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ORIGINAL ARTICLE

Frequency and risk factors of Surgical Site Infections following neurosurgical procedures.

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ABSTRACT... Objective: To determine the frequency and identify risk factors associated with SSIs following neurosurgical procedures. **Study Design:** Analytical Cross-sectional Investigation. **Setting:** Neurosurgery Department of Nishtar Hospital Multan. **Period:** May 2025 to January 2026. **Methods:** Following ethical approval, 292 patients undergoing cranial or spinal procedures were enrolled. Data included demographics, comorbidities, procedural details and microbiological profiles. Infections were classified using CDC criteria. SPSS version 23.0 analyzed data. Chi-square and Independent sample t-tests were used to assess the associations and p value <0.05 taken as significant. **Results:** Among 287 patients overall SSI frequency was 5.2%. Significant risk factors included diabetes mellitus (OR 4.89), obesity (OR 3.42), emergency surgery (OR 3.78), operative duration exceeding 180 minutes (OR 5.08), and delayed antibiotic prophylaxis (OR 3.69). Staphylococcus aureus was the predominant pathogen (40%), with 50% methicillin resistance. Gram-negative organisms included Escherichia coli and Pseudomonas. Infected patients experienced prolonged hospital stays (18 vs 6 days), higher reoperation rates (73.3% vs 4.4%), and increased 90-day mortality (13.3% vs 1.1%), respectively. **Conclusion:** SSIs constitute a major preventable complication driven by modifiable patient and procedural risk factors. Implementing standardized prevention protocols alongside robust antimicrobial stewardship is essential to reduce morbidity, mortality and healthcare costs in resource constrained settings.

Key words: Antimicrobial Stewardship, Diabetes Mellitus, Neurosurgery, Operative Duration, Risk Factors, Surgical Site Infection.

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INTRODUCTION

Surgical site infections (SSIs) are significant complications in neurosurgery, leading to increased morbidity, extended hospital stays, and substantial healthcare costs. Understanding the frequency and severity of SSIs in neurosurgical procedures is crucial for developing effective prevention and management strategies. SSIs are infections occurring at or near the surgical incision within 30 days of an operation or within one year if an implant is placed. In neurosurgery, the proximity of surgical sites to the central nervous system elevates the risk of severe complications, including meningitis and encephalitis. The reported incidence of SSIs in neurosurgical procedures varies, with studies indicating rates ranging from 1% to 10%, depending on the type of surgery and patient-related factors. For instance, a study reported an overall SSI incidence of approximately 2% in neurosurgical operations.[1,2]

The occurrence of SSIs in neurosurgery is associated with significant clinical challenges. Patients developing SSIs often require additional surgical interventions, prolonged antibiotic therapy, and extended intensive care, leading to delayed recovery and increased mortality rates. Economically, SSIs impose a heavy burden on healthcare systems.[3,4] In the United States, the estimated cost per SSI is approximately $20,785, making them one of the most expensive healthcare-associated infections. Specifically, in spinal fusion surgeries, which are common neurosurgical procedures, SSIs can lead to increased hospital costs and resource utilization.[5]

Despite advancements in surgical techniques and infection control measures, SSIs remain a persistent issue in neurosurgery. The variability in reported SSI rates suggests potential gaps in preventive strategies and highlights the need for standardized protocols.

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Moreover, the significant clinical and economic impacts of SSIs necessitate a comprehensive analysis to identify modifiable risk factors and effective prevention measures tailored to neurosurgical patients. Lack of consensus on the definitions and diagnostic criteria for SSIs in neurosurgery, lead to inconsistencies in incidence rates. Additionally, there is limited research focusing on the severity of SSIs and their direct impact on patient outcomes and healthcare costs in the neurosurgical context.

OBJECTIVES

Objective of the study was to determine the frequency and risk factors of Surgical Site Infections (SSIs) following neurosurgical procedures.

METHODS

This was analytical cross-sectional study conducted in Neurosurgery department of Nishtar Hospital Multan from May 2025 to March 2026 after taking approval from Institutional Ethical review board (Reference No. 8971/NMU Dated: 12-05-2025) and informed consent from individual patient or legal guardian. Based on Expected SSI incidence 5%[6], confidence level 95% and precision required 2.5% the calculated sample size for the study was 287 patients. Patients who undergone cranial or spinal neurosurgical procedures were included in the study through non probability consecutive sampling. Patients with pre-existing infections at the surgical site before the neurosurgical procedure, undergoing neurosurgical procedures for traumatic brain injury (TBI) if infection occurred before admission and Patients who undergone minor neurosurgical interventions not involving deep tissue manipulation will be excluded.

