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Global Patterns Of Microbial Prevalence And Antibiotic Resistance: A Literature Review Highlighting Research Gaps In The Free State And Northern Cape Provinces Of South Africa

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Abstract

Hospital-acquired infections (HAIs) are a growing public health challenge in Sub-Saharan Africa, particularly among hospitalized patients where bacteria account for the majority of microbial infections. Gram-negative bacteria (GNB), especially Enterobacteriaceae, are the most commonly observed drug-resistant pathogens in healthcare settings. Multi-drug resistant Enterobacteriaceae (MRDE) infections are associated with poor clinical outcomes and high mortality, especially in low- and middle-income countries. Studies show significant variability in resistance patterns across hospitals, with some reporting up to 57.3% MDR and 3.5% XDR strains of Enterobacteriaceae. Extended-spectrum β-lactamase-producing Enterobacteriaceae (ESBL-E) also present an increasing threat, with prevalence rates ranging from 0.7% in Malawi to 75.8% in Egypt. Notably, mortality was higher in ESBL-positive patients (47.3%) compared to ESBL-negative patients (22.4%). Additionally, infections with Carbapenem-resistant Enterobacteriaceae (CRE) have demonstrated the highest 30-day mortality rate (63.8%) among resistant organisms. In South Africa, the emergence of multidrug-resistant organisms such as MRSA, CRAB, and CRE further exacerbates the burden of HAIs. Despite these alarming trends, there is a lack of comprehensive data on microbial prevalence and antibiotic susceptibility patterns in regional hospitals of the Free State and Northern Cape provinces. This literature review highlights these critical gaps and underscores the urgent need for localized studies to inform effective infection control and antibiotic stewardship strategies

Keywords: *Hospital-acquired infections, Multidrug-resistant organisms, Antibiotic resistance, Enterobacteriaceae, Carbapenem-resistant Enterobacteriaceae*

INTRODUCTION

Hospital-acquired infections (HAIs) remain a major public health concern globally, with the burden particularly severe in low- and middle-income countries, including those in Sub-Saharan Africa. These infections, commonly caused by bacteria such as *Staphylococcus aureus*, *Enterobacteriaceae*, *Acinetobacter baumannii*, *Klebsiella pneumoniae*, *Enterococci*, and *Pseudomonas spp.*, are associated with increased morbidity, prolonged hospital stays, and high mortality rates. Drug-resistant Gram-negative bacteria (GNB), particularly multidrug-resistant *Enterobacteriaceae* (MDRE), pose a significant challenge to patient safety and effective treatment. The emergence of extended-spectrum β-lactamase-producing *Enterobacteriaceae* (ESBL-E) and carbapenem-resistant strains (CRE) has further complicated infection control and antibiotic therapy in hospital settings.

Although multiple studies have documented rising antimicrobial resistance globally, there is limited data on microbial prevalence and antibiotic susceptibility specific to hospitalized patients in regional and provincial hospitals of South Africa, especially in the Free State and Northern Cape provinces. Additionally, inconsistencies in infection prevention strategies and antibiotic stewardship policies contribute to the proliferation of multidrug-resistant organisms in healthcare facilities. Understanding the regional burden of resistant infections, particularly among vulnerable and immunocompromised patients, is crucial for informing local policies and public health interventions. This literature review aims to identify existing research gaps and highlight the need for targeted epidemiological studies in these underrepresented provinces.

This study adopted a desktop-based literature review methodology to explore existing knowledge on microbial prevalence and antibiotic resistance among hospitalized patients, with a particular focus on the Free State and Northern Cape provinces of South Africa. A comprehensive search of academic and scientific literature was conducted using several databases, including Google Scholar, Scopus, PubMed, ScienceDirect, Web of Science, EBSCOhost, Africa Journals Online (AJOL), and ProQuest Dissertations & Theses.

The literature search employed a combination of relevant keywords and Boolean operators to identify studies aligned with the scope of the review. These included terms such as *"hospital-acquired infections" AND "South Africa"*, *"nosocomial infections" AND "Free State" OR "Northern Cape"*, *"multidrug-resistant organisms" OR "MDROs"*, *"Enterobacteriaceae" AND "antibiotic resistance"*, *"extended-spectrum β-lactamase" OR "ESBL-E"*, *"carbapenem-resistant Enterobacteriaceae" OR "CRE"*, *"infection control" AND "regional hospitals"*, and *"microbial prevalence" AND "South African hospitals"*. Additional search terms included *"bacterial infections in ICUs"*, and *"student theses" OR "dissertations" AND "hospital infection" AND "South Africa"* to include unpublished academic work.

The search focused on literature published between 2010 and 2024, including peer-reviewed journal articles, postgraduate dissertations, and theses, with specific attention to research conducted by students and academic researchers at South African institutions. A total of 62 articles met the criteria and keywords for this desktop literature review with only English-language publications were considered. The selected literature was analysed thematically to identify trends, gaps, and challenges, particularly regarding antibiotic susceptibility patterns, hospital infection control practices, and the regional burden of drug-resistant microbial infections in hospitalized patients.

