



## The Role of *Pseudomonas aeruginosa* in Surgical Site Infections in Sub-Saharan Africa

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### ABSTRACT

*Surgical Site Infections remain a significant burden in healthcare settings, contributing to prolonged hospital stays, increased healthcare costs, and increased morbidity and mortality rates. Among the various pathogens implicated in these infections, Pseudomonas aeruginosa remains a particularly formidable bacterium due to its intrinsic resistance to many antibiotics and its ability to acquire additional resistance mechanisms. Despite this incidence, there is a geographical limitation of surveillance programs on this pathogen continues to cripple infection control and prevention in sub-Saharan Africa, crippling surveillance data on the infection management. We aimed at understanding the role of Pseudomonas aeruginosa (PA) on the seemingly growing and concerning infections of surgical site in sub-Saharan Africa (SSA). This study adopted systematic review and meta-analysis design in line with PRISMA guidelines. For data collection, therefore, we systematically searched PubMed and other relevant databases for articles (2015-2023) relevant to antimicrobial resistance (AMR) and predominance of Pseudomonas aeruginosa (PA) in sub-Saharan Africa (SSA). We examined 26 relevant articles out of 225 that matched the initial search. A standardized data extraction form was developed to capture relevant information from the selected studies. Data collected from the studies included were synthesized narratively and reported through Systematic Reviews and Meta Analyses (PRISMA). Through an in-depth analysis of the relevant literature, the low number of studies in the region focused on PA and AMR. Nevertheless, the relatively few studies demonstrate the high rates of PA involvement in surgical site infections. The studies further show high levels of multi-drug resistance and points to subsequent nosocomial clinical outcomes. In conclusion, the study underscores the burden posed by PA in SSA, highlighting on the prevalence, multi-drug resistance and virulence. Clearly, its surveillance remains geographically limited especially in the regions that are underrepresented. The study recommends that infections prevention and control programs (IPCs) be strengthened, that antimicrobial stewardship be sensitised to regulate antibiotic use, and that surveillance and research on PA be expanded in SSA.*

**Key Words:** Pseudomonas aeruginosa, Predominance, Surgical Site Infections, Sub-Saharan Africa

### I. INTRODUCTION

Surgical Site Infections; access to healthcare services but may not experience the same degree of PA-related respiratory infections (Bobbo et al., 2023). Nevertheless, PA has proven a major health concern as far as surgical site infections are concerned in sub-Saharan Africa. We therefore sort to establish how much is currently known about the role and involvement of PA in SSI in sub-Saharan Africa.

Surgical site infections (SSIs) remain a global challenge in healthcare systems, significantly contributing to increased healthcare costs, patient morbidity and mortality (Graf et al., 2011; Hou et al., 2022; Lubega et al., 2017; Maraş & Sürme, 2023). Whereas studies have well-documented the burden of SSIs globally, Sub-Saharan Africa (SSA) context still presents unique challenges intensifying the impact of *Pseudomonas aeruginosa* (PA) infections on wounds, thus implicating a serious threat to healthcare delivery mechanisms and patient safety in the region (Nejad et al., 2011; Lakoh et al., 2022; Lubega et al., 2017). In its Bacterial Priority Pathogens List (BPPL), the World Health Organization (WHO) featured 15 families of AMR bacterial pathogens into three categories including critical, high and medium in line with prioritization and combating the spread of AMR. *Pseudomonas aeruginosa* features among high-priority pathogen with high infection burden among others like *Salmonella*, *Shigella* and *Staphylococcus aureus*, in healthcare settings (WHO, 2024).

*Pseudomonas aeruginosa* is considered one of the most successful bacterial pathogens owing to several factors including antibiotic resistance which stems from the possession of efflux pumps, low permeability of outer membrane to antibiotics, acquisition of resistance genes and adaptive resistance (Pang et al., 2019; Coleman et al., 2020; Lorusso



et al., 2022; Fernández-Billón et al., 2023). Moreover, important aspects including virulence factors like proteases, pigments, and exotoxins (Jurado-Martín et al., 2021; Liao et al., 2022; Qin et al., 2022), which are known to immensely contribute to the organism's ability to cause disease, biofilm formation attributed to survival and adaptation of PA in hospital environments through quorum sensing mechanism (Lee & Zhang, 2014), have not been demonstrated for isolates recovered previously from SSA. Nevertheless, the emergence and reduced costs of whole genome sequencing now provide hope that these isolates can now be subjected to these assays and genomes sequenced to shed more light on their adaptation to SSIs in SSA. Therefore, there is need to explore just how much is known about the biology of PA in SSA and thus the extent of knowledge surrounding AMR, virulence factors, and biofilm-formation capabilities- the problem that sits at the heart of this review.

