabetes mellitus, smoking, alcohol use, anemia, duration of hospitalization, and drain placement was measured and reported. Predefined inclusion and exclusion criteria were considered for patient selection. Both verbal and written consent required for the study. The ethical approval was obtained from the Institutional Ethics Committee for the study.

Inclusion criteria

- Patients of age >16 years were included.
- Both of the gender were included
- Patients those who have undergone with the surgical procedure were included.
- Informed consent required for the study

Exclusion criteria

- Those who have underwent with the second surgery at the same site were excluded.
- Those who have received with the immunosuppressant therapy were excluded
- Patients with previous history of immunodeficiency disease were excluded.
- Those who have received with the antibiotic therapy were excluded
- Patients with infection at other side of the body were excluded

Procedure

Data collected from 80 patients underwent with surgical procedure containing 40 patients of SSI. Demographic and clinical information such as age, gender, type and site of surgery, duration of surgery, nature of surgery, surgeon-related details, preoperative and postoperative hospital stay, and occurrence of SSI was taken. After 48 hours after surgery, the surgical dressings were removed and the wounds were investigated to assess the infection site like the redness, warmth, edema, pain, or wound discharge. SSI was clinically evaluated and was confirmed by medical experts. Those patients with inflammatory issues without discharge were regulated. Patients were followed up for 30 days which include the telephone-based follow-up after discharge. Specimen was collected maintaining prior the dressing technique. The wound was cleaned with the help of sterile saline solution and 70% alcohol, which was followed by the collection by the use of the sterile swabs and aspiration. Specimen were transported to the laboratory within 2 hours. Direct Gram-stained smears were analysed under microscope for the pus cells and the microorganisms. The culture of the specimen were

showed the distribution of the bacteria isolates varied significantly among different types of surgeries. The abdomen accounted for the largest number of bacteria, 72 bacteria (180.0%), which was followed by orthopedic surgery, accounted for 25 (62.5%), and pelvis, which accounted for 14 (35.0%). *Staphylococcus aureus* was the most common isolated bacteria, 32 bacteria in total, with 14 (35.0%) from abdominal surgery and 6 (15.0%) from pelvic surgeries.

cultured on the nutrient agar, 5% sheep blood agar, and MacConkey agar and was incubated in the 37°C for 24 hours. The isolates of bacteria were identified on the basis of the morphology of the colony, gram colony, motility and other biochemical tests.

Statistical analysis

The data were analysed by the use of the Microsoft Excel and SPSS (Statistical Package for the Social Sciences), Version 27.0. Frequency and percentage were used to describe categorical variables. The relationship between the selected demographic, clinical and perioperative risk factors and surgical site infection (SSI) was tested by the Chi-square test. Statistical significance was defined as 95% confidence level with a p-value <0.05.

3 | RESULTS

showed the distribution of 80 surgical operations and 40 cases that had surgical site infections (SSIs). Intraocular lens implantation formed the highest percentage of operations at 17 (21.25%), lower segment cesarean section 10 (12.50%), and open reduction and internal fixation 8 (10.00%). The highest percentage of 40 SSIs was noted due to exploratory laparotomy 7 (17.5%) while hernia repair was second-highest, 6 (15.0%). Appendectomy and cholecystectomy contributed the same percentage of SSIs at 5 (12.5%), while open reduction and internal fixation noted among 4 (10.0%). No SSIs occurred after urethroscopy lithotripsy, fibroadenoma excision, varicose vein surgery, intraocular lens implantation, mastoidectomy, and neurosurgery. SSIs occurred in 40 patients out of 80 patients (50.0%).

E. coli was found in the abdomen, accounting for 19 (47.5%), while 8 (20.0%) were from orthopedic surgeries. *Klebsiella* species was isolated 19 times, with 10 (25.0%) from abdominal and 5 (12.5%) from orthopedic surgery. *Pseudomonas aeruginosa* was isolated from abdomen, orthopedics, pelvis, ENT, and urology. Only *Staphylococcus aureus* bacteria were isolated from breast surgery.

