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Surgical Site Infection Rates and Associated Risk Factors: A Prospective Observational Study at a Tertiary Care Teaching Hospital.

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Abstract

Background: Surgical site infection (SSI) is the most frequent healthcare-associated infection in low- and middle-income countries and a major cause of postoperative morbidity, prolonged hospitalization and avoidable cost. Because SSI rates, causative organisms and the relative weight of individual risk factors vary substantially between institutions, locally generated surveillance data are essential to guide prevention. ***Aim:*** To determine the incidence of SSI among patients undergoing general surgical procedures at a tertiary care teaching hospital and to identify the independent risk factors associated with its occurrence. ***Materials and Methods:*** A prospective observational cohort study was conducted over two years among 400 patients aged 18 years and above undergoing elective or emergency general surgical procedures. Patients were followed for 30 days postoperatively (90 days where an implant was placed) and SSI was diagnosed using the Centers for Disease Control and Prevention / National Healthcare Safety Network criteria. Pre-operative, intra-operative and post-operative variables were recorded on a structured proforma. Wound swabs from infected sites were cultured and antimicrobial susceptibility determined. Data were analysed in SPSS v29 using the chi-square test and multivariable logistic regression; $p < 0.05$ was taken as significant. ***Results:*** SSI developed in 48 of 400 patients, an overall incidence of 12.0%. Superficial incisional infection accounted for 32 (66.7%) of these, deep incisional for 11 (22.9%) and organ/space for 5 (10.4%). The infection rate rose steadily with wound contamination class, from 6.0% in clean wounds to 27.5% in dirty wounds ($p < 0.001$). On multivariable analysis, diabetes mellitus (aOR 3.12), contaminated or dirty wounds (aOR 2.87), operative duration exceeding 120 minutes (aOR 2.41), ASA grade III or above (aOR 2.28), inappropriately timed antimicrobial prophylaxis (aOR 2.15), pre-operative hair removal by razor shaving (aOR 2.11), emergency surgery (aOR 2.04), serum albumin below 3.5 g/dL (aOR 2.05) and pre-operative stay exceeding three days (aOR 1.96) emerged as independent predictors. Staphylococcus aureus was the commonest isolate (30.8%), and Gram-negative organisms accounted for 55.8% of all isolates. ***Conclusion:*** The SSI rate in this cohort was consistent with that reported from comparable resource-limited settings. The majority of the independent risk factors identified — glycaemic control, timing of prophylaxis, and method of hair removal, nutritional optimisation and duration of pre-operative stay — are modifiable, indicating that a substantial proportion of these infections is preventable through a structured care bundle and sustained surveillance.

Keywords: surgical site infection; healthcare-associated infection; risk factors; antimicrobial prophylaxis; wound class; surgical audit.

INTRODUCTION

Surgery is among the most widely delivered of all health interventions, with an estimated 313 million procedures performed worldwide each year.1 Against this volume, surgical site infection (SSI) — defined as infection occurring at or near the surgical incision within thirty days of an operative procedure, or within ninety days where a prosthetic implant has been placed — remains one of the most persistent complications of operative care.2 It is the most frequently reported healthcare-associated infection in low- and middle-income countries and the second most common in Europe and the United States, and it is unique among hospital-acquired infections in being, to a considerable degree, preventable.3,4

The reported burden differs sharply according to setting. A systematic review of endemic healthcare-associated infection in developing countries found a pooled SSI incidence of approximately 11.8 per 100 surgical procedures, whereas rates in high-income settings are generally reported between 1.2% and 5%.3,5 A large international prospective cohort of patients undergoing gastrointestinal surgery confirmed this gradient, demonstrating progressively higher infection rates as country income level fell, and identified the emergence of resistant organisms as an additional burden borne disproportionately by resource-limited hospitals.6 These disparities reflect differences in case mix, in the proportion of emergency and contaminated operations, in perioperative infrastructure and in the consistency with which preventive measures are applied.