Therefore, the present review aimed to unravel the epidemiology, antimicrobial resistant patterns, virulence carriage and distribution risk factors and subsequent implications of PA SSIs clinically in Sub-Saharan Africa. This is crucial in line with guiding policy decisions and interventions. Through the revelation of the unique challenges SSA faces in the context of PA infections on surgical sites, this review seeks to underscore the urgent need for mitigation strategies on the impact of SSIs on healthcare sector in this region.

### 1.1 Statement of the Problem

Surgical site infections (SSIs) continue to cause significant health challenges across several healthcare settings in sub-Saharan Africa, subsequently leading to increased costs of healthcare, high mortality rates owing to prolonged hospital stays (Graf et al., 2011; Hou et al., 2022; Lubega et al., 2017). Among the many pathogens already mapped out as the root cause for this, PA stands out as a concerning pathogen, deriving from its intrinsic ability to confer antimicrobial resistance, biofilm formation and virulence factors (Pang et al., 2019). Despite this level of threat by this pathogen, there is a dearth of data on adequate surveillance and associated research on the organism's epidemiology in SSA. The existing few studies have attempted to underscore the high rates of SSIs caused by PA, but this remains geographically limited, coupled with underrepresentation in marginalised areas. This is a major problem since it prevents the implementation of effective infection control programs, thus heightening the rates of AMR in the region. Addressing this problem is the forte of this review, in line with guiding interventions against PA.

### 1.2 Research Objectives

We set out to investigate the role of PA in SSIs within the context of sub-Saharan Africa. Specifically, the review aims to examine the prevalence and epidemiology of PA across SSA, to analyse AMR patterns in surgical site infections, to analyse the virulence and biofilm capabilities of the pathogen, to identify the key risk factors attributed to the success of PA, and lastly to come up with strategies to enhance surveillance and subsequent infection control strategies to curb the burden of SSIs in the region.

## II. METHODOLOGY

### 2.1 Literature Strategy Search

In this review, "sub-Saharan Africa" refers to the countries constituting the WHO- Africa region. A systematic search of electronic databases including PubMed, Google scholar and Scopus was conducted to identify all relevant studies which were published between 2015 and 2023. Medical subject headings (MeSH) and other Keywords related to "*Pseudomonas aeruginosa*", "Surgical site infections", "sub-Saharan Africa", and "Antimicrobial resistance" were used in various combinations such that the search sensitivity is maximized. Next, Boolean operators "AND" and "OR" were used to combine these search terms, which was inclined to syntax and filters of each database while incorporating truncation and where applicable, proximity operators. Moreover, references list for various relevant articles and review papers were manually searched to identify any additional studies.

### 2.2 Inclusion and Exclusion Criteria

In this review, studies reporting on the epidemiology, antimicrobial resistance patterns, virulence, risk factors, and interventions in line with PA in SSIs in SSA were included. Moreover, articles in peer-reviewed journals, conference abstracts were included. However, those studies not specific to sub-Saharan Africa as well as those only focusing on other pathogens or those lacking primary research data were excluded. Nevertheless, all non-English articles which are relevant were translated and included.

### 2.3 Study Selection

For this review, two independent reviewers screened titles and abstracts of retrieved articles for eligibility based on the inclusion and exclusion criteria. For eligibility, full-text articles for relevant studies were obtained and assessed for eligibility. Any differences between the reviewers were resolved through consultations with a third reviewer.



## 2.4 Data Extraction

A standardized data extraction form was developed to capture relevant information from the selected studies which included characteristics of the study (author, year, study design), demographics of study participants, PA prevalence, risk factors, AMR profiles and interventions.