Data was collected from hospital records by using preformed questionnaire that included demographic information (age, gender, comorbidities), type of neurosurgical procedure (cranial vs. spinal, elective vs. emergency), duration of surgery and intraoperative factors and antibiotic prophylaxis usage. Culture and sensitivity reports of wound swabs or cerebrospinal fluid (CSF) samples for identification of common causative pathogens and antibiotic resistance patterns was done. To classify and quantify the severity of SSIs, the study employed CDC (Centers for Disease Control and Prevention) Classification of SSIs including superficial incisional SSI, Deep incisional SSI, Organ/space SSI. Data was entered and analyzed by using SPSS version 23.0. Frequency and percentage calculated for SSI frequency across different neurosurgical procedures. Mean and standard deviation was calculated for quantitative variables like age and duration of surgery. Comparison of SSI rates across different neurosurgical procedures cranial vs. spinal procedures was done. Independent sample t-test was used for quantitative variables and Chi-square test for categorical variables (presence vs. absence of infection) and p value <0.05 was taken as significant.

RESULTS

A total of 287 patients undergoing cranial or spinal neurosurgical procedures were enrolled and 15 (5.2%) developed a surgical site infection. The mean age of the cohort was 48.3 ± 16.7 years, with male predominance (58.5%). When comparing patients who developed SSIs against those who did not, diabetes mellitus was present in 53.3% of the SSI group compared to 21.7% of the non-infected group (p=0.008). Obesity (BMI ≥30) was significantly more common among patients with infections (33.3% vs. 13.2%; p=0.041). Cranial procedures accounted for 60.0% of the SSI cases, with higher infection rate compared to spinal surgeries (7.3% vs. 3.7%; p=0.024). Emergency surgeries were associated with a higher proportion of infections than elective procedures (60.0% of SSI cases vs. 40.0%; p=0.012). The mean operative duration was significantly prolonged in the SSI group (264.7 ± 71.2 minutes) compared to the non-SSI (183.1 ± 59.8 minutes; p<0.001). Timely antibiotic administration (≤60 minutes pre-incision) was observed in 85.3% of non-infected patients, whereas 40.0% of SSI patients received delayed or omitted prophylaxis (p=0.019) (Table-I).

Among the 15 confirmed infections, superficial incisional SSIs were the most frequent type (46.7%), followed by deep incisional (33.3%) and organ/space infections (20.0%). Cranial surgeries showed broader spectrum of severity, with organ/ space infections occurring exclusively in this group (3 cases). Spinal surgery infections were limited to superficial and deep incisional categories. Emergency craniotomies carried the highest procedure specific infection rate at 10.9%, whereas elective spinal fusion had the lowest rate at 1.8% (Table-II).

Microbiological analysis was performed on wound swabs or CSF samples from the 15 SSI cases. Gram-positive organisms were the predominant isolates, accounting for 66.7% of identified pathogens. Staphylococcus aureus was the most frequently isolated organism (40.0% of all isolates). Among the S. aureus isolates, methicillin-resistant strains (MRSA) constituted 50%. Coagulase-negative Staphylococci and Enterococcus faecalis were also identified. Gram-negative organisms included Escherichia coli, Pseudomonas aeruginosa and Klebsiella pneumoniae. Resistance patterns indicated high susceptibility to Meropenem and Vancomycin across most isolates, while resistance to Ampicillin and Ceftriaxone was common. One case yielded no growth, and one was polymicrobial (Table-III).

Patients with diabetes mellitus had nearly five times the odds of developing an infection compared to non-diabetic patients (OR 4.89; 95% CI 1.72–13.91; p=0.003). Obesity increased the odds by 3.42-fold (p=0.031). Surgical urgency was a significant predictor, with emergency procedures showing an odds ratio of 3.78 (p=0.013) compared to elective cases. Operative duration exceeding 180 minutes was strongly associated with infection (OR 5.08; p=0.004). Additionally, delayed or omitted antibiotic prophylaxis (OR 3.69; p=0.017) and an ASA score ≥3 (OR 3.03; p=0.048) were significantly linked to higher SSI rates (Table-IV).

