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Prevalence, Distribution, and Associated Factors of Surgical Site Infections Linked to *Pseudomonas aeruginosa* with oprL Virulence Gene in Bauchi, Nigeria

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Abstract

Surgical site infections (SSIs) are a global healthcare challenge. The Pseudomonas aeruginosa is a significant SSI pathogen with the oprL gene conferring its multidrug resistance. Although extensive studies on pathogens in infection control are recommended, a study of this kind has not been conducted in Bauchi, Nigeria.
Objectives: This study determined the prevalence and associated factors for SSIs linked with *P. aeruginosa* with oprL gene. Surgical site swabs (n=250) collected from two hospitals in Bauchi, Nigeria, were cultured on Cetrimide agar to isolate *P. aeruginosa*. The oprL genes of the isolates were detected through a Polymerase chain Reaction. Chi-square tests, Fisher's exact test, and binary logistic regression analyzed the association between SSIs and other variables. About 2% (5/250) of the swabs were infected with *P. aeruginosa* with oprL gene. SSI occurrence was statistically associated with post-operative duration (p = 0.01). Prolonged postoperative periods increased the odds of developing SSIs by a factor of 3.81 (O.R.:3.81, p=0.02). No significant associations were found between SSIs and sex (p = 0.65), age (p = 0.09), surgery (p = 0.06), and HIV status (p = 0.31). The prevalence of *P. aeruginosa* linked to SSIs was low. Prolonged postoperative care significantly increased the risk of SSIs. Future research with longitudinal designs and large samples will monitor additional risk factors of SSIs. Infection control should emphasize post-operative care for SSIs.The integration of molecular confirmation of P. aeruginosa isolates should be routine in SSI management.

Keywords: Nigeria, Pathogen, Prevalence, Pseudomonas, Surgical Site, Infection

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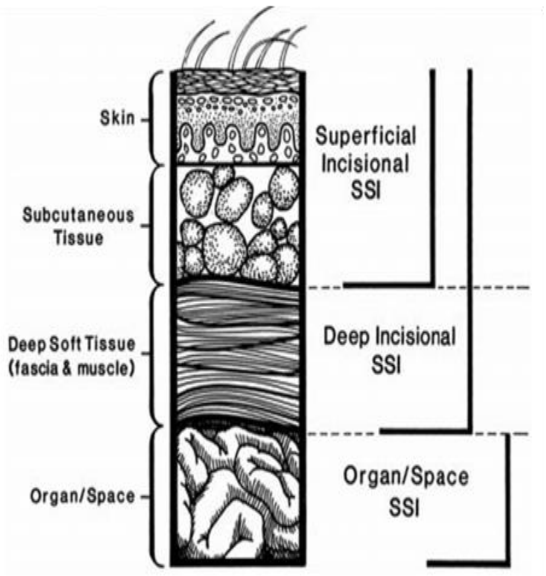
Introduction

A surgical site infection (SSI) is an infection in the part of the body where surgery takes place. Surgical site infections are defined as those confined to the incisions and involve structures adjacent to the wounds that were exposed during operation within one month after a surgical operation or one year after implant surgery (Berríos-Torres, 2017). SSIs are superficial incisional when they involve the skin and subcutaneous tissue of the incision. They are deep incisional when they involve the skin's muscle or connective tissue layers. They are organ/space when they involve structures, organs, or spaces deep into the incision (Horan et al., 1992). These are shown in Figure 1.

Patients with SSIs have purulent discharge at the incision site or/and at least one of the following: pain, tenderness, or high temperatures, greater than forty degrees Fahrenheit (El Zowalaty & Gyetvai, 2016). In immunocompromised patients, with discontinuity in their epithelial tissue, SSIs are caused by a spectrum of microorganisms including a notable multidrug-resistant pathogen, Pseudomonas aeruginosa (McKnight, Iglewski, & Pesci, 2000).