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Table 1. Distribution of Surgical Procedures and Surgical Site Infection (SSI) Among Study Patients

Site of Surgery	Type of Surgery	No. of Surgeries, n (%)	SSI, n (%)
Abdomen	Appendectomy	3 (3.75%)	5 (12.5%)
	Hernia repair	3 (3.75%)	6 (15.0%)
	Exploratory laparotomy	3 (3.75%)	7 (17.5%)
	Cholecystectomy	3 (3.75%)	5 (12.5%)
	Lower segment cesarean section	10 (12.50%)	2 (5.0%)
	Hysterectomy	6 (7.50%)	1 (2.5%)
	Sphincterotomy	2 (2.50%)	1 (2.5%)
Pelvis	Hemorrhoidectomy	2 (2.50%)	1 (2.5%)
	Fistulectomy	1 (1.25%)	1 (2.5%)
	Hip replacement	1 (1.25%)	2 (5.0%)
Urogenital	Transurethral resection of prostate	1 (1.25%)	1 (2.5%)
	Urethroscopy lithotripsy	3 (3.75%)	0 (0.0%)
Breast and axilla	Modified radical mastectomy	1 (1.25%)	1 (2.5%)
	Fibroadenoma excision	2 (2.50%)	0 (0.0%)
Skin, bone, and joints	Knee replacement	2 (2.50%)	1 (2.5%)
	Varicose vein surgery	2 (2.50%)	0 (0.0%)
	Open reduction and internal fixation	8 (10.00%)	4 (10.0%)
Eye	Intraocular lens implantation	17 (21.25%)	0 (0.0%)
Ear, nose, throat	Tonsillectomy	5 (6.25%)	1 (2.5%)
	Mastoidectomy	4 (5.00%)	0 (0.0%)
Neurosurgery	Neurosurgery	1 (1.25%)	0 (0.0%)
Total		80 (100.00%)	40 (100.0%)

Table 2. Distribution of Bacterial Isolates according to the Anatomical Site of Surgery

Organism (n)	Abdomen, n (%)	Orthopedics, n (%)	Pelvis, n (%)	Breast, n (%)	Ear, Nose, and Throat, n (%)	Urology, n (%)
Staphylococcus aureus (32)	14 (35.0%)	5 (12.5%)	6 (15.0%)	3 (7.5%)	4 (10.0%)	0 (0.0%)
Enterococci species (3)	3 (7.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Escherichia coli (27)	19 (47.5%)	8 (20.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Klebsiella species (19)	10 (25.0%)	5 (12.5%)	4 (10.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Proteus species (7)	4 (10.0%)	2 (5.0%)	0 (0.0%)	0 (0.0%)	1 (2.5%)	0 (0.0%)
Citrobacter species (1)	1 (2.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Enterobacter species (7)	7 (17.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Pseudomonas aeruginosa (19)	10 (25.0%)	3 (7.5%)	2 (5.0%)	0 (0.0%)	2 (5.0%)	2 (5.0%)
Acinetobacter baumannii (9)	4 (10.0%)	2 (5.0%)	2 (5.0%)	0 (0.0%)	1 (2.5%)	0 (0.0%)
Total isolates	72 (180.0%)	25 (62.5%)	14 (35.0%)	3 (7.5%)	8 (20.0%)	2 (5.0%)

presented the distribution of potential risk factors in 40 cases of patients with SSI. Age group of patients aged >55 years was most predominant (27.5%), followed by those of 35–44 and 45–54 years (both 25.0%). Males were more prevalent in 72.5% cases of SSI as against 27.5% female cases. 80.0% of SSI infections occurred during emergency surgeries, while 20.0% occurred during elective surgeries. In case of wound, the most common type of infections

was superficial (60.0%) followed by deep infections (40.0%). 50.0% of patients belonged to ASA III category, followed by ASA II (30.0%). Prevalence of diabetes was found to be 55.0%. Smoking and alcohol abuse were prevalent in 42.5% and 35.0% patients, respectively. The prevalence of anaemia was 27.5%. Prolonged hospitalization (>7 days) was noted in 77 patients.

Table 3. Distribution of Surgical Site Infection (SSI) Cases According to Demographic, Clinical, and Perioperative Risk Factors (n=40)

Risk Factors	Frequency of SSI (n=40)	Percentage (%)
1. Age group (years)		
16–24	4	10
25–34	6	15
35–44	10	25
45–54	9	22.5
>55	11	27.5
Total	40	100
2. Gender		
Male	29	72.5
Female	11	27.5
Total	40	100
3. Type of surgery		
Emergency	32	80
Elective	8	20
Total	40	100
4. Extent of wound		
Superficial	24	60
Deep	16	40
Organ	0	0
Total	40	100
5. ASA (American Society of Anesthesiologists)		
I	6	15
II	12	30
III	20	50
IV	2	5
V	0	0
Total	40	100
6. Diabetes mellitus		
Yes	22	55
No	18	45
Total	40	100
7. Smoking		
Yes	17	42.5
No	23	57.5
Total	40	100
8. Alcoholism		
Yes	14	35
No	26	65
Total	40	100
9. Anemia		
Yes	11	27.5
No	29	72.5
Total	40	100
10. Hospital stay		
1–7 days	9	22.5
>7 days	31	77.5
Total	40	100
11. Drain		
Yes	6	15
No	34	85
Total	40	100