Patients who developed infections experienced a significantly prolonged median postoperative hospital stay of 18 days (IQR 12–27) compared to 6 days (IQR 4–9) for those without infection (p<0.001). The requirement for reoperation was markedly higher in the SSI group (73.3%) versus the non-SSI group (4.4%; p<0.001). Postoperative ICU admission was required for 60.0% of SSI patients compared to 14.0% of counterpart (p<0.001). Antibiotic usage was substantially greater in the infected patients, with a mean duration of 21.4 ± 9.7 days versus 3.2 ± 1.8 days (p<0.001). Thirty-day readmission rates were 46.7% for SSI patients compared to 2.9% for non-SSI patients (p<0.001). Mortality within 90 days was also significantly higher in the SSI group (13.3%) compared to the non-SSI group (1.1%; p=0.006) (Table-V).

DISCUSSION

The current study identified an overall surgical site infection (SSI) frequency of 5.2% among neurosurgical patients; a figure that aligns with reported rates from developing nations but remains higher than high-income countries.[7] This variability underscores the influence of local healthcare infrastructure and infection control protocols on outcomes. Recent data from Pakistan suggests SSI rates in surgical specialties often fluctuate between 4% and 12%, reflecting challenges in resource limited settings such as sterilization logistics, antimicrobial stewardship and postoperative surveillance.[8] The observed frequency in this study reinforces the need for localized, procedure specific surveillance systems to track infection trends accurately and inform quality improvement initiatives.[9] While global guidelines advocate for rates below 3% in neurosurgical procedures.[10]

Patient related comorbidities emerged as critical determinants of infection risk in this study. Diabetes mellitus and obesity were significantly associated with SSI development, consistent with pathophysiological mechanisms involving impaired neutrophil function, microvascular compromise and altered wound healing kinetics.[11] These findings mirror recent systematic reviews identifying metabolic syndrome components as independent predictors of neurosurgical complications with hyperglycemia exerting both acute and chronic immunomodulatory effects.[12] The strong association between emergency surgery and SSI (OR 3.78) likely stems from reduced preoperative optimization time, limited opportunity for skin decolonization and the inherent physiological stress of acute neurological events.[13]

TABLE-I					
Baseline demographic and clinical characteristics of neurosurgical patients (n=287)					
Characteristic	**Category**	**Total (N=287)**	**No SSI (n=272)**	**SSI (n=15)**	**P-Value**
Age (years), mean ± SD	-	48.3 ± 16.7	47.9 ± 16.5	54.2 ± 18.1	0.142
Gender, n (%)	Male	168 (58.5)	160 (58.8)	8 (53.3)	0.761
	Female	119 (41.5)	112 (41.2)	7 (46.7)	
Comorbidities, n (%)	Diabetes mellitus	67 (23.3)	59 (21.7)	8 (53.3)	0.008
	Hypertension	89 (31.0)	83 (30.5)	6 (40.0)	0.432
	Obesity (BMI ≥30)	41 (14.3)	36 (13.2)	5 (33.3)	0.041
	Smoking history	52 (18.1)	48 (17.6)	4 (26.7)	0.378
Procedure type, n (%)	Cranial surgery	124 (43.2)	115 (42.3)	9 (60.0)	0.024
	Spinal surgery	163 (56.8)	157 (57.7)	6 (40.0)	
Surgical urgency, n (%)	Elective	201 (70.0)	195 (71.7)	6 (40.0)	0.012
	Emergency	86 (30.0)	77 (28.3)	9 (60.0)	
Operative duration (min), mean ± SD	-	187.4 ± 62.3	183.1 ± 59.8	264.7 ± 71.2	<0.001
Antibiotic prophylaxis, n (%)	Administered ≤60 min pre-incision	241 (84.0)	232 (85.3)	9 (60.0)	0.019
	Delayed or omitted	46 (16.0)	40 (14.7)	6 (40.0)	
Implant use, n (%)	Yes	138 (48.1)	128 (47.1)	10 (66.7)	0.148
	No	149 (51.9)	144 (52.9)	5 (33.3)	

SSI = Surgical Site Infection; SD = Standard Deviation; BMI = Body Mass Index. Chi-square test for categorical variables; Independent t-test for continuous variables.