Pseudomonas aeruginosa (*P. aeruginosa*) is a gram-negative bacterium known for its resilience and antibiotic resistance. It has been linked to several hospital-acquired diseases, including surgical site infections (SSIs) (Klockgether & Tümmler, 2017; Tang *et al.*, 2017; Paul, 2018).The bacterium is particularly pathogenic and equipped with various virulence factors including the *oprL* gene that assists in drug efflux and antibiotic resistance (Mohammad, 2013). This gene codes the outer membrane proteins of *P. aeruginosa* and plays an important role in the interaction of the bacterium with the environment (Wu *et al.*, 2015). These are L-peptidoglycan-associated lipoprotein and I-lipoproteins outer membrane proteins of *P.aeruginosa*.They alter the membrane permeability and utilize the efflux mechanism to confer antibiotic resistance for *Pseudomonas* species and *Pseudomonas aeruginosa* respectively. These L and I outer membrane proteins are coded by the *oprL* and *oprI* genes respectively. While the *oprI* is present in all *Pseudomonas* species, the *oprL* is specifically present in *P. aeruginosa*. Other intrinsic resistance factors encoded in plasmids are toxA, exoU, exoS, exoY, lasA, lasB, oprD, *oprL*, and *oprI* . (Peters & Galloway, 1990; Galloway, 1991; Choi *et al.*, 2002; Haghi *et al.*, 2018). These genes also confer multidrug resistance to the pathogen following the invasion of a surgical site from its reservoir.

The reservoirs of *P. aeruginosa* include water pools, fruits, flowers, and unsterilized medical and hospital instruments and devices. SSIs linked to *P. aeruginosa* usually occur after some alteration of the normal skin defense or architecture by the surgical incision. There are three distinct stages in the pathogenesis of SSIs after the introduction of the bacilli from the surgical site (Pollack, 2000). These three stages are (1) bacterial attachment on compromised epithelial tissues. This is aided by the pilli and flagella of the bacilli. Subsequently, there is colonization of the host tissue with extracellular polysaccharide slime called biofilm (Brandenburg *et al.*, 2015; Jensen *et al.*,2017; Maunders & Welch, 2017). (2) local invasion of the whole epidermis tissue and possibly the subcutaneous tissue. This is aided by flagella attachment, biofilms, and extracellular enzymes (Garcia *et al.*,2018). This stage impairs skin epithelial repair mechanisms and resists phagocytosis by the host immune system and (3) disseminated systemic disease, by blood-borne transfer of the infection, to other distant organs. The virulence factors are crucial in these stages while simultaneously aided by the pathogen's cell-to-cell communication systems called quorum sensing (Lee & Zhang, 2015). Following the invasion of the primary site, there is development of clinical signs of SSI including tenderness and purulent discharge from the surgical site. There may be secondary infections including urinary tract infections (UTIs), otitis externa, meningitis, brain abscess osteomyelitis, endocarditis, and a characteristic skin lesion called Ecthyma gangrenosum (Adhikari *et al.*,2019).

The SSIs linked to *P. aeruginosa* vary across geographical settings due to host resistance and the pathogenicity of *Pseudomonas* strains. This also affects the prevalence of *P. aeruginosa* across settings. The prevalence of SSIs and SSIs associated with *P. aeruginosa* vary across settings (Lamichhane *et al.*, 2020). A systematic review of the global prevalence of SSIs reported the range of the prevalence of *P. aeruginosa* in SSIs from 4.09% to 26.7% (Reid & Porter, 1981). Similarly, *P. aeruginosa* was linked to 13% of SSIs in a hospital setting in Mumbai, India (Marzoug *et al.*,2023). In Brazil, the prevalence of *P. aeruginosa* linked to SSIs was reported as 11.6% of SSIs (Shah *et al.*,2020). A systematic review of infected wound, skin, soft tissue, and surgical site infections in Central, Eastern, Southern, and Western Africa, reported the prevalence of *P. aeruginosa* in infected wound, skin, soft tissue, and surgical site infections as 14% (CI 11% to 18%) (Tuon *et al.*,2019). The study also found that out of the Gram-negative bacilli isolated, *P. aeruginosa* was more commonly isolated from the infected wounds (21%, CI 15% to 28%). *P. aeruginosa* was found to be multidrug-resistant to anti-pseudomonal carbapenems (imipenem or meropenem) in ≥ 20% of isolates (Tuon *et al*.,2019). In Nigeria, the prevalence of SSI was found to be 14.8% of surgeries (Monk *et al*.,2024). Out of this, 4.8% of the Gram-negative bacteria that infected the wound were *P. aeruginosa* (Monk *et al.*,2024). In another setting in Nigeria, the prevalence of *P. aeruginosa* was 19% of the pathogens associated with SSIs (Abiodun *et al.*,2014). The variations in the prevalence of SSIs linked to *P. aeruginosa* are affected by the risk factors of the SSIs.