The consequences extend well beyond the wound. Affected patients experience prolonged hospitalisation, repeated dressings and debridement, readmission and, in deep and organ-space infection, appreciable mortality; a systematic review across six European countries documented substantial attributable cost driven principally by additional bed-days.7 SSI is also a major driver of antimicrobial consumption and hence of selection pressure for resistance.6

The determinants of SSI are conventionally grouped as patient-related and procedure-related. Among the former are advancing age, diabetes mellitus, obesity, smoking, hypoalbuminaemia and malnutrition, anaemia, immunosuppression and a high American Society of Anesthesiologists (ASA) physical status grade.8,9 Diabetes has been shown in meta-analysis to confer a significantly increased risk across surgical disciplines, and smoking to impair wound healing through tissue hypoxia and impaired collagen deposition.10,11 Procedure-related determinants include the degree of wound contamination, the urgency and duration of the operation, the appropriateness and timing of antimicrobial prophylaxis, the method of pre-operative hair removal, the placement of drains and the duration of pre-operative hospital stay.12,13,14 The classical surveillance framework combines wound class, ASA grade and operative duration into a composite risk index that predicts infection more accurately than wound class alone.15

Comprehensive preventive guidance has been issued by the World Health Organization and the Centers for Disease Control and Prevention, and bundled interventions incorporating correctly timed prophylaxis, clipping rather than shaving, glycaemic control and adherence to a surgical safety checklist reduce infection.2,4,16,17 Yet such recommendations cannot be translated into practice without knowledge of local performance, since infection rates, causative organisms and the relative contribution of individual risk factors all vary between institutions. Continuous surveillance with feedback to surgical teams is itself among the most effective recommended measures.16

The present study was therefore undertaken to determine the incidence and anatomical depth of SSI among patients undergoing general surgical procedures at a tertiary care teaching hospital, to characterise the microbiological profile of the infections encountered, and to identify, by multivariable analysis, the risk factors independently associated with their occurrence, with a view to informing a locally applicable prevention strategy.

MATERIALS AND METHODS

Study design, setting and duration. This prospective observational cohort study was conducted in the Department of General Surgery of Employees State Insurance Corporation Medical College and Hospital Kalaburagi, tertiary care teaching hospital over a period of two years. Written informed consent was obtained from every participant prior to enrolment.

Participants. Consecutive patients aged 18 years and above undergoing elective or emergency general surgical procedures under general or regional anaesthesia were eligible. Patients were excluded if they had clinical or laboratory evidence of infection at the operative site at the time of surgery, were receiving therapeutic antibiotics for an established infection elsewhere, had undergone a surgical procedure within the preceding thirty days, were known to be immunocompromised on account of human immunodeficiency virus infection or ongoing chemotherapy, or were unwilling or unable to attend the scheduled follow-up.

Sample size. The sample size was calculated from the formula $n = Z^2pq/d^2$, taking an anticipated SSI incidence (p) of 12% derived from previously published data from comparable settings, q = 88%, an absolute precision (d) of 3.5% and a two-sided 95% confidence level ($Z = 1.96$, $Z^2 \approx 3.84$). This yielded $n = (3.84 \times 12 \times 88)/(3.5)^2 \approx 331$. Allowing for attrition and incomplete follow-up, 400 patients were enrolled.

Data collection. A structured, pre-tested proforma recorded pre-operative variables (age, sex, body mass index, comorbidity, smoking status, haemoglobin, serum albumin, ASA physical status grade and duration of pre-operative stay); intra-operative variables (urgency, wound contamination class, procedure performed, duration of surgery from incision to closure, method of hair removal, timing and choice of antimicrobial prophylaxis, blood transfusion and drain placement); and post-operative variables (day of onset, depth of infection, culture result and length of stay). Wounds were classified as clean, clean-contaminated, contaminated or dirty by standard criteria.20

Definition and ascertainment of the outcome. The primary outcome was the development of SSI within thirty days of the index operation, or within ninety days where a prosthetic implant had been placed, diagnosed according to the Centers for Disease Control and Prevention / National Healthcare Safety Network surveillance definitions and classified as superficial incisional, deep incisional or organ/space.2 Wounds were inspected daily during the inpatient period by an investigator not involved in the operative care, and patients were reviewed after discharge in the outpatient department on the seventh, fifteenth and thirtieth post-operative days; those failing to attend were contacted by telephone using a structured questionnaire and were invited for clinical assessment where any symptom suggestive of infection was reported.

Microbiological methods. Where SSI was diagnosed, pus or exudate was collected by sterile swab or aspiration before any therapeutic antibiotic was begun, inoculated onto blood and MacConkey agar and incubated aerobically at 37 °C for 24–48 hours. Isolates were identified by colony morphology, Gram staining and biochemical reactions, and susceptibility was determined by Kirby-Bauer disc diffusion interpreted against Clinical and Laboratory Standards Institute breakpoints, methicillin resistance being detected with a cefoxitin disc.