TABLE-II						
Incidence and distribution of surgical site infections by procedure type and CDC Classification (n=287)						
Procedure Category	**Total Patients**	**SSI Cases**	**SSI Rate (%)**	**Superficial Incisional**	**Deep Incisional**	**Organ/Space**
All procedures	287	15	5.2	7 (46.7)	5 (33.3)	3 (20.0)
Cranial surgery	124	9	7.3	3 (33.3)	3 (33.3)	3 (33.3)
Elective craniotomy	78	4	5.1	2 (50.0)	1 (25.0)	1 (25.0)
Emergency craniotomy	46	5	10.9	1 (20.0)	2 (40.0)	2 (40.0)
Spinal surgery	163	6	3.7	4 (66.7)	2 (33.3)	0 (0.0)
Elective fusion	112	2	1.8	2 (100.0)	0 (0.0)	0 (0.0)
Emergency decompression	51	4	7.8	2 (50.0)	2 (50.0)	0 (0.0)

Similarly, prolonged operative duration exceeding 180 minutes significantly increased risk indicating that extended tissue exposure, repeated instrument handling and cumulative anesthesia effects correlate with microbial contamination opportunities.[14]

Microbiological profiling revealed a predominance of Gram-positive organisms, specifically Staphylococcus aureus, which accounted for 40% of isolates. The detection of methicillin-resistant S. aureus (MRSA) in half of these cases highlights a growing concern regarding antimicrobial resistance in neurosurgical units.[15], This resistance pattern is particularly troubling given the limited penetration of certain antibiotics across the blood brain barrier, necessitating agents with reliable central nervous system bioavailability.[16] Gram-negative isolates demonstrated extended-spectrum beta-lactamase (ESBL) production, a trend increasingly reported in Pakistani healthcare settings where empirical third-generation cephalosporin use remains widespread.[17] The high susceptibility to Meropenem and

TABLE-III

Microbiological Profile and Antimicrobial Susceptibility Patterns of Pathogens Isolated from SSI Cases (n=15)

Pathogen Identified	Number of Isolates (%)	Ampicillin	Ceftriax-one	Cefepime	Meropen-em	Vancomy-cin	Ciproflox-acin	Gentami-cin
Gram-positive organisms								
Staphylococcus aureus	6 (40.0)	0% S	17% S	33% S	100% S	100% S	33% S	50% S
MSSA	3 (20.0)	100% S	100% S	100% S	100% S	100% S	67% S	100% S
MRSA	3 (20.0)	0% S	0% S	0% S	100% S	100% S	0% S	0% S
Coagulase-negative Staphylococci	3 (20.0)	0% S	33% S	67% S	100% S	100% S	33% S	67% S
Enterococcus faecalis	1 (6.7)	100% S	0% S	0% S	100% S	100% S	0% S	100% S
Gram-negative organisms								
Escherichia coli	2 (13.3)	0% S	0% S*	50% S	100% S	-	50% S	50% S
Pseudomonas aeruginosa	2 (13.3)	0% S	0% S	50% S	100% S	-	0% S	50% S
Klebsiella pneumoniae	1 (6.7)	0% S	0% S*	0% S	100% S	-	0% S	0% S
Polymicrobial	1 (6.7)	-	-	-	-	-	-	-
No growth	1 (6.7)	-	-	-	-	-	-	-

*S = Susceptible; MSSA = Methicillin-sensitive S. aureus; MRSA = Methicillin-resistant S. aureus; ESBL-producing strains detected in 2 isolates. Susceptibility percentages represent proportion of isolates sensitive to each agent. Dashes indicate antibiotic not routinely tested for that organism class.