The risk factors of SSIs are the same as those of SSIs linked to *P. aeruginosa* with *oprL* gene. These risk factors may be divided into two distinctive categories: patient-related (intrinsic) and process/procedural-related (extrinsic) factors (Bucataru *et al.,* 2023). The patient-related risk factors include factors intrinsic to the patient's health, such as underlying medical conditions or immunosuppression. Modifiable patient-related risk factors may include behaviors such as smoking, alcoholism, or obesity. Smoking, alcoholism, or obesity profoundly impact wound healing and immune function through impairment of oxygen delivery to tissues, malnutrition, impaired wound closure, and increased susceptibility of the tissue to infection respectively (Bucataru *et al.,* 2023). The non-modifiable patient-related risk factors include age or gender (Bucataru *et al.*, 2023; Trevejo-Nunez *et al*.,2015). Age and gender affect wound healing through immunity and surgery type respectively. The other category is process- and procedure-related risk factors.

Process- and procedure-related risk factors are extrinsic risk factors associated with the surgical process. They include intraoperative risk factors e.g. asepsis maintenance or the length of the procedures. Others are emergency surgeries, surgical site contamination, extended hospital stays, use of foreign bodies such as implants and transplants, use of a heart-lung machine, blood transfusions, immunosuppressive medication, contamination of the allograft, shaving of t he operative site, ventilation, inadequate sterilization, poor preoperative antibiotic prophylaxis, and poor postoperative wound care and monitoring (Bucataru *et al.*, 2023).

The investigation of human infections like *P. aeruginosa* and its prevalence within a hospital is essential for the articulation of effective preventive measures. Moreover, the diagnosis of infection prevention techniques requires an understanding of the pathogen's prevalence and distribution (WHO,2017; Pinchera *et al.*,2022). The World Health Organization, WHO, recommends the prioritization of extensive research on hospital-specific SSIs for infection control and to build national data on Hospital hospital-acquired infections (HAIs) (WHO,2017; Tacconelli *et al.,*2018; Pinchera *et al*.,2022). Bauchi in North-East Nigeria has unique challenges in healthcare delivery and a huge burden of SSIs (Olowo-Okere e*t al*.,2019; Onyi *et al*.,2024a; Onyi *et al.*,2024b). There is a paucity of studies on the prevalence and distribution of surgeries infected with *P. aeruginosa.* Most of the strains of the bacilli are multidrug-resistant and have the *oprL* virulence factor. These strains are associated with SSIs with poor health outcomes including poor wound healing, extended hospital stays, and deaths. The study was an attempt to bridge this research gap. The findings might optimize the management of these SSIs and provide reference data for other related studies. The specific objectives of the study were to investigate the (1) prevalence and (2) factors associated with SSIs linked to *P. aeruginosa* with the *oprL* gene.

Methodology

Study Design: The approval for the study was obtained from the Bauchi State Health Research Ethical Committee and the research approval number is NREC/12/05/2103/2018/05. The study was a cross-sectional hospital-based study. It was conducted in two selected secondary hospital facilities in the Bauchi local government of Bauchi State, in the North-East geo-political region of Nigeria. The hospitals are New General Hospital Bayara and Specialist Hospital Bauchi. These are shown in Figure 2.

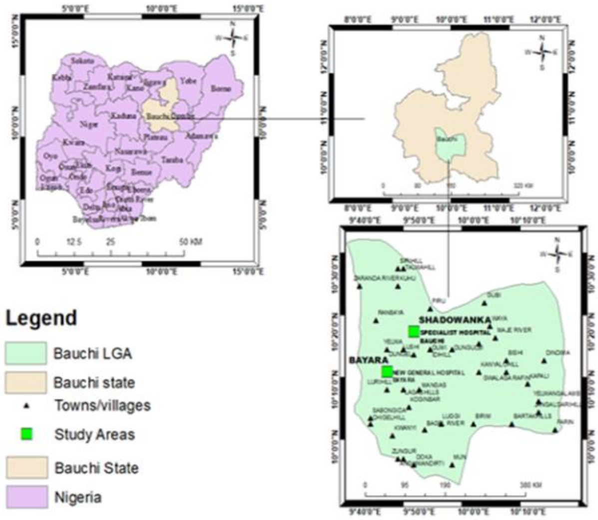


Figure 2. Map of Bauchi State of Nigeria showing the Study area (Onuh, 2019).

Sample Size Determination

The sample size for the study was determined using the Cochrane formula for cross-sectional studies (Cochran, 1963). A prevalence of 19% reported for *P. aeruginosa* in surgical site infection by Yazidi *et al*. (2015) was utilized for estimating the minimum sample size.

