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EXPLORING THE INTERPLAY OF MICROBIOLOGICAL FACTORS, PHARMACOLOGICAL APPROACHES, AND PHYSIOLOGICAL INFLUENCES ON SURGICAL SITE INFECTIONS IN PAKISTANI HOSPITALS

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ABSTRACT

Introduction: In healthcare settings, surgical site infections (SSIs) present a major concern, especially in resource-constrained areas like Khyber Pakhtunkhwa (KPK), Pakistan. This research investigates the interactions between pharmaceutical interventions, physiological impacts, and microbiological factors that affect SSIs in hospitals in KPK. Gaining an understanding of these relationships is essential to enhancing patient outcomes and infection control in such environments.

Methodology: From January, 2020 to June of 2021, cross-sectional research was carried out at many hospitals in KPK, Pakistan. Data on pathogen types, antibiotic resistance trends, prophylactic antibiotic usage, comorbidities, and nutritional condition were gathered from a total of 300 patients with SSIs. To find correlations between these variables and SSI rates, statistical studies were carried out using chi-square tests and logistic regression.

Results: Pseudomonas aeruginosa (15%), Escherichia coli (22%), and Staphylococcus aureus (38%), were the most frequently found pathogens. In 67% of the cases, methicillin-resistant S. aureus (MRSA) was found, while 71% of E. coli samples produced extended-spectrum beta-lactamase (ESBL). Antibiotic prophylaxis considerably decreased the incidence of SSI (OR = 3.21, $p < 0.001$). Significant risk variables for SSIs were diabetes and low blood albumin levels. Infections also resulted in considerably longer hospital stays (12.6 days vs to 7.4 days for individuals without infections).

Conclusion: Antibiotic-resistant organisms are widely present in the research, which also emphasizes the crucial role that nutritional status and comorbidities play in the development of SSIs. Targeted interventions—like improved infection management, customized antibiotic usage, and preoperative nutritional assessments—are crucial to improving outcomes. Reducing SSI incidence and improving surgical outcomes in KPK hospitals need addressing these variables.

Keywords: Surgical Site Infections, Antibiotic Resistance, Khyber Pakhtunkhwa, Prophylactic Antibiotics, Comorbidities, Nutritional Status

Introduction

Surgical site infections (SSIs) pose a serious threat to postoperative treatment, with implications for hospital expenses, patient outcomes, and the standard of care. SSIs have become a significant issue in Pakistani hospitals, highlighting the need for a thorough knowledge of the complex variables influencing their frequency and severity[1]. The goal of this study paper is to provide a comprehensive view of the interdependencies and consequences of the complex interactions of pharmaceutical treatments, physiological impacts, and microbiological variables on surgical site infections (SSIs) in Pakistani hospitals[2, 3]. Microbiological elements have a critical role in the emergence and advancement of SSIs. The kind of pathogens—bacteria, fungi, and viruses—that cause an infection is a major factor in defining the kind and severity of secondary septic illnesses[4]. The microbial environment in Pakistani hospitals is varied, and there are serious dangers associated with both common and drug-resistant bacteria. To effectively manage infections, efforts involving these bacteria must take into account their prevalence and patterns of resistance[5]. Antibiotic-resistant bacteria are becoming more common, as previous research has shown. This complicates treatment plans and raises the risk of unfavorable outcomes[6].

Antibiotics and other antimicrobial medicines are used in pharmacological methods to treating surgical site infections (SSIs). Numerous variables, including as the antibiotic of choice, dose schedules, and patient adherence, affect how successful these therapies are [7, 8]. Given the rising worry about antimicrobial resistance, hospitals in Pakistan must utilize antibiotics sparingly. This study examines the use of antibiotics already in practice, ranks the effectiveness of those uses, and analyzes the effect of antimicrobial stewardship initiatives on SSI rates[9] . The research attempts to discover possible areas for improvement in infection prevention and antibiotic treatment by examining the pharmacological techniques used. Moreover, physiological variables are very important in determining the severity and vulnerability of SSIs[10]. Infection outcomes are highly influenced by patient-related variables such as immunological response, nutritional condition, and comorbidities. Comprehending these physiological factors is essential for customizing preventative and therapeutic approaches in Pakistani hospitals, where patients often come with a range of health problems and access to healthcare resources. The study looks at how various physiological circumstances affect the likelihood and results of SSIs, offering insights into individualized strategies for lowering infection rates[11].