## 2.5 Quality Assessment

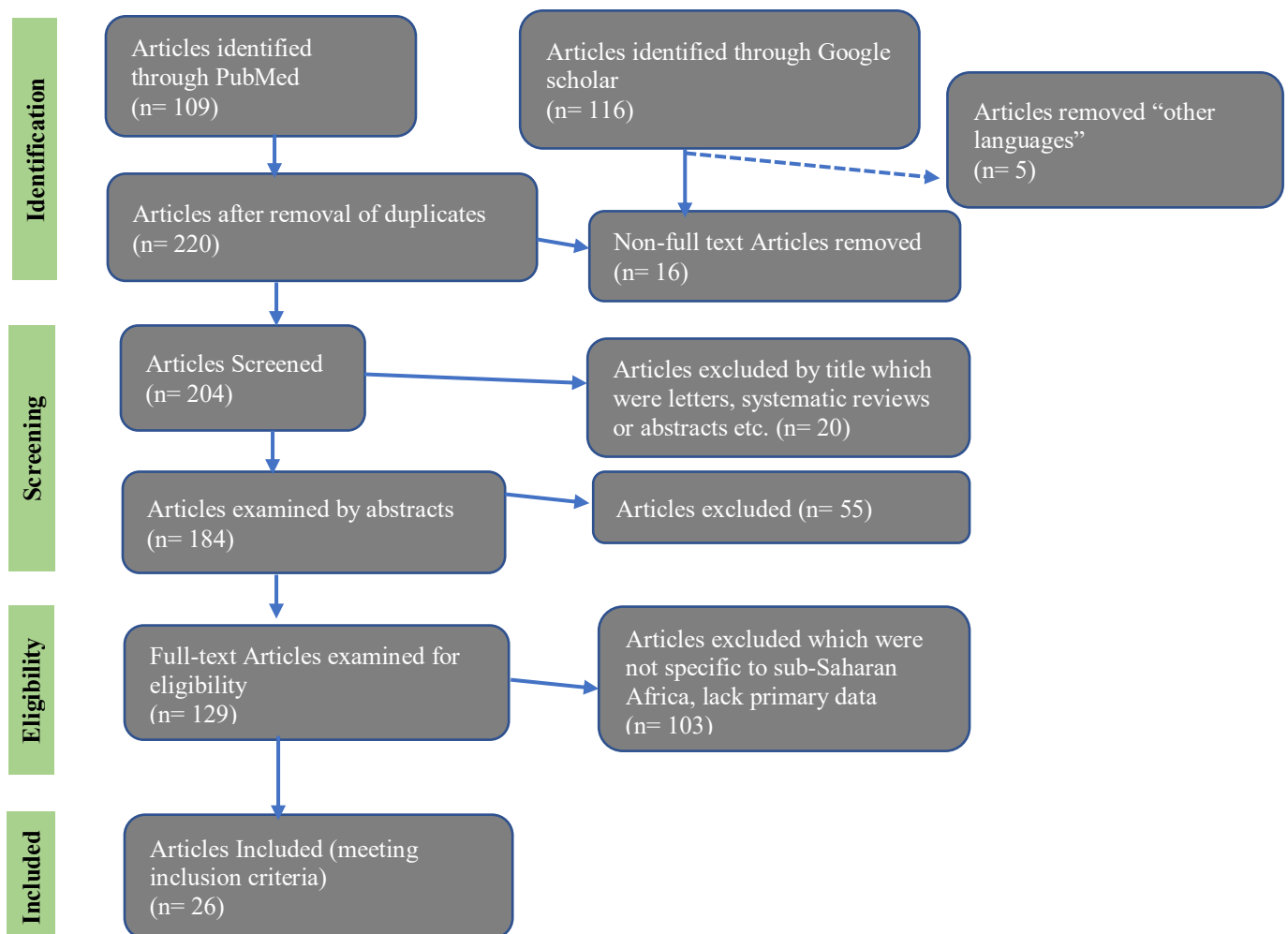
In this review, the methodological quality of the selected studies was evaluated using the Newcastle-Ottawa Scale for observational studies and the Cochrane Risk of Bias tool for studies that were randomized controlled trials. Quality assessment here helped inform the interpretation and synthesis of findings with higher quality studies.

## 2.6 Data Synthesis and Analysis

In this review, findings from the studies included were synthesized narratively, organized in line with key themes and outcomes. Additionally, subgroup analyses were conducted as appropriate in line with exploring heterogeneity of results.

## 2.7 Reporting

The preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) (Figure 1) were followed to ensure comprehensive and transparent reporting of the findings of this review.



**Figure 1**

*The PRISMA Flow Diagram Showing the Process of Identifying, Screening, and Selecting Articles for Inclusion in the Review*

**NB.** The numbers represent the cumulative count of articles at each stage of the review process, and where applicable, reasons for exclusion or removal.



### III. FINDINGS & DISCUSSION

#### 3.1 Response Rate

A total of 225 articles were initially identified by use of the systematic literature search across PubMed, Scopus and Google Scholar, while focusing on the role of PA in surgical site infections in Sub-Saharan Africa. After screening titles and abstract, 26 articles of the 225 were deemed eligible for full-text review. The included studies embedded a number of themes around PA, including the epidemiology, risk factors, AMR patterns, clinical outcomes and interventions surrounding the infection incidences (Table 1). The results of this analysis are presented as follows.