Statistical analysis. Data were analysed in IBM SPSS Statistics version 29. Categorical variables are presented as frequencies and percentages, continuous variables as mean ± standard deviation, and SSI incidence as infections per 100 operations with its 95% confidence interval. Univariable associations were tested by the chi-square or Fisher's exact test and continuous variables by the independent-samples t-test. Variables attaining $p < 0.10$ were entered into a multivariable binary logistic regression model built by backward stepwise elimination, results being reported as adjusted odds ratios with 95% confidence intervals. Calibration was assessed by the Hosmer-Lemeshow test and explained variance by the Nagelkerke R^2. A two-tailed $p < 0.05$ was considered significant.

RESULTS

Four hundred patients were enrolled and completed the stipulated follow-up. Their baseline demographic, clinical and operative characteristics are presented in Table 1.

Table 1 — Baseline demographic, clinical and operative characteristics of the study cohort (n = 400). Mean age 46.3 ± 15.7 years. ASA = American Society of Anesthesiologists

Characteristic	Category	n	%
Age (years)	≤ 50	240	60.0
	> 50	160	40.0
Sex	Male	230	57.5
	Female	170	42.5
Diabetes mellitus	Present	96	24.0
Body mass index	≥ 25 kg/m²	124	31.0
Current smoker	Yes	110	27.5
Serum albumin	< 3.5 g/dL	88	22.0
ASA physical status	Grade III or above	104	26.0
Urgency of operation	Emergency	150	37.5
	Elective	250	62.5
Operative duration	> 120 minutes	130	32.5
Pre-operative stay	> 3 days	118	29.5
Hair removal	Razor shaving	96	24.0
Prophylaxis timing	Not within 60 min of incision	112	28.0
Drain placed	Yes	146	36.5

The cohort comprised 230 males (57.5%) and 170 females (42.5%) with a mean age of 46.3 ± 15.7 years. Nearly one quarter of patients were diabetic (24.0%) and 22.0% were hypoalbuminaemic. Emergency procedures accounted for 37.5% of the caseload. Three practices departing from current recommendations were prevalent: razor shaving for hair removal in 24.0%, antimicrobial prophylaxis administered outside the recommended sixty-minute window before incision in 28.0%, and a pre-operative hospital stay exceeding three days in 29.5%.

Table 2 — Incidence and anatomical depth of surgical site infection (CDC/NHSN classification).

Type of surgical site infection	n	% of all SSI	% of cohort (n = 400)
Superficial incisional	32	66.7	8.00
Deep incisional	11	22.9	2.75
Organ / space	5	10.4	1.25
Total	48	100.0	12.00

Surgical site infection developed in 48 of the 400 patients, giving an overall incidence of **12.0% (95% CI 9.1–15.5)**. Two thirds of these were superficial incisional infections (32; 66.7%), while deep incisional infection occurred in 11 patients

(22.9%) and organ/space infection in 5 (10.4%). The mean day of onset was the 6.4 ± 2.8 post-operative day, and 14 infections (29.2%) were detected only after discharge, underlining the importance of post-discharge surveillance. The mean duration of hospital stay was significantly longer among infected patients (14.2 ± 4.6 days) than among those without infection (6.8 ± 2.3 days; $p < 0.001$).

Table 3 — Surgical site infection rate stratified by wound contamination class (χ^2 for trend, $p < 0.001$).

Wound contamination class	Operations (n)	SSI (n)	SSI rate (%)
Class I — Clean	150	9	6.0
Class II — Clean-contaminated	140	15	10.7
Class III — Contaminated	70	13	18.6
Class IV — Dirty / infected	40	11	27.5
Total	400	48	12.0

A clear and statistically significant gradient was observed across the wound classes. The infection rate rose more than fourfold from 6.0% in clean wounds to 27.5% in dirty wounds ($p < 0.001$). Clean and clean-contaminated procedures together accounted for 290 operations but only 24 infections, whereas the 110 contaminated and dirty procedures accounted for the remaining 24 — that is, 27.5% of the caseload contributed half of the total infection burden.

Table 4 — Univariable analysis of factors associated with surgical site infection (chi-square test). * = statistically significant ($p < 0.05$).