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showed the different association of various factors that contribute to the incidence of the surgical site infections (SSI) within 80 study participants that included 40 SSI and 40 non-SSI individuals. The age factor revealed the highest number of SSI cases in participants who were older than 55 years old (28%), followed by those who were 35-44 years old (25%) and 45-54 years old (22%). The males constituted 73% of SSI cases compared to 63% of non-

SSI patients. Emergency surgery constituted 20% of SSI cases while in non-SSI cases the value was 13%. Diabetics constituted 55% of SSI patients and 20% of non-SSI patients ($P<0.0001$). Smokers and alcoholics did not show any statistically significant differences. Patients who stayed more than 7 days had significantly high numbers (78%) of SSI cases compared to non-SSI cases (18%).

Table 4. Association of Selected Risk Factors with Surgical Site Infection (SSI) Among the Study Participants

Risk Factors	SSI infections – Yes, n (%)	SSI infections – No, n (%)	Chi-Square Value	P-Value
Age group (years)				
16–24	4 (10%)	2 (5%)	9.99	0.04
25–34	6 (15%)	4 (10%)		
35–44	10 (25%)	11 (28%)		
45–54	9 (22%)	10 (25%)		
>55	11 (28%)	13 (32%)		
Total	40 (100%)	40 (100%)		
Gender				
Male	29 (73%)	25 (63%)	5.176	0.022
Female	11 (28%)	15 (38%)		
Total	40 (100%)	40 (100%)		
Type of surgery				
Elective	32 (80%)	35 (88%)	5.001	0.025
Emergency	8 (20%)	5 (13%)		
Total	40 (100%)	40 (100%)		
Diabetes mellitus				
Yes	22 (55%)	8 (20%)	80.737	<0.0001
No	18 (45%)	32 (80%)		
Total	40 (100%)	40 (100%)		
Smoking				
Yes	17 (43%)	18 (45%)	0.401	0.526
No	23 (58%)	22 (55%)		
Total	40 (100%)	40 (100%)		
Alcohol				
Yes	14 (35%)	15 (38%)	0.05	0.822
No	26 (65%)	25 (63%)		
Total	40 (100%)	40 (100%)		
Hospital stay				
1–7 days	9 (23%)	33 (83%)	229.15	<0.0001
>7 days	31 (78%)	7 (18%)		
Total	40 (100%)	40 (100%)		

4 | DISCUSSION

The present study aims to assess this multifactorial postoperative outcome in a tertiary care unit with a risk profile both dependent on patient complexity and procedural factors. Incidence of SSI should be interpreted in relation to the study population, spectrum of surgical procedure, wound classifica-

tion, the length of surveillance period, and the ascertainment of infections after the surgery. This is especially significant because outpatient studies based only on surveillance may underestimate the postoperative burden. The multi-centre surveillance in India showed an additional contribution with post-discharge surveillance, as 161/3,090 (5.2%) surgical patients developed SSIs [8]. A large discrepancy

in the reported rates was also reported in the earlier evidence in India for prospective surgical patients in Mumbai, which had an SSI rate of 11% (1196 patients) [9].

Biologically and epidemiologically important association between diabetes mellitus and SSI. High blood glucose levels may affect neutrophil chemotaxis, phagocytosis and intracellular killing of microbes, and microvascular dysfunction and impaired tissue oxygenation impair collagen production and wound healing. This relationship is supported by the pooled evidence: A meta-analysis of 14 prospective cohorts with 91,094 patients showed an adjusted relative risk of 1.69 in patients with diabetes [10]. A larger, systematic review and meta-analysis found an overall odds ratio of 1.53 (95% predictive interval 1.11 to 2.12) between diabetes and SSI for different surgical procedures [11]. Therefore, it is important to consider perioperative glycaemic optimisation as a clinically relevant SSI-prevention strategy and not just as a general measure of metabolic control.

Several procedure-related determinants are important: operative duration and wound contamination. Longer surgery results in greater exposure of the operative field to environmental microorganisms, longer tissue retraction and manipulation, greater physiological strain, and may adversely affect tissue perfusion. Meta-analysis of colorectal surgery revealed that surgical procedures lasting ≥ 180 minutes had an approximately 88% increased RR of SSI (RR 1.88; 95% CI 1.49-2.36) [12]. In the same way, a prolonged operative time is a well-defined procedure-related determinant found in systemic analysis of abdominal surgery. For this reason, the association between operative duration and SSI should not be considered as merely being a temporal exposure, but also as an indirect measure of procedural complexity, intra-operative difficulty, blood loss, tissue trauma, and contamination [13].