**Table 1**  
*Epidemiology of PA in sub-Saharan Africa*

Country	Sample Source	Incidence of SSI by PA (%)	Prevalence of MDR (%)	Antimicrobial Resistance (%)														Common Resistant Genes	Reference Sources
				GEN	MEM	TZP	IPM	TOB	CAZ	AMK	FEP	CIP	LVX	CRO	DOR	LVX	COL		
Ethiopia	Surgical wound cultures	12.8	33.33	62.97	11.1	11.1	7.4	18.5	25.9	11.1	14.8	22.22	-	-	-	-	-	-	Abdi et al. (2024)
	Blood, wound swab, urine, and sputum	19.3	45.9	62.2	-	-	28.4	-	51.4	29.7	50	14.9	-	-	-	-	-	-	Asamenew et al. (2023), 15(30%)
	Wound swabs	17.6		27.8	16.7	61.1	-	-	83.3	-	-	61.1	-	-	-	-	0	-	Mekonnen et al. (2021)
Ghana	Surgical wound cultures	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Bediako-Bowan et al. (2020)
Nigeria	Surgical wound swabs	33.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Iliyasu et al. (2016)
	Wound swabs	30.6	-	91.3	-	-	13.0	-	95.7	-	-	56.5	-	43.5	-	-	-	-	Omoyibo et al. (2018)
Egypt	Wound swabs	40.0	54.9										83.3	-	-	-	-	-	Ahmed et al. (2023)
	General	-	75.6	65	-	-	-	-	-	50	68	70	-	-	-	-	-	-	<i>bla</i> <sub>VIM</sub> (52.9%), <i>bla</i> <sub>KPC</sub> and <i>bla</i> <sub>NDM</sub> (2.9% each), <i>bla</i> <sub>OXA-48</sub> (0%). Other mutations: <i>oprD</i> (0%), <i>mexAB</i> (21.8%), <i>mexCD</i> (75%), <i>mexEF</i> (18.7%), <i>mexXY</i> (62%)



	Wound swabs	5.6	59.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Talaat et al. (2016)	
DRC Congo	Surgical wound swabs	5.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Kakupa et al. (2016)	
Tanzania	Wound swabs	14.0	-	29.4	17.7	41.2	17.7	29.4	35.3	29.4	-	29.4	-	-	-	-	0.0	-	Moremi et al. (2017)	
Morocco	Pus swabs	10.8	29	-	-	-	29	-	29	-	-	-	-	-	-	-	-	-	Abourrich et al. (2023)	
Sudan	Clinical isolates		18	25.13	5.53	77.89	-	-	18.09	-	-	21.61	-	-	-	-	-	-	<i>aadA6, APH (3')-VI, PDC-2, VEB-9, PmrA, PmrB, Mutant gyrA, cysB, alaS, ileS, MexS, mdtB, mdtC, nalC, nalD, NfxB, FloR, PmrA, and TetG</i>	Hussain et al. (2023)
	Wound Swabs	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Hassan et al. (2022)	
Sierra Leone	Wound swabs	42.9		83.3	33.3	16.7	33.3	83.3	33.3	0	25.0	83.3	66.7	-	-	-	-	-	Lakoh et al. (2022)	
Uganda	Wound swabs	11.1		-	-	-	-	-	-	-	-	100	-	100	-	-	-	-	Lubega et al., (2017)	
Malawi	Pus swabs	6		17	66	7	-	7	17	-	-	-	-	-	-	-	-	-	Choonara et al. (2022)	



Reported by different studies are percentages of resistance and are not directly comparable, owing to variation in selection criteria and period of time, antimicrobial and susceptibility methodologies. MDR PA rates represent the most recent reported MDR rates in *P. aeruginosa* in the respective country. The antimicrobial resistance rates are the percentages of *P. aeruginosa* resistant to the respective antibiotic: PTZ, piperacillin-tazobactam; CTZ, ceftazidime; FEP, cefepime; AZT, aztreonam; GEN, gentamicin; AMK, amikacin; CIP, ciprofloxacin; LEV, levofloxacin; MER, meropenem; IMP, imipenem; COL, colistin. Values that were reported as resistance rate to antibiotic groups (carbapenem/aminoglycoside/fluoroquinolone) rather than to individual antibiotics are indicated with an asterisk. -, not reported/available. In the Resistance genes column, the genes and the percentages of the carbapenem-resistant (CR) *P. aeruginosa* strains with the reported gene from these countries are shown. MBL, metallo- $\beta$ -lactamase. Values that were results from different studies are indicated with a pound sign (#). -, not reported/available.