$n=Z^2Pq/L^2$

Where n = number of samples

Z = standard normal deviate at 95% CI = 1.96

P = 19% (Yasidi *et al*.,2015) = 0.19 q = 1 – 0.19 = 0.81

L = precision of 5% (0.05)

$n = 1.96^2 \times 0.19 \times 0.81/0.05^2 = 0.59122224/0.0025 = 236.48 \sim 237$

With a non-response rate assumed to be 5%, the 237 was multiplied by a factor of 1.05, giving 248.85. This was approximated to 250. A sample size of 250 surgical swabs was utilized for the study. The inclusion criteria for the participants were as recommended by the Centre for Disease Control, CDC. The study included consented patients who had surgeries and were on admission within 30 days of the surgeries; and who had purulent discharge from the surgical wound sites or/and at least had one of the following: pain, tenderness, or high temperature (greater than 40 degrees Fahrenheit (Bucataru *et al.*, 2023). Patients who had antibiotics two weeks before the surgery or who did not consent to the study were excluded.

c. Samples collection, bacterial isolation and identification

Two hundred and fifty surgical site wound swabs were collected from Bauchi Specialist Hospital (205 samples) and New General Hospital Bayara patients (45 samples) within five months from January 2019 to May 2019. A total of two hundred and fifty (250) surgical wound swab samples were collected during wound review or wound dressings at the wards. The swabs were labeled and transported in sterile ice packs to the Abubakar Tafawa Balewa University Teaching Hospital's (ATBUTH's) Microbiology Unit for sample analysis. The sample analysis involved three steps: identification of colonial morphology of culture on Cetrimide agar, Gram staining, and biochemical analysis of isolates (Public Health England,2015). For the phenotypic, there was an identification of culture on Cetrimide agar. The Gram staining of the pure isolates of *P. aeruginosa* isolates was conducted as described by Bartholomew and Mittwer (1952). The biochemical characterization of the isolates was conducted with Oxidase and Catalase tests. The Molecular confirmation of isolates was with Polymerase Chain Reaction, PCR, with *oprL*, with an amplicon size of 504, as the target gene. The details of these procedures are highlighted in other study reports (Public Health England,2015; Tacconelli *et al.*,2018; Olowo-Okere *et al.*, 2023)

D. Data analysis: The included patients' folders were sought for data extraction. The variables extracted from patients' hospital folders were health facility, ward, age, sex, surgery type, duration in hospital, HIV status, and occupation. Other variables that were included after laboratory analysis were phenotypic identification of colony, Gram staining result, Catalase test, Oxidase test, and molecular confirmation of isolates. The data are recorded in a data extraction sheet and then transferred to Excel Spreadsheet and Statistical Products and Service Solutions (SPSS) version 25 for analysis. A p-value less than 0.05 was considered statistically significant for the Chi-square tests, Fisher's Exact tests, and binary logistic regression analysis.

Results

Demographic characteristics of respondents

The demographic variables of the patients with SSIs linked to *P. aeruginosa* are shown in Table 1

Table 1: Demographic characteristics of respondents

Variables	No. Tested	No. Positive	% positive	χ^2	df	p-value
Sex						
Female	107	3	2.80	0.62	1	0.43
Male	143	2	1.40			
Age						
1-10	10	1	10.00	10.01	5	0.08
11-20	62	1	1.61			
21-30	89	0	0.00			
31-40	61	1	1.63			
41-50	19	1	5.26			
51-60	9	1	11.11			
Education status						
No formal education	119	1	0.84	3.54	3	0.32
Primary	88	2	2.27			
Secondary	31	1	3.22			
Tertiary	12	1	8.33			
Occupation						
Unemployed	9	0	0.00	9.12	10	0.52
Domestic work	43	1	2.32			
Student	46	1	2.17			
Manual labor	9	0	0.00			
Trading	85	0	0.00			
Hotel management	1	0	0.00			
Professional soccer player	1	0	0.00			
Public relations	3	0	0.00			
Civil service	14	0	0.00			

Key: χ^2 = chi-squared test; df = degree of freedom; p-value ≤ 0.05 is statistically significant

Data on demographic features are shown in Table 1. It shows the variables - occupation, age, sex, and educational status. Additionally, it shows the number of tests, the number of positive cases, the percentage of positive cases, the degrees of freedom, p-values, and the chi-square statistics of each variable. The subunits of each variable are shown in the rows

For the "Sex" variable, the range of values includes "Female" and "Male." The highest number tested for this variable is 143 for males, with 2 positive cases and a percentage positive of 1.40%. The lowest number tested is 107 for females, with 3 positive cases and a percentage positive of 2.80%. The chi-square statistic is 0.62 with 1 degree of freedom, and the p-value is 0.43.