LITERATURE REVIEW

Infections are the major cause of morbidity and mortality in immune-compromised subset of patients (Singh et al., 2014). Over 1.4 million people worldwide suffer from infections acquired in hospital that are caused by microbes (Xia, Gao and Tang, 2016). There are a wide range of microorganisms that can cause a severe harm to the body and become lethal (Pinky Sarmah *et al.*, 2018). Patients are exposed to a wide variety of microbes during their hospital stay and they acquire these microbes through different pathways, which can be contaminated hospital equipment, bedding articles or aerosols (Xia *rt al.*,2016), in addition, cross contamination between patients can be spread through contact with hospital staff members. Microbial contamination can also occur because of patients' hands or direct shedding of microorganisms that can live for long period on dry surfaces (Temesgen *et al.*, 2023). Legal costs are also involved in the present environment of litigation, as nosocomial infections are often attributed to negligence or substandard health care (Nair *et al.*, 2018). Bacteria are responsible for 95% of microbial infections, however, they can be also caused by fungi (82.9%), viruses (88.3%) and parasites (86%) (Nazeerah et al., 2022; Katarzyna *et al.*, 2015). Bacteria such as *Staphylococcus aureus, Enterobacteriaceae, Acinetobacter baumannii, Klebsiella pneumoniae, Enterococci* and *Pseudomonas* spp are the most common pathogens that cause infections in hospitalized patients. Hospital acquired infections are an increasing problem across Sub-Saharan Africa (Archary *et al.*, 2017), and bacterial contamination of indoor hospitals, particularly in Intensive Care Units is a serious health hazard in the world with high morbidity and mortality rates (Temesgen *et al.*, 2023). Only the bacteria that are sensitive to antibiotic are suppressed or killed, while the resistant strains survive and become endemic and burst out in the hospital (Xia, Gao and Tang, 2016). The present available antibiotics are becoming less effective on microbes and it is important to develop new strategies to manage them (Cerini *et al.*, 2023). The rapid increase by microbes constitutes one of South Africa's challenging health care problem particular nosocomial infections caused by Multidrug-resistant organisms, this includes; Methicillin-resistant *Staphylococcus aureus* (MRSA), Carbapenem-resistant *Acinetobacter baumannii* (CRAB) and carbapenem-resistant *Enterobacterales* (CRE), which show resistance to most available antibiotics and lead to high mortality rate. It has been previously reported that some hospitals (2 to 49%) in developing countries (Mbim *et al.*, 2016) lack general infection prevention measures, prevention of cross-transmission and a policy of restricted antimicrobial use (Blot, 2008). The rate of microbial infections differs from region to another, along with time variations (Nimer, 2022). An important factor in achieving a high index of appropriate antimicrobial therapy is rapid reporting of microbial results, species identification and sensitivity testing, in this way an observed regimen that is not appropriate for the causative pathogen can be corrected within the clinically important time frame of 48h (Blot, 2008). Healthcare setting and patient population also has a huge impact on the prevalence of

infections caused by microorganisms (Szabó *et al.*, 2022). The number of microbial infections seems to be increasing to hospitals caring for an increasing number of patients and increasing antibiotic resistance (Szabó *et al.*, 2022). The consequences that are associated with microbial infections include longer hospital stay, high morbidity rate and mortality. These consequences affect the cost of patient healthcare services and reduce the reliability of available resources in developing countries (Nimer, 2022). There are many patient risks factors that influence the acquisition of nosocomial infections, such as age, immune status, pre-existing disease and diagnostic or therapeutic interventions (Nair *et al.*, 2018). Patients with chronic diseases, such as cancer, diabetes mellitus, renal failure TB or HIV are vulnerable to infections, especially to opportunistic organisms (Nair *et al.*, 2018). Modern diagnostic and therapeutic procedures such as biopsies, endoscopic examinations, catheterisation, ventilation and surgical procedures have also been reported to increase the risk of contracting nosocomial infections (Nair *et al.*, 2018). Another contributing risk factors are crowded conditions within the hospital, frequent transfers of admitted hospital patients from one unit to another, and concentration of patients highly susceptible to infection, this includes neonates, burn patients and patients in intensive care units in one area (Nair *et al.*, 2018). Even though research and development in the treatment and the prevention procedures has advanced, infectious diseases remain the topmost cause of death in the world, especially in developing countries (Sarmah *et al.*, 2018). Critically ill patients in Intensive Care Unit (ICU) have five to seven higher risks of nosocomial infection with ICU infections reported to contribute to 20% to 25% of all hospital nosocomial infections (R *et al.*, 2012).