### 3.1.1 Epidemiology of *Pseudomonas aeruginosa* SSI in Sub-Saharan Africa

Among the articles reviewed, a consistent trend emerged underscoring the predominance of PA in SSIs across various healthcare settings in Sub-Saharan Africa from 4 articles. Based on **table 2**, several studies reported high rates of PA isolation from surgical wound specimens ranging from 12%-33%, with one particular study in Ethiopia reporting 27 (12.86%) and 74 (19.3%) of all the wound cultures (Abdi et al., 2024; Asamenew et al., 2023), 15(30%) in Ghana (Bediako-Bowan et al., 2020) and 3/9 (33.3%) on samples from post-renal transplant patients in Nigeria (Iliyasu et al., 2016). Currently, most of the studies available were done in West Africa, and the other regions were underrepresented. Nevertheless, these ranges depended on the type of surgery and patient population sampled. Noteworthy, Omoyibo et al., (2018) and Ahmed et al., (2023) also appreciated PA as one of the most prevalent pathogens responsible for SSIs alongside other common pathogens like *Staphylococcus aureus* and *Escherichia coli* in Sub-Saharan Africa.

**Table 2**

*Prevalence of Pseudomonas aeruginosa*

Country	% Levels of PA Reported	Reference
Ethiopia	12.86%	Abdi et al. (2024)
	19.30%	Asamenew et al. (2023)
Ghana	30%	Bediako-Bowan et al. (2020)
Nigeria	33.30%	Iliyasu et al. (2016)

### 3.1.2 Risk Factors Associated with *Pseudomonas aeruginosa* Surgical Site Infections

The search was able to unravel 4 risk factors (**Table 3**), which appeared to contribute to the acquisition as well as the development of SSIs by PA in Sub-Saharan Africa. While Kakupa et al., (2016) and Dégbey et al., (2021) identified prolonged hospitalization, inadequate control measures for infections, use of indwelling medical devices as significant risk factors, Moremi et al. (2017) and underscored the role of surgical procedures in the increased risk of infections by PA, especially among patients undergoing or recovering from abdominal surgeries. These findings highlight the importance of targeted strategies aimed at preventing SSIs attributed to PA in Sub-Saharan Africa.

**Table 3**

*Risk factors for infection by PA*

Factor	Reference
Prolonged hospitalization	Kakupa et al. (2016) and Dégbey et al. (2021)
Inadequate control measures for infections	Kakupa et al. (2016) and Dégbey et al. (2021)
Use of indwelling medical devices	Kakupa et al. (2016) and Dégbey et al. (2021)
Surgical procedures	Moremi et al. (2017)

### 3.1.3 Antimicrobial Resistance Patterns of *Pseudomonas aeruginosa*

In the review, AMR among several PA isolates in the studies in SSA was notably high and therefore of concern. Reports indicate high resistance levels to piperacillin-tazobactam Sierra Leone, Uganda, Nigeria and Malawi at 83.3%, 100%, 91.3% and 66% respectively (Lakoh et al., 2022; Lubega et al., 2017; Omoyibo et al., 2018; Choonara et al., 2022) respectively. Moreover, PA has continued showing high levels of resistance to Ciprofloxacin in these countries with rates as high as 83.3% and levofloxacin at 83.3% in Sierra Leone (Lakoh et al., 2022). Elsewhere, Al-Orphaly et al., (2021) and Abourrich et al., (2023) underscored the importance of resistance of PA to commonly used antibiotics like beta-lactams, fluoroquinolones, and aminoglycosides, to the onset of SSIs. Additionally, multi-drug resistance appeared to be prevalent, with some important studies appreciating the resistance of PA to multiple antibiotics classes



attributed to derailment of treatment processes or options therefore exacerbating the risk of treatment failure. For example, as Imipenem appears effective against PA (only 7.4% resistance rate), the pathogen appears commonly resistant to Gentamycin (63% resistance and only 30% sensitivity rate) in the recent study (Abdi et al., 2024). These levels of resistance can also draw from the genes encoding resistance in these strains. Not many studies in SSA have highlighted the AMR genes. However, a few studies have shed light into several AMR genes in PA. For example, carbapenem resistance is observed in multiple regions, suggesting the possible presence of carbapenemase genes like, blaIMP, blaVIM or blaNDM. On their study of MDR organisms in a teaching facility in Ghana, Bediako-Bowan et al., (2020), 352 isolates were cultured out of 438 SSIs noted. Majority of these organisms were MDR, calling for re-evaluation of antibiotic prophylaxis in surgical practices. Other cases of MDR appeared in other studies (Mekonnen et al., 2021; Hussain et al., 2023).