For the "Age" variable, the range of values includes different age groups. The highest number tested is 89 for the 21-30 age group, with 0 positive cases. The lowest number tested is 9 for the 51-60 age group, with 1 positive case and % percentage positive of 11.11%. The chi-squared statistic varies for different age groups is 10.01, with degrees of freedom of 5, and a p-value of 0.08.

For the "Education Status" variable, the range of values includes "No formal education," "Primary," "Secondary," and "Tertiary." The highest number tested is 119 for individuals with no formal education, with 1 positive case and a percentage positive of 0.84%. The lowest number tested is 12 for individuals with tertiary education, with 1 positive case and a percentage positive of 8.33%. The chi-square statistic is 3.54, with degrees of freedom of 3, and a p-value of 0.32

For the "Occupation" variable, the range of values includes a variety of occupational categories such as Unemployed, Domestic work, Student, Manual labor, Trading, Hotel management, Professional Soccer player, Public relations, and Civil service. The highest number tested is 85 for individuals engaged in trading, with 0 positive cases, resulting in a percentage positive of 0.00%. The lowest number tested is 1 for individuals in several categories such as Hotel management, Professional Soccer player, Public relations, and Civil service, with 0 positive cases for each of these categories. The chi-square statistic is 9.12. The degree of freedom is 10, and the corresponding p-value is 0.52.

Prevalence of positive isolates

Five isolates that were analyzed and phenotypically identified as *P. aeruginosa* had a colony morphology characterized by a blue-green smooth colony with smooth edges and an elevated appearance. The colonies had the smell of 'grapefruit'. On Gram staining, they were Gram-negative rods. They were also Oxidase and Catalase positive. Five isolates were *P. aeruginosa* positive. Moreover, all five (5) isolates (A-E) showed the *oprL* gene with an amplicon size of 504bp. This is shown in Figure 2. Therefore, this study found a prevalence of 2% (5/250) of Pseudomonas infection associated with surgical site infections.

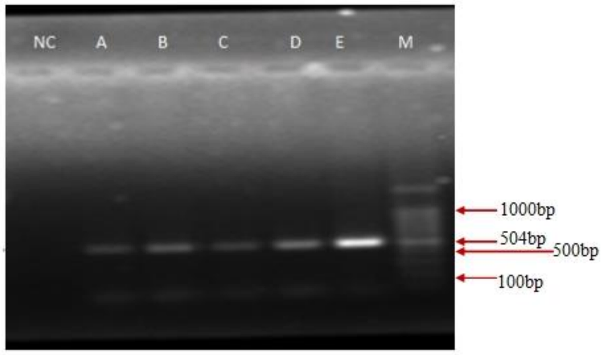


Figure 3: Gel electrophoresis of *oprL* gene with amplicon size of 504 bp

Key:

Lane NC = Negative control

Lanes A-E = Samples

Lane M = 100bp molecular marker

Prevalence of positive isolates at the facilities

The Prevalence of positive isolates at the facilities is shown in Table 2.

Table 2: Prevalence of positive isolates at the facilities.

Hospital Facilities	**No of swabs analyzed**	**No positive isolated confirmed**	**% of positive isolates**	**χ2**	**df**	**p-value**
Specialist Hospital Bauchi	205	5	2.4	1.12	1	0.29
New General Hospital Bayara	45	0	0.0			

Key: χ^2 = chi-squared test; df=degree of freedom; p-value ≤ 0.05 is statistically significant

Table 2 shows the analysis of swabs and positive isolates in two different hospitals- Specialist Hospital Bauchi and New General Hospital Bayara. In Specialist Hospital Bauchi, out of 205 swabs that were analyzed, there were 5 confirmed positive isolates, accounting for 2.4% of positive isolates. Forty-five (45) swabs from New General Hospital Bayara were analyzed with no positive isolates. This data suggests that Specialist Hospital Bauchi had a higher percentage of positive isolates compared to New General Hospital Bayara. The χ^2 value is 1.12, with 1 degree of freedom, and a p-value of 0.29, indicating no statistical significance.

Factors associated with surgeries infected with *Pseudomonas aeruginosa*

The Factors associated with surgeries infected with *P. aeruginosa* are shown in Table 3.