Clinical signs and symptoms suggestive of infections are fever >38°C, leukocytosis >10000/mm^3, new infiltrates on chest X-ray, persistent tracheal aspirates, turbid urine, suprapubic tenderness, abdominal pain and microorganisms in peritoneal dialysis fluid (R *et al.*, 2012). Depending on the patient's symptoms and clinical suspicion, laboratory samples such as urine, sputum, pus, body fluids, blood and stool are collected from the patient for further investigation (R *et al.*, 2012). Critically ill patients in ICU have a higher chance to acquire bacterial infections in the blood stream (None Ayu Permatasari Tribuana Tungga Dewi et al., 2023). Bacteremia is a bacterial infection in the blood stream and can reflect the presence of blood infection in a patient (Dewi et al., 2023). Bacteremia is more common in patients that are undergoing surgical procedures or invasive medical devices such as central venous catheters, where microbes can enter the patients' bloodstream (Dewi et al., 2023). Blood stream infections that are caused by bacteria can be life-threatening infections, especially in immunocompromised patients (Dewi et al., 2023). Microorganisms can also indirectly get through an infected surgical wound (Dewi et al., 2023). In most of the cases, there is a need to initiate empirical antimicrobial treatment before obtaining microbial results, however, the situation is complicated by the emergence of multiple beta-lactamase producers and multidrug resistant pathogens (Goel *et al.*, 2009). Most of the admitted patients are treated with empirical prescribed antibiotics, however, it commonly leads to antimicrobial resistance (AMR) and emergence of multidrug resistance (MDR) as well as death of patients' (Temesgen *et al.*, 2023). It is imperative that empirical antibiotic therapy for suspected nosocomial infection in patients be sufficiently broad spectrum to cover likely pathogens, however, this must be backed up with adequate diagnostic microbiology facilities to ensure the recognition and sensitivity testing of the responsible microorganism, further aiding the switch to targeted therapy (Archary et al., 2017). Multidrug resistance bacteria are usually encountered among immunocompromised patients (Bhat et al., 2021). The ability of bacteria to develop resistance to antimicrobial agents has made treating bacterial infections more difficult in recent years (Temesgen *et al.*, 2023). The emergence of resistance to antibiotic agents is a global public health problem, particularly in microbes causing nosocomial infections which contributed to morbidity, mortality, increased health care costs resulting from treatment failures and longer hospital stays from invasive procedures, high antibiotic usage and transmission of bacteria among patients due to inadequate infection control measures (Temesgen *et al.*, 2023). A study regarding the prevalence in pathogenic bacteria in patients with bacteremia from 1996 to 2016 in hospitals found an increase in the prevalence of Multidrug resistant (MDR) bacteria from 6.2% in 1997 to 2000 to 15.8% in 2013 to 2016 (Dewi et al., 2023). The increase includes Extended Spectrum b-lactamase (ESBL) producing bacteria, Carbapenem resistant *Enterobacteriaceae*, *Pseudomonas aeruginosa* and *Acinetobacter baumannii* (Dewi et al., 2023). Thorough research on the prevalent in bacterial profiles and patterns of antimicrobial sensitivity in blood culture specimen isolates from patients experiencing bacteremia can provide information that can be used in basic diagnostic

approaches and treatment strategies for patients (Dewi et al., 2023). The understanding of research outcomes will aid in personalizing treatment, improving prognosis and reducing the cost of health care (Bhat et al., 2021). The management of the infections is based on the use of appropriate empirical antimicrobial therapy with a comprehensive understanding of the encountered pathogens and antibiotic sensitivity (Bhat et al., 2021).

Human Immunodeficiency virus affects and weakens the immune system of the infected individual, leaving it exposed susceptible of opportunistic diseases (Kamara *et al.*, 2024). In 2019, about 38 million people were thought to be living with HIV globally, and 25.6 millions of these people are in Sub-Saharan Africa and South Africa contains the highest number of people living with HIV (Okon et al., 2023). HIV destroys the white blood cell lymphocyte subpopulations of CD4 T-cells and B-cells, therefore, this results in the body to lose its ability to defend itself against opportunistic pathogens (Okon et al., 2023). HIV infection causes changes in several lines of the host defences in the respiratory tract that contribute to an increased risk for pulmonary infection and its attending difficulties (Enitan Seyi et al., 2019). HIV and its related immunodeficiency increases the risk and mortality of bacterial infections (Archary et al., 2017), and bacterial infections in HIV positive patients could be severe, leading to prolonged hospital stay, admittance in Intensive Care Unit (ICU) or even result to mortality (Franceschini et al., 2020). HIV epidemic still remains a major cause of morbidity and mortality globally, especially in Sub-Saharan Africa due to co-infection with opportunistic infection (Okon et al., 2023). HIV positive people are at increased risk of hospital acquired infections due to their regular contacts with health care system through regular clinic visits and hospital admissions (Lubega et al., 2023). The continuous attack and elimination of the alveolar macrophages and CD4 cells in HIV positive people by the virus makes respiratory tract infection common among HIV infected patients and a wide range of opportunistic pathogens (bacteria, fungi, parasites and viruses), armed with variance virulent factors have been found to co-exist with each other (Enitan Seyi et al., 2019). *Streptococcus pneumoniae (S. pneumoniae)* and *Mycobacterium tuberculosis (M. tuberculosis)* are the most dangerous bacterial pathogens of respiratory tract infection in HIV positive patients and their prevalence depends on geographical region and the CD4 cell count in HIV patients (Enitan Seyi et al., 2019). (Tilahun *et al.*, 2023) conducted a study to assess bacteriology of community-acquired pneumonia in 6 health care facilities in Ethiopia, they mentioned that etiological differences are due to environmental contamination and the study observed 64% bacterial growth in rural facilities and 40.8% bacterial growth in urban facilities (Tilahun et al., 2023). People living with HIV (PLWH) have an improved quality of life since Antiretroviral therapy (ART) was introduced (Lubega et al., 2023). However, even in the era of combination of antiretroviral therapy (cART), respiratory tract infections are the major cause of morbidity and mortality among HIV positive patients (Kamara *et al.*, 2024) and when it comes to patients with HIV seropositivity, the infection rate differs from 3.9 to 20 infections per 100 people per year (Kamara *et al.*, 2024). About 70% of illness in HIV positive people are respiratory tract infections (Lubega *et al.*, 2023) and factors associated with these infections are low CD4 counts (<200 cells/µl) and detectable viral loads (Lubega et al., 2023). When HIV infection is untreated in a patient, the patient experience immune system deficits that results to deadly opportunistic infections like lower respiratory tract infection, however, when a patient initiates ART, the ART reduces the incidence of opportunistic infections by increasing the CD4 count to normal range, furthermore, clinicians use CD4 cells to monitor the effectiveness of antiretroviral treatment (ART) (Okon et al., 2023).
Lower respiratory tract infections are also the most common bacterial infections in immunocompromised patients that are in Intensive Care Unit, occurring in 10-25% of all ICU patients and resulting in high overall mortality which may range from 22-71% (Goel *et al.*, 2009). It is the most prevalent illness among HIV positive people in Sub-Saharan African nations (Kamara *et al.*; 2024). Diagnosing LRTI is done using GeneXpert MTB/RIF or sputum microscopy culture sensitivity (MCS) and the right diagnosis or identification of the pathogens causing LRTI and their antimicrobial susceptibility provide a great direction to health care givers for better management of the HIV patient (Okon et al., 2023). Bacterial, fungal, viral, mycobacterial and parasitic infections are all included in the broad spectrum of HIV associated opportunistic lower respiratory tract infections (LRTI) (Kamara *et al.*, 2024). LRTI is responsible for about 3 million deaths annually in all ages over the world and are the leading cause of mortality in low-income countries (Carrim et al., 2023). The most common bacterial agents in Lower respiratory tract infection are *Pseudomonas, Acinetobacter, Klebsiella, Citrobacter, Escherichia coli* (Goel *et al.*, 2009). In the study that was conducted by (Okon *et al.*, 2023) on sputum samples of