### 3.1.4 Virulence

The success of PA in infecting surgical wounds has been attributed to its virulence factors which include exotoxins, pigments, proteases, and biofilm formation (Kiyaga et al., 2022). While there is much data on this globally, there still remains a significant gap on PA strain isolated in SSA. A few studies have made efforts on the isolation of PA, but this remains region-specific following resource constraints (Kiyaga et al., 2022). For example, eight (14%) out of 57 samples were positive for PA in a study in Tanzania (Moremi et al., 2017) and 26.1% isolated from surgical wounds in Ethiopia (Chimi et al., 2024). Nevertheless, some reports on the virulence mechanisms of PA have started coming in (Kiyaga et al., 2022). However, the extent of this activity on tissues still remains underexplored. Elsewhere (Kiyaga et al., 2022; Chimi et al., 2024), the role of biofilm formation in chronic infections and antibiotic resistance has been documented. However, there's limited data on the molecular mechanisms-the driving forces behind the surging infections. Similarly, research data on QS genes and a correlation with virulence expression remains unexplored sufficiently, despite available data on QS as a survival mechanism of PA.

### 3.1.5 Impact and Clinical Outcomes of *Pseudomonas aeruginosa* in SSIs

The severity of infection within the host organism on these wounds have been attributed to extended hospital stays and increased healthcare costs (Moremi et al., 2017), period of surgery (Hassan et al., 2020) due to prolonged use of invasive devices like exposure to pathogens thus heightened morbidity and mortality rates (Hou et al., 2022; Lubega et al., 2017). Additionally, Patients presenting with PA have been reported to experience delayed healing of wounds (Hassan et al., 2022), systemic complications and sepsis (Brown et al., 2021) hence decreased quality of life. Furthermore, other reports attribute the economic burden of PA to weak infrastructure, underscoring the need for effective prevention and other management strategies in line with mitigating the menace (Lowe et al., 2021).

### 3.1.6 Preventive and Management of PA in SSIs

Despite the challenges posed by PA, most studies identified a number of prevention and interventions strategies that can help alleviate the impact of PA SSIs in sub-Saharan Africa. While some sensitized on the enhanced surveillance of SSIs, implementation of infection control programs (ICPs) (Talaat et al., 2016; Mmari et al., 2021), others underscored the importance of promotion of AMR stewardship (Choonara et al., 2022), improved access to effective antibiograms in line with reducing the incidence of PA in the region. Moreover, strengthening of infrastructure, community engagement and capacity building appeared in several studies as a recommendation as approach to fighting AMR by PA (Forrester et al., 2020; Al-Orphaly et al., 2021).

Although there are not many studies in SSA done on PA infecting surgical sites, the result of this review highlights the concerning trend of PA predominance in surgical site infections on the few sampled clinical settings in SSA. While there's data on AMR and virulence of PA, its regional variability could spell challenges in infection control for surgical site infections. Incomplete understanding of epidemiology of PA affects surveillance efforts. Moreover, gaps in the sequencing data could have severe implications to control of antibiotic resistance and novel therapies.

## 3.2 Discussion

In this review, the results point out a concerning trend of the prevalence and impact of PA in SSIs within sub-Saharan Africa. This trend is indicative of a significant predominance of PA. This serves as an alarm owing to PA's well-documented propensity for AMR and the associated clinical outcomes.

### 3.2.1 Prevalence and Risk Factors of *Pseudomonas aeruginosa* in Surgical Site Infections

This study serves to demonstrate that PA is understudied in Africa. Bearing in mind that our review focused on studies in the recent 8 years, with only four articles revealed PA as the prevalent pathogen in SSIs. There is however consistency in the studies which highlighted the predominance of PA in SSI within the context of SSA, that the organism shows potential of outcompeting other microbes on wounds. This phenomenon is possible owing to the presence of



virulence factors, biofilm formation, antibiotic-degrading enzymes, metabolic versatility, and immune evasion (Kiyaga et al., 2022; Chimi et al., 2024). Additionally, what emerges from the studies are high rates of PA recovery from SSIs, demonstrating a considerable burden of PA in SSA, and underscoring the role of PA in nosocomial infections in the region. Additionally, the variability of risk factors is important since it underscores the influence local factors have on the AMR trends. Inadequate control measures, prolonged hospital stays, and prolonged surgery heavily influence the prevalence and severity of infections by PA on surgical wounds. These factors are especially pertinent in SSA owing to unexplored gaps in clinical research, leading to limited surveillance data and inadequate monitoring of resistant strains. These trends therefore call for localized surveillance. Studies reviewed here point out that these nosocomial infections are a major source of PA, a disturbing trend in the region and perhaps no differences from wound samples across the globe. Nevertheless, most of the studies on SSI and PA appear to be based in West Africa with other regions in SSA underrepresented. This limitation in geography may perhaps not give the true representation of the situation in SSA and calls for more comprehensive research across other regions.