Table 3 Factors associated with surgeries infected with P. *aeruginosa*

Variables	No. Tested	No. Positive	% positive	Fisher's Exact	P value
Sex					
Female	107	3	2.80		0.65
Male	143	2	1.40		
Age					
1-10	10	1	10.00	7.73	0.09
11-20	62	1	1.61		
21-30	89	0	0.00		
31-40	61	1	1.63		
41-50	19	1	5.26		
51-60	9	1	11.11		
Surgery type					
Cesarean section	105	2	1.90	19.42	0.06
Laparotomy	38	1	2.63		
Sutured Laceration (upper limb/arm)	20	0	0.00		
Amputation of Right toe	1	0	0.00		
Inguinal/Herniorrhaphy	19	0	0.00		
Sutured Breast lumpectomy	6	1	16.67		
Incisional hernia	3	0	0.00		
Appendectomy	5	0	0.00		
Amputation (Below the knee)	28	0	0.00		
Sutured laceration scalp	18	0	0.00		
Amputation below elbow	1	1	100.00		
Sutured laceration (left foot)	6	0	0.00		
Post-operative duration					
1-5	206	2	0.97	11.39*	0.01
6-10	28	1	3.57		
11-15	16	2	12.50		
HIV status					
Positive	8	1	12.50		0.31
Negative	242	4	1.65		

Key: Fisher's Exact test is utilized when at least 80% observed frequency is less than 5. Exact significance ≤ 0.05 is statistically significant (*). All values approximated to 2 decimal places

Table 3 shows the risk factors associated with Surgical Site Infections (SSIs) linked to *P. aeruginosa* are presented. The variables are age, sex, surgery type, post-operative duration, and HIV status. The number of tests, positive cases, percentage of positive cases, Fisher's exact Value, and Exact significance p value (2-sided) were detailed for each variable.

In the analysis of SSIs, the "Sex" variable was examined. It shows that out of 143 males tested, 2 cases were positive, yielding a percentage positive of 1.40%. Similarly, out of 107 females tested, 3 cases were positive, resulting in a percentage positive of 2.80%. Fisher's Exact Test yielded a value of 0.65, with an Exact significance (2-sided) of 0.25, indicating that the difference in SSIs between the sexes is not statistically significant.

Age groups were also investigated, showing varying percentages of positive cases across different ranges. Notably, the age groups 1-10 and 51-60 demonstrated higher percentages of SSIs, ranging from 0% to 11.11%. Despite a Fisher's Exact value of 7.73, the Exact significance (2-sided) of 0.09 suggests that the age groups are not significantly associated with SSIs.

Analysis of surgery types revealed that patients undergoing amputation below the elbow showed the highest percentage of SSIs at 100%. However, Fisher's Exact value of 19.42 and an Exact significance of 0.06 indicated an insignificant association between the type of surgery and SSIs.

Post-operative duration showed that longer durations were associated with higher percentages of SSIs, with a significant p-value of 0.01. The highest percentage of 12.50% was recorded for post-operative duration of 11-15 days.

Additionally, for HIV status, a higher percentage of SSIs was observed in HIV-positive patients (12.50%) compared to HIV-negative patients (1.65%). However, the Exact significance (2-sided) of 0.31 indicated that this difference was not statistically significant.

The SSI data was further regressed against some of the variables that are known risk factors of SSIs.The binary logistic regression analysis involved two steps- bivariate and multivariate regression analysis. This bivariate analysis is shown in Table 4 while the multivariate analysis is shown in Table 5.

Table 4 SSI risk factors: Bivariate regression analysis

Variables	B	S.E.	Wald	df	Sig.
Age	0.62	0.38	2.76	1	0.10
Constant	-6.11	1.56	15.38	1	0.00
Sex	-0.76	0.92	0.68	1	0.41
Constant	-2.76	1.37	4.04	1	0.04
Surgery	0.04	0.12	0.12	1	0.73
Constant	-4.06	0.68	35.53	1	0.00
Post-Operation Duration (Days)	1.38	0.52	6.90	1	0.01*
Constant	-6.02	1.12	28.84	1	0.00
HIV Status	-1.21	1.14	1.12	1	0.29
Constant	-1.62	2.12	0.59	1	0.44

Table 4 shows the results of a binary logistic regression analysis on surgical site infection and its potential risk factors. The variables examined are age, sex, surgery type, post-operative duration, and HIV status. These are individual bivariate analyses that have been combined in the same table for the sake of simplicity.

Age: The variable age yielded a coefficient of 0.62 with a standard error (S.E.) of 0.38. The Wald statistic was 2.76 with 1 degree of freedom (df), and the significance level (Sig.) was 0.10.

Sex: The coefficient for sex was -0.76 with a standard error of 0.92. The Wald test yielded a statistic of 0.68 with 1 degree of freedom, and the significance level was 0.41.