HIV positive patients, the rate of LRTI was higher among patients with CD4 cell of 201-300 cells/mm^3 (64.3%), while patient with CD4 cells above 301-400 cells/mm^3 (2:16.7%) had the lowest LRTI rate (Okon et al., 2023). Patients with viral load above 1000 copies/ml (45.1%) had the highest LRTI prevalence rate when compared with those that had viral load below 1000 copies/ml (1:10%) (Okon et al., 2023). The study further showed that Gram positive and Gram negative bacteria were mostly sensitive to Imipenem, 93.3% and 77.8%, respectively (Okon *et al.*, 2023), they further stated that Trimethoprim-sulfamethoxazole (40%) and Ceftriaxone (51.7%) were the highly resistant antibiotics by gram positive bacteria, while Gentamicin (44.4%), Azithromycin (33.3%) and lastly Trimethoprim-sulfamethoxazole (33.3%) were highly resisted antibiotics by gram positive bacteria (Okon et al., 2023). Respiratory diseases are responsible for more than 50% of all HIV related mortality in Sub-Saharan Africa and studies in Malawi, Zimbabwe and South Africa have estimated about 30% prevalence of Chronic Lung Disease (CLD) (Abotsi *et al.*, 2021), which is a contributing factor for HIV positive persons to be admitted in an ICU (Abotsi et al., 2021). Bacteria implicated in forms of HIV-associated CLDs such as bronchiectasis in people living with HIV include *S. pneumoniae, Staphylococcus aureus (S. aureus), Haemophilus influenzae (H. influenzae)* and *Moraxella catarrhalis* (Abotsi et al., 2021). *Streptococcus pneumoniae* is the leading bacterial cause of community acquired LRTI and the carriage is assumed to be a source of pneumococcal disease transmission through close contacts, therefore this is important in high human HIV prevalence settings because HIV positive people have high chances of developing severe pneumonia and have a higher mortality rate due to pneumonia when compared to HIV negative people (Carrim et al., 2023). *S. pneumoniae* was responsible for about 60% of bacterial pneumonia of adults who require hospitalization and the typical symptoms include cough, fever, chest pain and sputum production (Enitan Seyi et al., 2019). Bacterial pneumonia infection rate is ranged from 3.9 to 20 cases per 100 persons per year in HIV-seropositive patients (Alem, 2021). In immunocompromised patients, especially those that are HIV positive, pneumonia is a common opportunistic infection (Alem, 2021) and the most common bacterial opportunistic pathogens in the development of bacterial pneumonia are *Streptococcus pneumoniae, Haemophilus influenzae, Staphylococcus aureus* and *Mycobacterium tuberculosis* (Alem, 2021). Pneumococcal disease may occur at any time during the course of HIV-1 infection, even though, pneumococcal disease can be an early presentation of HIV-1 infection and its incidence spread as HIV-1 disease progress (Enitan Seyi et al., 2019). The incidence of pneumococcal disease was 50 times higher in children <2 years of age and in adults it is >65 years (Alem, 2021). A male: female ratio of 1.5-2:1 had been seen in most 80% of cases of bacterial pneumonia occur with a CD4 count, 400 cells per mm^3 and in recurrent pneumonia with a CD4 count of 300 cells per mm^3 (Alem, 2021). This study includes patients that are from the ages of 18 years and above, however, we also looked at the study that was conducted by (Abotsi et al., 2021), where they investigated the prevalence of these bacteria and their antibiotics susceptibility in children living with HIV recovered from nasopharyngeal (NP) swabs and sputa, the study discovered that in the CLD positive group, 67% of the swabs had at least one of the four bacteria species, while the CDL negative group had 39% (Abotsi *et al.*, 2021). (Kamara *et al.*, 2024), conducted a study in Uganda to check for bacterial isolates in the sputum of HIV positive patients that were having cough symptoms, bacterial growth was observed in 56/180 participants (31.1%) and the most prevalent organisms isolated in the study were *Staphylococcus aureus* (35.7%), followed by *Pseudomonas aeruginosa* (19.6%), *Streptococcus pneumoniae* (17.9%), *Klebsiella pneumoniae* (12.5%) and *Enterobacter* species (8.9%). (Kamara *et al.,* 2024), further discussed that *Staphylococcus aureus* was observed to be sensitive to Imipenem, Ceftriaxone and Chloramphenicol, however, it was resistant to Piperacillin-tazobactam. Furthermore, *Pseudomonas aeruginosa* was sensitive to Imipenem, ceftriaxone and ciprofloxacin, while *Enterobacter* species were sensitive to gentamicin and cefepime but resistant to ampicillin. Lastly, *Klebsiella pneumoniae* was sensitive to Imipenem but resistant to azithromycin (Kamara *et al.*, 2024). Factors that were associated with sputum culture positive among HIV positive patients in the study were age, education, viral load and peripheral oxygen saturation, therefore, an unsuppressed viral load ≥200 copies per millilitre of blood and low peripheral oxygen saturation of ≤94% on room air were independently linked with a sputum culture positive cough, which means that a patient with an unsuppressed viral load was 2.315 times likely to have a sputum culture positive cough when compared to the patients whose viral load was fully suppressed (Kamara *et al.,* 2024). A patient with low peripheral oxygen saturation was 2.448 times likely to have a sputum culture positive cough when compared to the patients with normal peripheral oxygen saturation (Kamara *et al.,* 2024). (Lubega *et al.*, 2023) conducted a study to check the susceptibility pattern of microbes isolated from respiratory samples taken from HIV positive