Risk factor	Category	n	SSI n (%)	p-value
Age	> 50 years	160	26 (16.3)	0.031*
	≤ 50 years	240	22 (9.2)	
Sex	Male	230	29 (12.6)	0.658
	Female	170	19 (11.2)	
Diabetes mellitus	Present	96	22 (22.9)	< 0.001*
	Absent	304	26 (8.6)	
Body mass index	≥ 25 kg/m²	124	22 (17.7)	0.017*
	< 25 kg/m²	276	26 (9.4)	
Smoking	Yes	110	19 (17.3)	0.041*
	No	290	29 (10.0)	
Serum albumin	< 3.5 g/dL	88	19 (21.6)	0.001*
	≥ 3.5 g/dL	312	29 (9.3)	
ASA grade	III or above	104	21 (20.2)	0.002*
	I – II	296	27 (9.1)	
Urgency	Emergency	150	27 (18.0)	0.003*
	Elective	250	21 (8.4)	
Operative duration	> 120 minutes	130	25 (19.2)	0.002*
	≤ 120 minutes	270	23 (8.5)	
Pre-operative stay	> 3 days	118	23 (19.5)	0.003*
	≤ 3 days	282	25 (8.9)	
Prophylaxis timing	Outside 60-min window	112	22 (19.6)	0.003*
	Within 60 min of incision	288	26 (9.0)	
Hair removal	Razor shaving	96	19 (19.8)	0.005*
	Clipping or none	304	29 (9.5)	
Drain placement	Yes	146	24 (16.4)	0.037*
	No	254	24 (9.4)	
Wound class	Contaminated / dirty	110	24 (21.8)	< 0.001*
	Clean / clean-contaminated	290	24 (8.3)	

On univariable analysis, thirteen of the fourteen factors examined were significantly associated with the development of SSI. The strongest associations were seen with diabetes mellitus (22.9% versus 8.6%; $p < 0.001$) and with contaminated or dirty wounds (21.8% versus 8.3%; $p < 0.001$). Sex was the only variable showing no significant association (12.6% in males versus 11.2% in females; $p = 0.658$). Notably, each of the three departures from recommended practice identified in Table 1 — razor shaving, mistimed prophylaxis and prolonged pre-operative stay — approximately doubled the observed infection rate.

Table 5 — Multivariable binary logistic regression identifying independent predictors of surgical site infection. OR = odds ratio; CI = confidence interval. Hosmer-Lemeshow $\chi^2 = 6.42$, $p = 0.601$; Nagelkerke $R^2 = 0.29$. * = statistically significant ($p < 0.05$).

Independent variable	Adjusted OR	95% CI	p-value
Diabetes mellitus	3.12	1.58 – 6.16	0.001*
Contaminated / dirty wound	2.87	1.42 – 5.80	0.003*
Operative duration > 120 minutes	2.41	1.21 – 4.80	0.012*
ASA grade III or above	2.28	1.13 – 4.60	0.021*
Prophylaxis outside 60-min window	2.15	1.08 – 4.28	0.029*
Hair removal by razor shaving	2.11	1.04 – 4.28	0.038*
Serum albumin < 3.5 g/dL	2.05	1.02 – 4.12	0.043*
Emergency surgery	2.04	1.02 – 4.09	0.044*
Pre-operative stay > 3 days	1.96	1.01 – 3.83	0.048*
Body mass index ≥ 25 kg/m²	1.61	0.81 – 3.20	0.174
Smoking	1.55	0.76 – 3.16	0.229
Age > 50 years	1.42	0.72 – 2.80	0.311
Drain placement	1.38	0.70 – 2.72	0.352

After adjustment for confounding, nine variables retained independent significance. Diabetes mellitus carried the greatest weight, more than trebling the odds of infection (aOR 3.12; 95% CI 1.58–6.16), followed by contaminated or dirty wounds (aOR 2.87) and prolonged operative duration (aOR 2.41). Body mass index, smoking, age and drain placement, although significant on univariable testing, lost significance once adjusted, indicating that their apparent effect was mediated through the stronger covariates. The Hosmer-Lemeshow statistic (p = 0.601) indicated satisfactory model calibration, and the model explained approximately 29% of the variance in outcome. Of the nine independent predictors, six — glycaemic status, operative duration, prophylaxis timing, hair removal method, nutritional status and pre-operative stay — are potentially modifiable.

Table 6 — Microbiological profile of isolates from 44 culture-positive surgical site infections. MRSA = methicillin-resistant Staphylococcus aureus.

Organism isolated	n	%
Staphylococcus aureus (MRSA 7)	16	30.8
Escherichia coli	12	23.1
Klebsiella pneumoniae	8	15.4
Pseudomonas aeruginosa	6	11.5
Coagulase-negative staphylococci	4	7.7
Enterococcus species	3	5.8
Acinetobacter baumannii	2	3.8
Proteus species	1	1.9
Total isolates	52	100.0

Of the 48 infected wounds, 44 (91.7%) yielded bacterial growth, and 8 of these were polymicrobial, giving a total of 52 isolates. Staphylococcus aureus was the single commonest organism (16 isolates; 30.8%), of which 7 were methicillin-resistant, followed by Escherichia coli (12; 23.1%) and Klebsiella pneumoniae (8; 15.4%). Taken together, Gram-negative organisms accounted for 29 isolates (55.8%) and Gram-positive organisms for 23 (44.2%). Gram-positive isolates predominated in clean wounds, whereas Gram-negative and polymicrobial growth was characteristic of contaminated and dirty abdominal procedures.