As the review indicates, the prevalence of PA is documented in West Africa primarily may be predictive of increased nosocomial infections in the underserved regions in the future thus increasingly problematic since there is limited surveillance. Moreover, AMR crisis will likely worsen in healthcare facilities due to lack of AMR stewardship programs, consequently leading to untreatable PA thus extended hospital stays and increased mortality rates.

### 3.2.2 Antimicrobial Resistance Patterns of *Pseudomonas aeruginosa*

PA is listed by WHO as a microbe of priority and public concern. From the studies clearly SSA studies don't point to this, there is little effort to show that it is being monitored and important resistance being monitored. This is indicative of the challenges attributed to SSIs (Elton et al., 2020; Berhe et al., 2021; Kariuki et al., 2022). The numbers of antibiotics tested and how this corresponding to resistance seems directly proportional, and therefore the impacts of such representation especially when the numbers captured the antimicrobial sensitivity tests are quite low. Moreover, certain environmental reservoirs have been attributed to this spread. Resistant strains of PA have been isolated from water sources (Moremi et al., 2017), medical devices and hospital surfaces (Asker et al., 2021). Additionally, the high resistance rates to the commonly used antibiotics in the region including fluoroquinolones, beta-lactams, and aminoglycosides (Ntirenganya et al., 2015; Tadesse et al., 2017; Kariuki et al., 2022; Moyo et al., 2023), limit the available treatment options which further pose a major challenge in line with patient care. Several other studies have attributed this cause to the multi-drug resistance nature of PA, rendering the organism capable of surviving amidst several classes of antibiotics, consequently leading to treatment failure (Lister et al., 2009; Pachori et al., 2019; Mancuso et al., 2021). This problem is further expedited by unregulated prophylactic administration of antibiotics especially 3rd generation cephalosporins that is basically abused in the SSA region, increasing the risk of AMR emerging and spreading. The rise of AMR observed, therefore, outlines the urgent need to promote enhanced antimicrobial stewardship programs, and studies pointing to what genetic markers for resistance are circulating in the region, in line with developing an alternative treatment options or strategies, for example, novel antimicrobial agents.

### 3.2.3 Virulence

Biofilm formation is a key component of PA virulence, enabling the organism to thrive on wounds, medical and hospital surfaces. After attachment, maturation and detachment follows, which disperses them not only to hospital settings, but also community settings. Nevertheless, most isolation on PA in SSA has focused heavily on hospital settings where PA infections are more prevalent like intensive care units, isolation from community settings remains limited and thus incomplete picture on the pathogen's distribution. Other implications for lack of widespread and systematic isolation of the pathogen is difficulty in monitoring the pathogen's dynamics in SSA, as well as limited sequencing data which cripples the efforts to identify region-specific virulence factors which may guide its control. Additionally, the underrepresentation of some data on virulence of PA could be the driving force behind the success of PA in infecting surgical wounds in SSA, looking at the already available data in West Africa. For example, a dearth of information on genomic data to compare PA from other regions, toxin production and host-pathogen interaction cripples the full understanding of virulence potential of the organism in SSA. The limited focus seen here, thus, leaves much to be explored. There is therefore a compelling need to address these gaps on genome sequencing, to reduce the burden of PA in SSA (Chilam et al., 2021; Verhoeve et al., 2022).

### 3.2.4 Preventive and Management of PA in SSIs

There is need for an interdisciplinary approach in addressing the trend of PA predominance in SSIs in sub-Saharan Africa to enhance both therapeutic and preventive interventions (Elton et al., 2020; Iskandar et al., 2021). Additionally, this would enable comprehensive understanding of the organism through genomics, enhanced infection control, improved surgical practices and postoperative care, as well as strengthened research and innovation. Sub-Saharan Africa comprises different countries including lower-and-middle income countries with varying degree of



resources and healthcare infrastructure (Shears, 2007; Mehtar et al., 2020), possibly prompting a challenge in the mitigation and management of SSIs (Rickard et al., 2020). In this region, the heightened risk of healthcare-associated infections like SSIs stems from a limited access to resources (Misha et al., 2021; Lakoh et al., 2022). Additionally, such socioeconomic factors as poverty, overcrowding and malnutrition furthers the SSI burden especially those by PA (Moremi et al., 2017; Khan et al., 2020; Mezemir et al., 2020; Hirani et al., 2022). Recent studies have emphasized the need to mitigate the widespread overuse and misuse of antibiotics, owing to a likely oversight by medical institutions and pharmacies, as well as limited surveillance (Llor & Bjerrum, 2014; Shallcross & Davies, 2014). Perhaps the number of scientists interested in PA in SSA may be low. Or because of the miss conception of the role of PA, and its role in SSI. This makes the region particularly vulnerable to attack by multi-drug resistant (MDR) strains of PA (Ayukekbong et al., 2017; Kariuki et al., 2022; Murug). Beside this incident compromising the efficacy of available antimicrobial treatment, it seems to heighten the risk of adverse clinical outcomes drawing from treatment “flops” and extended hospital stays.