This work is noteworthy because it aims to give a thorough knowledge of SSIs in Pakistani hospitals by integrating physiological, pharmacological, and microbiological aspects. Through examining these variables simultaneously, the study seeks to identify underlying trends and connections that may guide better preventative and therapeutic approaches. It is anticipated that the results would advance better patient outcomes, infection control procedures, and general healthcare quality in Pakistan. This study aims to explore the intricate relationships that exist between pharmaceutical interventions, physiological states, and microbiological parameters in the setting of surgical site infections (SSIs) in Pakistani hospitals. The objective is to provide evidence-based recommendations that will advance infection control and prevention methods, improving patient outcomes in the process and streamlining healthcare delivery.

Methodology

The study's objective was to investigate how pharmaceutical strategies, physiological effects, and microbiological variables interact to cause surgical site infections (SSIs). Cross-sectional observational research with both quantitative and qualitative analysis was the study design.

Sample Size and Selection: For the research, a total of 300 individuals who had surgeries at participating institutions were Some of the major hospitals in Khyber Pakhtunkhwa (KPK) include

Lady Reading Hospital (LRH) Peshawar, Khyber Teaching Hospital (KTH) Peshawar, Hayatabad Medical Complex (HMC) Peshawar, Ayub Teaching Hospital in Abbottabad, and Saidu Teaching Hospital, Swat. A power analysis was used to calculate the sample size in order to guarantee that there was enough power to identify meaningful connections between the variables of interest. The sample size calculation showed that 300 participants would provide accurate estimates of SSI rates and the impact of different variables, assuming a 95% confidence level and a 5% margin of error.

Data Collection: Direct observations, structured interviews, and patient medical records were all used to gather data. Patients were enrolled between January and December of 2020, and post-operative results were monitored until June of 2021. Swabs and cultures were obtained from SSI sites in order to identify microorganisms and evaluate trends of antibiotic resistance. Analysis was done on the different kinds of bacteria, how common they were, and how resistant they were. Medical records provided information on treatment plans and antibiotic prophylaxis. Information was gathered and assessed on the kind of antibiotics used, doses, length of therapy, and patient adherence. Age, sex, comorbidities, dietary condition, and immune system health were among the patient-related variables that were noted. Reviews of medical histories and patient interviews provided this information.

Data Analysis: To ascertain the connections between pharmaceutical strategies, physiological effects, and microbiological elements on SSIs, data were subjected to statistical analysis. Treatment results, infection rates, and patient demographics were compiled using descriptive statistics. In order to evaluate the effect of various variables on SSI risk, inferential statistics were used, such as logistic regression analyses and chi-square tests.

Result

Across hospitals in Khyber Pakhtunkhwa (KPK), Pakistan, a total of 300 patients had different surgical operations. Of them, 170 men (56.7%) and 130 females (43.3%) were included in the research. The participants' ages ranged from 18 to 78 years old, with a mean age of 45.2 years and a standard deviation of 12.8 years. In the study population, the total risk of surgical site infections (SSIs) was 26%, and 78 patients had SSIs throughout the follow-up period (Table 1).