DISCUSSION

The overall SSI incidence of 12.0% observed in this cohort accords closely with the pooled figure of approximately 11.8 per 100 procedures reported for developing countries, and is appreciably higher than the 1.2–5% typical of high-income settings.3,4,5 A large multinational cohort of gastrointestinal surgery has similarly demonstrated a stepwise rise in infection rates as country income level falls.6 The predominance of superficial incisional infection (66.7%) is consistent with the published distribution, and the finding that 29.2% of infections presented only after discharge reinforces the argument that surveillance confined to the inpatient period materially underestimates the true rate.16

The graded increase in infection across wound classes, from 6.0% in clean to 27.5% in dirty wounds, reproduces the relationship first formalised in the National Nosocomial Infections Surveillance system, in which wound class combined with ASA grade and operative duration predicted infection more accurately than any single variable.15 That all three components of that index — wound class, ASA grade above II and operative duration exceeding 120 minutes — retained independent significance in the present multivariable model lends internal coherence to the findings and supports the continued use of composite risk stratification in surgical audit.

Diabetes mellitus emerged as the strongest independent predictor (aOR 3.12), in keeping with a systematic review and meta-analysis that confirmed a significantly increased risk across surgical specialties and implicated perioperative hyperglycaemia rather than the diagnosis of diabetes alone.10Hypoalbuminaemia was likewise independently predictive, consistent with evidence that a low pre-operative serum albumin is an independent determinant of infection after gastrointestinal surgery and a marker of the impaired collagen synthesis and blunted immune response that accompany malnutrition.18 Smoking, although significant on univariable testing, did not survive adjustment in this cohort, despite meta-analytic evidence of impaired wound healing in smokers; the discrepancy is most plausibly explained by the modest number of events and by collinearity with comorbidity.11

Three of the independent predictors identified represent straightforward failures of process rather than immutable patient characteristics. Antimicrobial prophylaxis administered outside the sixty-minute window preceding incision doubled the odds of infection, echoing the classical demonstration that infection risk rises sharply when prophylaxis is given either too early or after incision.12,13 Pre-operative hair removal by razor shaving was similarly predictive; a Cochrane review has established that shaving produces microscopic epidermal injury that becomes colonised, and that clipping — or omitting hair removal entirely — is associated with significantly fewer infections.14 A pre-operative stay beyond three days also retained independent significance, reflecting colonisation of the patient with hospital flora, and is readily addressed through streamlined pre-operative assessment.8,9

The microbiological profile, with Staphylococcus aureus predominant overall but Gram-negative organisms forming the majority of isolates, mirrors that reported from comparable Indian institutions and reflects the contribution of contaminated abdominal procedures to the caseload.19 The recovery of methicillin-resistant S. aureus in 7 of 16 staphylococcal isolates bears directly on empirical therapy and antimicrobial stewardship.

Limitations. This was a single-centre study, and the case mix of a tertiary referral hospital — weighted towards emergency and contaminated procedures — may limit generalisability. Post-discharge ascertainment relied in part on telephone follow-up, which may have underestimated mild superficial infection. Certain recognised determinants, including intra-operative normothermia, tissue oxygenation and glycaemic indices such as glycated haemoglobin, were not captured. Finally, the number of deep and organ-space infections was too small to permit separate multivariable modelling by depth of infection.

CONCLUSION

Surgical site infection complicated 12.0% of general surgical procedures in this cohort, a figure consistent with that reported from comparable resource-limited settings and substantially above that achieved in high-income institutions. Infection rates rose steeply with increasing wound contamination, and nine factors were independently predictive of infection: diabetes mellitus, contaminated or dirty wounds, prolonged operative duration, ASA grade III or above, mistimed antimicrobial prophylaxis, razor shaving, hypoalbuminaemia, emergency surgery and prolonged pre-operative stay. Critically, the majority of these are modifiable. Perioperative glycaemic control, nutritional optimisation, adherence to the sixty-minute prophylaxis window, replacement of razor shaving by clipping, minimisation of pre-operative hospital stay and measures to shorten operative time together constitute a coherent and inexpensive prevention bundle. Their implementation, coupled with continuous surveillance incorporating post-discharge follow-up and regular feedback of rates to surgical teams, offers a realistic prospect of reducing the burden of surgical site infection in this and comparable institutions.

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