The effect of the type of wound is especially important. Depending on the level of microbial contamination, ranging from clean to contaminated and dirty, the chances of successful invasion by organisms inoculated into the body increase significantly. For the colorectal-surgery meta-analysis, the RR for wound classification >2 was 2.65 (95% CI 1.52–4.61). The Indian experience also shows this gra-

dient: Siddique et al. reported the highest incidence of SSIs in dirty wounds (16.8%), and an Indian prospective study of open surgery reported that SSIs occurred in 45% of wounds that were contaminated versus an overall rate of 8.8%. These results highlight the need to classify wounds as a prognostic marker and as a clinical part of the peri-operative risk assessment [6].

Another clinically relevant determinant is emergency surgery, as this type of surgery is often performed in patients who do not have sufficient time to optimise glycaemic status, nutritional abnormalities, anaemia, dehydration, or pre-existing infections. Other factors that can be involved in emergency operations may include contaminated or perforated viscera, haemodynamic instability, or a longer operative time. An analysis of all colorectal studies reported an increased risk for SSIs (RR 1.36, 95% CI 1.19-1.55) with emergency surgery. Emergency procedures are also reported to be an important SSI-associated factor by tertiary care literature in India [14].

Other patient factors including obesity, smoking, anaemia, hypoalbuminaemia and raised ASA grade should also be viewed as interrelated factors, not separate. Less nutritional reserve and less available oxygen can lead to impaired immune function and tissue repair, while obesity can make operation more difficult, create more dead space, cause hypoperfusion of tissues, and create tension on the wound. Abdominal surgery identified increased BMI, diabetes, smoking, ASA >2 , low albumin and low haemoglobin as potential independent determinants of SSI. Evidence from orthopaedics also shows strong relationships with diabetes and smoking, with one tertiary care study in India finding that diabetes and smoking were separate risk factors for SSI [15].

The results provide a rationale for a multifaceted, risk-based approach to prevention, instead of using just one intervention, from an infection control standpoint. WHO guidelines include the following: preoperative optimisation, appropriate antimicrobial prophylaxis, skin preparation, intraoperative asepsis, management of temperature and oxygenation, and wound care after the surgery [16]. The CDC guidance also highlights the importance of evidence-based perioperative interventions and that implementation of successful preventive measures

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can prevent a significant number of SSIs. Therefore, there is a need for institutions to adopt a suite of measures for SSI surveillance alongside other measures for antibiotic stewardship, surgical safety, perioperative glycaemic management, wound-risk stratification and systematic post-discharge follow-up [17].

The microbiological profile also has therapeutic implications. In tertiary-care settings in India, *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella* spp., and other Gram-negative organisms have also been reported as important pathogens associated with SSI, and antimicrobial resistance is a significant challenge in management. This is because empirical antimicrobial therapy should be based on local antibiograms and subsequently tailored based on culture and susceptibility testing as clinically appropriate, rather than unnecessary broad-spectrum antibiotic exposure [18].

In summary, SSI should be considered a result of any combination of host, operative, environmental and microbial factors. These relationships should therefore be considered in the context of the surgical case-mix and surveillance approach used at this institution. A prospective multicentre study with 30-day follow-up, standardised definitions of SSI, wound classification, ASA score, glycaemic indices, nutritional markers, duration of surgery, timing of antimicrobial prophylaxis, and microbiological analysis, along with multivariable regression analysis, would help in getting better estimates of independent factors and make comparisons possible between the different tertiary care centres in India.

5 | CONCLUSION

The study concluded that the high rate of incidence of SSI where 40 out of 80 patients (50.0%) developed SSI. Abdominal surgeries showed highest number of SSI including exploratory laparotomy, hernia repair, appendectomy, and cholecystectomy. The organisms isolated included *Staphylococcus aureus*, was the highest, then *Escherichia coli*, *Klebsiella* spp., and *Pseudomonas aeruginosa*. SSI was most reported in the patient category of age >55 years, male patients, emergency surgery patients, and patients with superficial infections and high ASA grades. Diabetes mellitus had a strong statis-

tically significant relationship with SSI ($p<0.0001$), where diabetes among SSI was 55% compared to 20% in non-SSI group. Hospital stay of more than 7 days was significantly associated with SSI ($p<0.0001$). Smoking and alcohol consumption did not have a significant relationship with SSI.

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