Table 1: Pathogens Isolated from Surgical Site Infections (SSIs)

Pathogen	**Number of Cases (n=78)**	**Percentage (%)**
Staphylococcus aureus	30	38
Escherichia coli	17	22
Pseudomonas aeruginosa	12	15
Klebsiella pneumoniae	8	10
Enterococcus spp. and others	11	15
Total	78	100

A wide variety of pathogens were identified from microbiological cultures obtained from SSI sites. Of these, Staphylococcus aureus was found to be the most prevalent, isolated in 38% of SSI cases. Other frequent infections were Escherichia coli (22%), Pseudomonas aeruginosa (15%), and Klebsiella pneumoniae (10%). Fungi and Enterococcus species were among the other microbes responsible for 15% of SSIs. There were notable patterns of resistance, with 71% of Escherichia coli isolates generating extended-spectrum beta-lactamase (ESBL) and 67% of Staphylococcus aureus infections being methicillin-resistant (MRSA). With a chi-square value of 29.42 and $p < 0.001$, a chi-square test revealed a strong correlation between the prevalence of SSI and specific pathogens, suggesting that pathogens were not dispersed equally among infections.

Table 2: Antibiotic Resistance Patterns in SSI Pathogens

Pathogen	Total Cases (n)	Antibiotic Resistance	Number of Resistant Cases (n)	Percentage Resistant (%)
Staphylococcus aureus	30	MRSA	20	67
Escherichia coli	17	ESBL-producing	12	71

Ninety percent of the patients had a history of prophylactic antibiotic usage, according to the study. Of these, 5.5% were treated with carbapenems, 11.1% with penicillin-based antibiotics, 16.7% with fluoroquinolones, and 66.7% with cephalosporins. In spite of receiving preventive antibiotics, 19.3% of patients had SSIs, whereas 43.3% of patients did not get any prophylactic treatment. Prophylactic antibiotic use significantly reduces the risk of surgical site infections (SSIs); patients who do not get antibiotics had a 3.21-fold increased risk of developing SSIs ($p < 0.001$), according to a logistic regression study. Additionally, patients who acquired infections from antibiotic-resistant strains spent an average of 15.4 days in the hospital, compared to 9.2 days for patients who developed non-resistant illnesses ($p < 0.001$).

Table 3: SSI Incidence by Prophylactic Antibiotic Use

Prophylactic Antibiotics	Number of Patients (n)	SSI Cases (n)	SSI Rate (%)
Yes (Total)	270	52	19.3
No	60	26	43.3
Total	300	78	26

The development of SSI was also significantly influenced by physiological variables. Comorbidities were frequent, with 20% of the patients being obese, 33% having hypertension, 15% having diabetes, and 15% suffering from chronic obstructive pulmonary disease (COPD). SSI rates were significantly greater in patients with diabetes, with 35.7% developing SSIs compared to 22.2% in individuals without diabetes. Chi-square analysis verified this substantial difference ($p = 0.015$). Additionally, a strong correlation was found between hypertension and an increased risk of stroke (SSI), with infections occurring in 32.3% of hypertensive patients vs 20.6% of normotensive individuals ($p = 0.042$). Low blood albumin levels, in particular, were a strong predictor of SSIs in relation to nutritional status. SSI rates were 40.6% in patients with low albumin levels and 20.9% in patients with normal levels; logistic regression analysis revealed a 2.8-fold increase in SSI risk ($p = 0.002$) in patients with low albumin levels.

Table 4: SSI Incidence by Comorbidities

Comorbidity	Number of Patients (n)	SSI Cases (n)	SSI Rate (%)
Diabetes mellitus	84	30	35.7
Hypertension	99	32	32.3
COPD	45	12	26.7
Obesity (BMI > 30)	60	18	30.0
No Comorbidity	141	18	12.8

The study's overall SSI rate was 26%, and patients who acquired infections had an average hospital stay that was substantially longer (12.6 days compared to 7.4 days for non-SSI patients, $p < 0.001$). Furthermore, patients who had SSIs had a higher likelihood of needing subsequent operations (19% vs 4% for those without infections; $p < 0.001$).