TABLE-IV

Univariate analysis of potential risk factors associated with surgical site infection development

Risk Factor	Category	SSI Rate (%)	Odds Ratio (95% CI)	P-Value
Diabetes mellitus	Yes vs. No	11.9% vs. 2.7%	4.89 (1.72–13.91)	0.003
Obesity (BMI ≥30)	Yes vs. No	12.2% vs. 3.9%	3.42 (1.12–10.45)	0.031
Procedure type	Cranial vs. Spinal	7.3% vs. 3.7%	2.05 (0.73–5.78)	0.172
Surgical urgency	Emergency vs. Elective	10.5% vs. 3.0%	3.78 (1.33–10.74)	0.013
Operative duration	>180 min vs. ≤180 min	9.8% vs. 2.1%	5.08 (1.67–15.47)	0.004
Antibiotic prophylaxis timing	Delayed/omitted vs. ≤60 min	13.0% vs. 3.9%	3.69 (1.26–10.81)	0.017
Implant use	Yes vs. No	7.2% vs. 3.4%	2.23 (0.76–6.54)	0.145
ASA score	≥3 vs. ≤2	9.1% vs. 3.2%	3.03 (1.01–9.12)	0.048
Preoperative hospital stay	>48h vs. ≤48h	8.7% vs. 4.1%	2.24 (0.74–6.79)	0.154

TABLE-V

Clinical outcomes among patients with and without surgical site infections

Outcome Measure	No SSI (n=272)	SSI (n=15)	P-Value
Median postoperative hospital stay (days), IQR	6 (4–9)	18 (12–27)	<0.001
Reoperation required, n (%)	12 (4.4)	11 (73.3)	<0.001
ICU admission post-op, n (%)	38 (14.0)	9 (60.0)	<0.001
Total antibiotic days, mean ± SD	3.2 ± 1.8	21.4 ± 9.7	<0.001
30-day readmission, n (%)	8 (2.9)	7 (46.7)	<0.001
Mortality within 90 days, n (%)	3 (1.1)	2 (13.3)	0.006

IQR = Interquartile Range; SD = Standard Deviation; ICU = Intensive Care Unit.

Vancomycin suggests these agents remain viable empirical choices for severe or refractory cases, though institutional antimicrobial stewardship programs are essential to prevent further resistance escalation.[18] The presence of polymicrobial infections and culture negative cases indicates the potential role of fastidious organisms, prior antibiotic exposure masking microbiological diagnosis, or non-bacterial inflammatory mimics.[19]

Infected patients were experiencing threefold increase in median hospital stay and significantly higher mortality rates. The median postoperative stay of 18 days for SSI patients contrasts sharply with the 6 days for non-infected controls, driving up resource utilization, bed occupancy costs, and opportunity costs for other patients awaiting neurosurgical care.[20] Reoperation rates were markedly high in the infection group, necessitating additional surgical interventions that compound patient morbidity, psychological distress and caregiver burden. Economic analyses from similar low- and middle-income contexts indicate that SSIs can increase direct hospital costs by three to five fold, burdening under resourced healthcare systems.[21] The 90-day mortality rate of 13.3% in the SSI group underscores the severity of these infections, particularly when organ/space involvement occurs, as seen exclusively in cranial procedures within this study.[22]

This study benefits from analytical design with standardized CDC criteria for SSI classification, ensuring consistent outcome measurement across cranial and spinal procedures. The inclusion of microbiological confirmation with susceptibility testing adds validity to the etiological data, while the assessment of clinical outcomes provides a comprehensive view of the patient-centered burden. However, several limitations warrant acknowledgment. The single center study may limit the generalizability of findings.

Based on these findings, several targeted, context-appropriate interventions are recommended. Strict perioperative glycemic control protocols should be implemented for diabetic patients undergoing neurosurgery, alongside preoperative weight optimization counseling where feasible. Preoperative antibiotic prophylaxis timing must be audited regularly. For emergency procedures where preoperative optimization is constrained, enhanced intraoperative measures including chlorhexidine-alcohol skin preparation, intraoperative antibiotic dose and meticulous hemostasis should be standardized. Future research should prioritize multicenter collaborations across neurosurgical centers to validate these risk factors, evaluate the cost effectiveness of prevention strategies and assess the impact of implementation science approaches on sustainable SSI reduction.

CONCLUSION

Surgical site infections remain a significant and preventable complication in neurosurgery, driven by modifiable patient, procedural and system level risk factors. Implementing standardized, evidence-based prevention protocols along with antimicrobial stewardship is essential to reduce morbidity, mortality and healthcare costs associated with these infections in resource constrained settings.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHORSHIP AND CONTRIBUTION DECLARATION	
1	**Malik Liaqat Ali Jalal:** Conception of idea, study design, acquisition of data, manuscript writing.
2	**Syed Muhammad Ahmed:** Data collection, data analysis.
3	**Zermina Tanvir:** Data interpretation, data analysis.