Surgery: The variable surgery showed a coefficient of 0.04 with a standard error of 0.12. The Wald statistic was 0.12 with 1 degree of freedom, and the significance level was 0.73.

Post-Operative Duration: This variable had a coefficient of 1.38 and a standard error of 0.52. The Wald statistic was 6.90 with 1 degree of freedom, and the significance level was 0.01.

HIV Status: The variable HIV status yielded a coefficient of -1.21 with a standard error of 1.14. The Wald statistic was 1.12 with 1 degree of freedom, and the significance level was 0.29.

Based on the coefficients and significance levels, the post-operative duration exhibited a statistically significant association with the occurrence of surgical site infection (Sig. = 0.01). Age also showed a trend towards significance (Sig. = 0.10), suggesting a potential relationship with the SSIs.

The variables were further analyzed with multivariate analysis shown in Table 5.

Table 5: SSI risk factors: Multivariate regression analysis

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
Surgery	0.01	0.17	0.00	1	0.97	1.01
Post-Operation duration	1.34	0.58	5.41	1	0.02	3.82
Sex	-0.03	1.25	0.00	1	0.98	0.97
Age	0.43	0.38	1.30	1	0.26	1.54
HIV Status	-1.21	1.36	0.80	1	0.37	0.30
Constant	-5.17	4.22	1.50	1	0.22	0.01

From Table 5, none of the variables -surgery, sex, age, and HIV status- have a statistically significant effect on the outcome, as indicated by their higher p-values and odds ratios around 1. However, "Post-Operation Duration" has a statistically significant effect on the outcome, as indicated by a p-value that is less than 0.05(Sig. = 0.02) and an odds ratio of 3.82, suggesting that for each unit increase in post-operative duration, the odds of the having SSIs increase by a factor of 3.82, holding other variables constant. It is important to note that other factors did not confound post-operation duration during the multivariate analysis

Discussion

The study found that the prevalence rate of *P. aeruginosa* associated with SSIs was 2%. This finding indicates a relatively low occurrence of this pathogen in the studied population. It suggests that *P. aeruginosa* is not a dominant pathogen in linked to the SSIs in this particular study. Other pathogens like *Staphylococcus aureus*, *E. Coli*, etc. may have been implicated in the bacteriology of the SSIs (Abiodun *et al.*,2014; Yasidi *et al.*,2015). Factors such as good wound care practices, patient demographics, effective sterilization practices, and good infection control measures in the healthcare facility environment may have contributed to this low prevalence. (Kaplan *et al.*,2003; WHO,2018). The prevalence rate observed in this study differs from those reported in other studies. For example, it is lower than the 4.8% obtained in a hospital facility in Nigeria in 2023. Additionally, it is significantly lower than the 13% reported in India (Marzoug *et al.*,2023),11.6% reported in Brazil (Shah *et al.*,2020), and 14% reported in African regions (Tuon *et al.*,2019). These variations in prevalence rates may be attributed to differences in wound care practices, patient demographics, hospital environments, and the gene diversity of *P. aeruginosa* among geographic regions and the immune statuses of individuals (Kaplan *et al.*,2003; WHO,2018). The reported prevalence at Specialist Hospital Bauchi and New General Hospital Bayara were 2.4% and 0.0% respectively. The variations in the prevalence may be due to geographical location and patient load. While Specialist Hospital Bauchi is located in the urban city of Bauchi metropolis with more patient load, New General Hospital Bayara is located in a rural area with a lower patient load.

The study found that SSIs caused by *P. aeruginosa* are significantly associated with the duration of post-operative care. The binary regression analysis found that for each unit increase in post-operative duration, the odds of having SSIs caused by *P. aeruginosa* increased by a factor of 3.82, controlling for other variables. The SSIs caused by multidrug-resistant *P. aeruginosa* require extended hospital stays for effective treatment, often involving long-term use of potent antibiotics, repeated surgical debridement, wound care, and sometimes revision surgeries, all contributing to extended hospital stays and increased risk of additional complications (Rogers *et al*.,2018). Comparable to the findings in this study, Monk *et al.* (2024) found that patients with *P. aeruginosa* SSIs had significantly longer hospital stays compared to those with infections caused by other pathogens. This finding underscores the need for optimal surgical site wound care to minimize morbidity associated with wound care and minimize the duration of admission and cost.