patients in Uganda, in their study, the isolated bacteria were *Moraxella* species (27.4%), *Streptococcus pneumoniae* (25.4%), *Haemophilus influenzae* (22.4%), *Mycobacterium* species (4.5%), *Pseudomonas* species (4%), *Staphylococcus aureus* (4%), *Escherichia coli* (1%) and other bacteria (10.4%) out of 201 samples that had bacterial growth. Most bacterial growth in their study were highly sensitive to amoxicillin + clavulanic acid and Ceftriaxone with *Moraxella sp.* and *S. pneumoniae* having 100% sensitivity to both antibiotics (Lubega et al., 2023). 100% sensitivity to Gentamycin was observed in *Pseudomonas* while *H. influenzae* had 100% sensitivity to Ceftriaxone and 88.6% sensitivity to amoxicillin + clavulanic acid (Lubega et al., 2023). Other bacteria showed high sensitivity to Ceftriaxone and Gentamycin with the rate of 85.7% (Lubega et al., 2023). All microorganisms had low sensitivity to Cotrimoxazole (<17%), while *Moroxella sp., H. influenzae* and *Pseudomonas* showed zero sensitivity to Cotrimoxazole (Lubega et al., 2023).The study further had low sensitivity towards erythromycin that was observed from *Moraxella sp.* (28.8%), *H. influenzae* (31.6%), *S. aureus* (42.9%) and other bacteria (42.9%) (Lubega et al., 2023). Ciprofloxacin showed low sensitivity in *H. influenzae* (50%) and other bacteria (69.2%) (Lubega *et al.*, 2023). In more resource limited areas, late stage diagnosis of HIV with associated opportunistic infections remain a common reason for ICU admission in developing countries (Ueckermann et al., 2022). The need for ICU admission and ventilation increases the mortality risk (Ueckermann et al., 2022). The mortality rates of HIV positive patients in Sub-Saharan Africa shows a huge variability in the practice and outcome among different hospitals (Ueckermann *et al.*, 2022). The risk factors for Bloodstream Infections in HIV positive people are high HIV-RNA, low CD4 cell counts and concomitant AIDS-defining conditions (Franceschini et al., 2020), however, some studies have proved that severe bacterial infections, still occurred at a high rate even in the absence of severe CD4 cell depletion (Shahcheraghi *et al.*, 2016). In the post combination antiretroviral treatment (cART) period, Persons Living With HIV (PLWH) are often admitted to ICU due to Blood Stream Infection (BSIs) than *Pneumocytostis jiroveci pneumonia* (Franceschini et al., 2020). Recent studies have shown that clinical manifestations of BSIs in PLWH are the same with those in HIV seronegative patients, however, the BSIs prevalence and mortality rate are often higher in HIV positive population (Franceschini et al., 2020). In the study conducted by (Franceschini et al., 2020), they described the BSI epidemiology in PLWH and they discovered that 34% of patients had more than one bacterial episode, they further discovered that 48% of the cases were community-acquired BSI, while 52% of the cases were hospital-acquired and 9% were polymicrobial (Franceschini et al., 2020). The study further elaborated that 82.8% of the cases were collected in the Internal Medicine Wards, 8% in ICU and 8.8% in surgical wards(Franceschini et al., 2020), while 27.4% of the BSI originated from the central indwelling caterers (4/9 in ICU, 40%) (Franceschini et al., 2020). Gram-positive bacteria have been reported to be more in ICU and medical wards, while Gram-negative bacteria were prevalent in surgical wards (Franceschini et al., 2020). The incidence of bacterial pneumonia in HIV positive people is higher than in people that are HIV negative (Alem, 2021). As mentioned earlier that the most prevalent pathogens that cause bacterial pneumonia in HIV positive patients include *Streptococcus pneumoniae, Haemophilus influenzae, Klebsiella pneumoniae, Pseudomonas aeruginosa, Staphylococcus aureus* and *Escherichia coli*, however, it has been reported that *S. pneumonia* is the most prevalent cause of pneumonia in HIV positive persons which accounts for 40 of all bacterial pneumonia (Alem, 2021). *Streptococcus pneumoniae* is the most common agent in HIV-infected adults which has been confirmed in various etiological studies from Africa (Shahcheraghi *et al.*, 2016). It is the most prevalent bacterial pathogen that causes pneumonia in HIV positive individuals, and implicated around 20% of all bacterial pneumonia, while *H. influenzae* accounts for 10-15% of cases of bacterial pneumonia in HIV positive patients (Alem, 2021). More than 60% bacterial pneumonia in adults are caused by *S. pneumoniae* and require hospitalization, in addition, the risk is higher in people whose CD4 lymphocyte counts less than 200 cells/µl (Alem, 2021). In HIV-infected adults, p*neumococcus* has been investigated to be implicated in 20% of bacterial pneumonia, 40% of Pneumonia with an identified organisms and 70% of pneumonia with positive blood cultures (Shahcheraghi *et al.*, 2016). The highest prevalence of pneumonia was 59.76% in HIV-seropositive patients in a study that was conducted in Tanzania (Alem, 2021). Studies that were conducted previously showed that bacterial pneumonia is the most common infection in HIV-seropositive patients, and the frequency of the infection is increased by >10 times than in healthy people (Alem, 2021). The risk factors of pneumonia development are common in both developed and developing counties and bacterial pneumonia may occur in the entire course of HIV infection but the incidence increases as CD4 cell counts decreases (Alem, 2021). Intravenous drugs and smoking are also risk factors for the development of bacterial pneumonia in HIV