Table 5: Length of Hospital Stay Based on Infection and Resistance Status

Infection/Resistance Status	Number of Patients (n)	Mean Hospital Stay (days)	Standard Deviation (SD)
Antibiotic-resistant SSIs	32	15.4	4.2
Non-resistant SSIs	46	9.2	2.7
No SSIs	222	7.4	2.3

To investigate the combined impact of pharmacological, physiological, and microbiological variables on the development of SSI, a multivariable logistic regression model was used. The model, which accounted for albumin levels, antibiotic resistance, diabetes, and prophylactic antibiotic usage, was significant and explained 28.6% of the variation in the risk of SSI ($p < 0.001$). Antibiotic-resistant organisms were the best indicator of surgical site infections (SSIs), followed by low serum albumin levels.

Discussion

The results of this study highlight the complex interaction between microbiological, pharmacological, and physiological factors in the development of Surgical Site Infections (SSIs) in hospitals across Khyber Pakhtunkhwa (KPK), Pakistan. These findings are consistent with global trends but also reveal region-specific challenges, particularly related to antibiotic resistance and healthcare practices[12]. Our study found *Staphylococcus aureus* as the leading pathogen in SSIs, with methicillin-resistant *S. aureus* (MRSA) present in 67% of cases, a significantly higher rate than seen in many regions. The high prevalence of MRSA and extended-spectrum beta-lactamase (ESBL) production in *Escherichia coli* (71%) suggests severe antibiotic resistance, a growing concern in KPK hospitals[15, 16]. This emphasizes the need for improved microbiological surveillance and antibiotic stewardship programs to combat resistance.

Prophylactic antibiotics were effective in reducing SSIs, with those not receiving them over three times more likely to develop infections. However, even among those who received prophylaxis, the SSI rate (19.3%) was higher than in developed countries, likely due to resistance issues. Cephalosporins, the most commonly used antibiotics in our study, were less effective against resistant pathogens like MRSA and ESBL-producing *E. coli*[17]. Tailored antibiotic regimens based on local resistance patterns are critical to improving outcomes. Comorbidities like diabetes and hypertension significantly increased the risk of SSIs, with diabetic patients showing a 35.7% infection rate. Nutritional status also played a crucial role, with patients having low serum albumin levels experiencing a 40.6% infection rate. Addressing malnutrition and optimizing the health of at-risk patients preoperatively could help reduce infection rates[18].

SSIs extended hospital stays significantly, with infected patients staying an average of 12.6 days compared to 7.4 days for non-infected patients. This finding reflects the burden SSIs place on healthcare systems, particularly in resource-limited settings like KPK. The presence of antibiotic-resistant infections further prolonged hospitalizations, increasing both clinical and economic challenges. Our study found a higher SSI rate (26%) compared to previous studies in Pakistan (10–20%), likely due to the inclusion of multiple hospitals with varying healthcare infrastructure[19, 20]. The high prevalence of antibiotic resistance, comorbidities, and malnutrition likely contributed to this elevated rate.

Limitation and future research: This study's concentration on hospitals in Khyber Pakhtunkhwa (KPK) is one of its limitations; this might restrict the applicability of the results to other areas with different healthcare systems. Furthermore, the data collection for the research was based on hospital records, which might have resulted in some missing or inconsistent data. To offer a more thorough knowledge of SSIs, future study should involve a bigger, more varied sample from other locations in Pakistan. The effect of focused treatments, including better nutritional assistance and antibiotic stewardship, on lowering SSIs in environments with limited resources should also be investigated in further research.

Conclusion

This research emphasizes how physiological, pharmacological, and microbiological variables interact significantly to cause surgical site infections (SSIs) in hospitals in Khyber Pakhtunkhwa. The effect of comorbidities and malnutrition, in addition to the increasing frequency of antibiotic-resistant bacteria, highlight the need of focused efforts to reduce SSIs. Lowering infection rates and improving surgical outcomes in resource-constrained settings requires improved infection control procedures, customized antibiotic regimens, and preoperative patient care. Subsequent initiatives have to concentrate on all-encompassing approaches to lessen the impact of SSIs in Pakistan.

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