### 3.2.5 Need to Strengthen IPCs Programs to Reduce the Incidence of the Infections in Resource-Poor Settings

Recent studies have also emphasized on the need to curb the transmission of PA (Talaat et al., 2016; Mmari et al., 2021). This could span from the implementation of strict hand hygiene to the optimization of sterilization process of the surgical equipment. Additionally, antimicrobial prophylaxis may be administered pre-operatively according to local AMR patterns and any risk factors that may be patient-specific (Baseel et al., 2022). Recent reports indicate that early recognition and initiation of antimicrobial therapy can help kick-start this (Leekha et al., 2011). Furthermore, such programs as antimicrobial stewardship can be reinforced and expanded to marginalized areas within SSA such that the community is sensitized on the appropriate use of antimicrobials (Engler et al., 2021; Dlungel & Mathibe, 2023). This could entail more initiatives like surveillance on regular basis of the patterns of antimicrobial susceptibility as well as educating pharmacists on the specific guidelines for dispensing antimicrobials (Saleem et al., 2019; Vieira et al., 2022). Improving access to diagnostic testing procedures could also be significant in fighting AMR of PA. In the broader demesne of the fight against antimicrobial resistance, more effort is needed to expedite the management of the seemingly established PA in SSA, such that patient outcomes are optimized. For other cases observed like localized infections, wound irrigation and surgical debridement could be ideal (Liu et al., 2022) while other complicated cases like sepsis may need more delicate support like intensive care. While looking into the clinical aspect of it, it is also important to address the underlying socio-economic and other environmental factors attribute to healthcare infections. For example, recent studies have suggested an improvement of access to clean water and sanitation points and to a greater extent, strengthening the healthcare infrastructure in sub-Saharan Africa (Seward et al., 2022).

In summary, the review highlights data discrepancy on PA research with only a few studies identifying PA as a pathogen of interest on SSIs. While these studies demonstrate the dominance of PA in SSA, they are concentrated in West Africa, hence underrepresentation of other regions and thus need for more studies in the other countries on the pathogen. Additionally, there's need for localized surveillance efforts due to lack of comprehensive surveillance on the pathogen. Finally. The rise of AMR and virulence continues to be a growing challenge in the region due to the above gaps and therefore addressing these gaps will be critical in reducing the burden of the organism in SSA.

## IV. CONCLUSION & RECOMMENDATIONS

### 4.1 Conclusions

This review underscores the important challenges in the healthcare sector across sub-Saharan-Africa, owing to the epidemiology, antimicrobial resistant patterns, virulence carriage and distribution risk factors and subsequent implications of PA SSIs clinically in Sub-Saharan Africa. This is crucial in line with guiding policy decisions and interventions. The low rates of PA isolation and antimicrobial resistance highlight an urgent need for mitigation measures to combat this seemingly growing problem. When IPC programs are strengthened, rational antimicrobial use will be enhanced, as well as a stronger healthcare infrastructure in line with mitigating the burden posed by PA.

### 4.2 Recommendations

Healthcare facilities must implement rigorous infection control measures to prevent the transmission of MDR PA. This includes isolation of infected patients, strict adherence to hand hygiene, and environmental cleaning. Moreover, raising public awareness about the responsible use of antibiotics, infection prevention, and the implications of antibiotic resistance is essential in the fight against MDR *P. aeruginosa* and other drug-resistant pathogens.



## List of Abbreviations

PA	<i>Pseudomonas aeruginosa</i>
SSIs	Surgical Sites Infections
SSA	Sub-Saharan Africa
AMR	Antimicrobial resistance
IPC	Infection Prevention and Control
pwCF	persons living with cystic fibrosis
DALYs	disability-adjusted life years
CF	cystic fibrosis
MeSH	Medical subject headings
WHO	World Health Organization
BPPL	Bacterial Priority Pathogens List
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta Analyses
MDR	Multi-Drug Resistance
ICPs	infection control programs

## Competing Interests

The authors declare no conflict of interest

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