positive patients (Alem, 2021), and smoking cigarettes are associated with a two-to-five fold increase in the risk, especially in patients with low CD4+ T cell counts (Alem, 2021). Age, gender, detectable viral load and recurrent pneumonia are also identified as risk factors (Alem, 2021). Bacterial pneumonia in HIV-seropositive patients is commonly persistent, and a persistent pneumonia is an AIDS-defining condition (Alem, 2021). *Escherichia coli* is the most common etiological agents of bacterial gastroenteritis in HIV- infected individuals, whose diseases presents with varying severity (Chabala et al., 2020). With the whole PLWH population in the study that was conducted by (Franceschini et al., 2020), *Enterobacteriaceae* were the most prevalent microbes with the rate of 29.8%, followed by Coagulase-Negative Staphylococci with the rate of 21.4% and *Staphylococcus aureus* with the rate of 12.7%. Non-fermenting Gram-negative bacteria were reported to be 12.4%, *Streptococci* with the rate of 8% and *Enterococci* with the rate of 7.4% (Franceschini et al., 2020). In the group of *Streptococci, S. pneumoniae* was the most prevalent pathogen at the rate of 54.8% and then followed by *S. viridans* at the rate of 20.8% (Franceschini et al., 2020). In the group of *Enterobacteriaceae, E. Coli* was the most prevalent microorganism at the rate of 55.7% then followed by *K. pneumoniae* at 21.6% and lastly *E. cloacae* at the rate of 9.1% (Franceschini et al., 2020). *E. Faecalis* was the most prevalent microbe among *Enterococci* with the rate of 11.50% followed by *E. faecium* with the rate of 45.5% (Franceschini et al., 2020). In the group of *Staphylococcus* bacteremia, Congulase-Negative *Staphylococci* were the most isolated (62.4%), *S. aureus* had 37.6% isolates (Franceschini et al., 2020). Enteric diseases are part of the primary causes of morbidity and mortality in developing countries (Marbou and Kuete, 2017). Enteric diseases represents the second most common cause of death after tuberculosis in HIV positive people in developing countries (Marbou and Kuete, 2017). Enteric pathogens like *Salmonella* and *Shigella* species have been described to be among the causative microbes of diarrhoea in people that are HIV positive or that have AIDS especially in low income or developing countries (Belay et al., 2020). About 90% occurrence of HIV/AIDS in adults and children in low income countries constant diarrhoea is affiliated with II-fold increase in mortality when compared to uninfected people (Belay et al., 2020). *Salmonellosis* is estimated to be about 20 times common and 5 times more bacteraemia in patients that have HIV/AIDS than those without the disease (Belay et al., 2020). Furthermore, in HIV positive adults, the rates of Gram-negative bacteria enteric infections are at least 10-fold higher than in general population and HIV infection increases the risk of *Salmonella* bacteraemia by 20-to-100 fold and mortality as high as 7-fold when compared to people that are HIV negative (Belay et al., 2020). Longer period on ART or low viral load are associated with reduced carriage for bacterial species (Abotsi *et al.*, 2021). Cotrimoxazole has been used as a prophylactic agent against opportunistic infections in HIV patients worldwide (Marwa *et al.*, 2015) and the current guidelines recommend the test and treat strategy, however, late presentation represents a high clinical problem in HIV infection and some microorganisms such as Non-typhoidal *Salmonella,* Mycobacteria and *Cryptococci* represent AIDS-defining conditions and they are strictly linked to late presentation (Franceschini et al., 2020). Previous studies have demonstrated a relationship between antibiotic consumption and the incidence of antimicrobial resistance in various bacterial infections (Marwa *et al.*, 2015). Studies have reported a much higher prevalence of drug-resistant bacteria in HIV positive patient (79%) compared to HIV negative patients (30%) (Lubega et al., 2023). (Archary et al., 2017), discovered that Gram-positive microorganisms were susceptible to most first-line antibiotics and resistance was more prevalent among Gram-negative microorganisms. A study that was done in Soweto, South Africa, reported high resistance of *K. Pneumoniae* and *S. aureus* to contrimozole among isolates from HIV infected patients (Marwa *et al.*, 2015). (Franceschini *et al.*, 2020) reported that majority of the patients in their study were on effective cART with the rate of 65.3%, however, 34.7% of patients with BSI had a virological failure, 25% and 13% of the patients showed HIV-RNA above 10 000 copies/mL and 100 000 copies/mL, respectively, while the median CD4 count at the moment of the episode was low (207 CD4/μL (Franceschini et al., 2020). (Franceschini et al., 2020), mentioned that 48% of patients died during the study, with a median survival duration of 28 days after the last episode of bacteraemia, furthermore, the 30-day mortality rate after the last episode was 24.2% while 90-day mortality rate was 32.4% and the mortality rate of MDR microorganisms were 33.3% and 46.9% at 30 and 90-days after the last bacterial episode, respectively (Franceschini et al., 2020).The mortality for BSI due to MDR microorganisms was higher than that observed in people without MDR at the rate of 44.7% versus 24.3%, respectively (Franceschini et al., 2020).