Interestingly, this study did not find any statistical association between SSI and the type of surgery, age, sex, or HIV status. Further analysis showed that none of these variables individually or collectively predicted the likelihood of developing SSI in the presence of other variables. This finding is contrary to existing knowledge that suggests these variables are known risk factors for the development of SSIs linked to *P. aeruginosa* (Bucataru *et al.,* 2023). The extensive deep tissue disruption and exposure during these surgeries create a conducive environment for colonization by *P. aeruginosa* (dela Merced *et al.*,2021; Tornero et al.,2018) Sex is a risk factor for SSIs and is related to surgery type and frequency of surgeries which may vary across males and females (Bucataru *et al.,* 2023). HIV and old age are normally associated with a weakened immune system, increasing susceptibility to infections, including SSIs. However, sample size, random error, and uncontrolled confounders like obesity, alcoholism, and diabetes may have been a reason for this insignificant association of SSIs and these variables in this study (Penn State University, n.d.).

The study utilized a cross-sectional design, which involved the observation of a defined population at a single point in time or over a short period (Mann, 2003). This type of study is beneficial for analyzing data regarding the prevalence of an outcome, such as surgical site infection, and for identifying immediate risk factors associated with infections (Mann, 2003). It is also commonly used in epidemiological research to assess the burden of disease within a population (Mann, 2003). This design allowed for the analysis of data regarding the prevalence of SSIs and provided valuable insights into the factors associated with SSIs linked to *P.aeruginosa*. The combined use of culture methods and molecular techniques enhanced the reliability of the detection of *P. aeruginosa* linked to SSIs. First, the culture methods allowed for the growth and initial identification of the bacteria. Then, the molecular technique confirmed the presence of *oprL* resistance genes associated with the pathogen, ensuring precise identification (Anuj *et al.*,2009; Deschaght *et al*.,2011). Many studies have similarly utilized multi-step identification of *P. aeruginosa* to increase the specificity or identification of pathogens (Anuj *et al.*,2009; Deschaght *et al*.,2011)

However, the study had some limitations. It was limited by the cross-sectional design. The cross-sectional design does not provide information on the trend or pattern of surgical site infections (SSIs) associated with *P. aeruginosa*. A longitudinal study design would track changes over time and establish temporal relationships between SSIs and *P. aeruginosa*. The low prevalence found in this study suggests that a huge portion of the pathogens implicated in the SSIs are not *P. aeruginosa*. However, the study scope was limited to *P. aeruginosa* and was unable to identify other pathogens possibly implicated in the SSIs. Other culture media could have been simultaneously utilized to identify these other pathogens to elaborate on the bacteriology of the SSIs. Moreover, the PCR technique utilized only detected the *oprL* resistance gene. While the *oprL* gene is a notable intrinsic resistance gene implicated in the multidrug resistance of *P. aeruginosa*, other resistance genes are integral in the overall multidrug resistance of *P. aeruginosa.* (Peters & Galloway, 1990; Galloway, 1991; Choi *et al.,* 2002; Haghi *et al.,* 2018). Future studies could investigate these virulence factors through multiplex PCR techniques (Anuj *et al*.,2009). This will enhance a broad understanding of the multidrug resistance of *P. aeruginosa* associated with SSIs. The study did not investigate many other risk factors of SSIs associated with *P. aeruginosa.* These include obesity, alcoholism, surgical techniques, and duration of surgeries (Bucataru *et al.,* 2023). This incomplete data on these variables has the potential of omitting crucial factors that contribute to the SSIs (Deschaght *et al*.,2011)

The findings of the study have significant implications for future research. Future studies should utilize a larger sample size to investigate SSIs linked to *P. aeruginosa*. The studies should investigate more risk factors associated with SSIs. Longitudinal study design should be also utilized to track the trends of SSIs linked to *P.*

aeruginosa and explore the efficacy of different infection control measures.

Health policies should prioritize stringent infection control measures, especially in post-operative care. Such measures should be conducted with updated surgical wound care guidelines. In the monitoring of SSIs associated with *P. aeruginosa*, molecular techniques should be routine investigations.

Conclusion

The study reported a 2.0% prevalence of surgical site infections associated with *Pseudomonas aeruginosa* that were confirmed with *oprL* target gene. Post-operative duration increased the odds of developing SSIs associated with *P. aeruginosa* infection. Further studies with larger sample sizes should utilize longitudinal design to and possibly multiplex PCR techniques to detect and monitor *Pseudomonas aeruginosa associated* with SSIs.Infection control of SSIs should emphasize postoperative care. These will optimize the treatment outcomes and patients' health.

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Competing Interest

This manuscript has not been submitted to, nor is it under review at, another Journal or other publishing venue.

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