Mycobacterium tuberculosis causes a chronic infection of the lungs called Tuberculosis (TB) and it's characterized by slight fever, weight loss, sweating at night and chronic cough producing blood-stained sputum (Enitan Seyi et al., 2019). Tuberculosis is a deadly disease despite the novel advances in its diagnosis tools and drug therapy (Gashaw et al., 2021). Factors that contributes to the high prevalence of tuberculosis in developing countries and difficulties in its control include co-infection with HIV, emergence of multi-drug resistant tuberculosis, inadequate treatment, continuing poverty, malnutrition, overcrowding and increasing numbers of displaced persons (Enitan Seyi et al., 2019). Almost 10% of new TB cases are HIV positive globally, however, this number varies on a country basis and can be as high as 80% (Enitan Seyi et al., 2019). Tuberculosis has been a major co-morbidity in HIV positive individuals since the beginning of the HIV epidemic (Enitan Seyi et al., 2019), and the emergence of HIV in South Africa has resulted in a huge rise in the incidence of Tuberculosis (Cohen *et al.*, 2010). The risk of developing TB is 5% to 10% if HIV negative and 50% in HIV positive people and this results in difficulty for health systems to keep up with the increasing demands for health services for both diseases (Enitan Seyi et al., 2019). TB and HIV co-infection form a lethal combination, and each accelerates each other's progress and without TB treatment, one in three people infected with HIV will develop TB (Enitan Seyi et al., 2019). TB is difficult to diagnose and progress faster in HIV positive people and in HIV positive, TB is certain to be rapidly fatal if undiagnosed or is untreated (Enitan Seyi et al., 2019). The two diseases constitute a deadly combination together as they are extra destructive than when a patient is infected with one disease (Seyi et al., 2019). A systemic review of previous studies recorded that hospital admissions in HIV positive patients reported that community acquired pneumonia and tuberculosis accounted for 57% of in-patient death globally (Owusu et al., 2024). Tuberculosis is mostly implicated in HIV associated pneumonia, however, information on the role of other bacterial and viral pathogens is not much in many developing countries (Owusu *et al.*, 2024) and the risk of mortality in hospitalized patients is believed to be higher due to limited diagnosis of microbial aetiologies of pneumonia (Owusu *et al.*, 2024). An estimation from the World Health Organization (WHO) is that TB causes about 40% of AIDS death in Sub-Saharan Africa and Southeast Asia (Enitan Seyi et al., 2019). About 80% of incident TB cases in South Africa are HIV-seropositive (Cohen *et al.*, 2010). Pulmonary infection is the most common immunodeficiency virus affiliated illness with complication in the period of antiretroviral therapy (ART) (Owusu et al., 2024). Mixed pulmonary infections with two or more pathogens are common in HIV positive patients and they often present diagnostic difficulties for doctors and resulting in potentially serious consequences for the patient if it is unrecognized (Enitan Seyi et al., 2019). ART has prompted in a reduction of the rate of respiratory disorders, including tuberculosis (Mushunje *et al.,* 2024). In 2019, about 2.8 million children and adolescents were living with HIV globally and 90% was recorded in Sub-Saharan Africa and respiratory infections remain the major popular manifestation of HIV among children and adolescents (Mushunje *et al.,* 2024). Pulmonary tuberculosis has been reported to be increasing in children that were diagnosed with pneumonia, furthermore, culture confirmed TB has been reported in 8% of South African children hospitalized with acute pneumonia with no difference by HIV status of the patient (Dube et al., 2016). Studies in Sub-Saharan Africa reported that nearly 30% of HIV positive older children experience chronic respiratory symptoms that include cough and reduced tolerance to exercise, which often results to presumptive Tuberculosis treatment (Mushunje *et al.,* 2024). There are few published data on the role of other respiratory organisms in patients that are suspected to have TB, however, in Africa, there was a study conducted in Botswana that reported microbiologically confirmed TB in 52%, *Mycoplasma pneumonia* infection in 17% and *Pneumocystics jirovecii* infection in 3% of PTB adults suspects (Dube et al., 2016). (Dube *et al.*, 2016), conducted a study to investigate the respiratory pathogen in nasopharynx (NP) of children that were hospitalized with suspected TB, and in the study, 16% of the children were TB positive and 13% of the children were HIV infected with similar HIV prevalence by TB category (Dube et al., 2016). The most common bacteria detected in NP were *Moxaxella catarrhalis* (64%), *S. Pneumonia* (42%), *H. influenzae* spp (29%) and *Staphylococcus aureus* (22%) (Dube et al., 2016), however, *M. pneumoniae* (9%), *B. pertussis*(7%) and *C. pneumoniae* (4%) were detected less prevalent in the study (Dube et al., 2016). The most detected viral agents were *human metapneumovirus* (hMPV) (19%), *rhinovirus* (15%), *influenza C virus* (9%) *adenovirus* (7%) and *Coronavirus* O43 (5.6%) (Dube et al., 2016). Furthermore, seasonal patterns were observed when it comes to hMPV, *rhinovirus, enterovirus* and influenza viruses with peak prevalence in late winter (August) and spring (November) (Dube et al., 2016). The study conducted by (Dube et al., 2016), further detailed that bacteria alone was detected on 40% of samples, viruses alone were detected in 5% of samples

and both bacteria and virus were detected in 55% of the samples, furthermore, children that were diagnosed with TB, both bacterial and viral targets were detected with the rate of 71% (Dube et al., 2016). In the cohort study that was conducted by (Ueckermann et al., 2022), pulmonary tuberculosis was diagnosed in 33%(41/117) patients while *P. jirovecii* was the associated pathogen in 21.4% (25/117) patients. (Ueckermann et al., 2022),reported that in their study, 22 sputum and BAL cultures revealed other bacteria as the aetiology for pneumonia, which includes *Psudomonas aeruginosa* 45% (9/20), *Streptococcus pneumoniae* 30% (6/20), *Klepsiella pneumoniae* 20% (4/20) and *Staphylococcus aureus* 5% (1/20) (Ueckermann et al., 2022). 52% (61/117) patients in the study required admission to ICU and the in-hospital mortality rate was 40.2% (47/117) (Ueckermann et al., 2022). (Ueckermann *et al.*, 2022) mentioned that in their study, the mean CD4 count of those with TB was lower than those without TB and some patients are diagnosed with HIV during the presenting admission and late diagnosis of HIV has been shown to be a risk factor for admission in the ICU (Ueckermann et al., 2022). Patients on Highly Active Antiretroviral Therapy (HAART) in the study conducted by (Ueckermann *et al.*, 2022) were more likely to survive than those who were not, 38.6% of survivors were on HAART compared to 31% of non-survivors. Patients with TB admitted to ICU had a high mortality rate of 33% to 67% and a South African study in patients with TB admitted in ICU showed that 53% of patients were co-infected with HIV and the mortality was 59% (Ueckermann *et al.*, 2022). The co-infection of *S. pneumoniae* and *M. tuberculosis* is regarded as defining disease of Acquired Immunodeficiency Syndrome and their establishment in a person depends on if certain conditions are favourable such as smoking, crowded environment, use of drugs and use of steroids as low CD4 cell count in patients may be indicated by *Streptococcus pneumoniae* and *Mycobacterium tuberculosis* co-infection in HIV positive patients (Enitan Seyi et al., 2019). *Streptococcus pneumoniae* and *Mycobacterium tuberculosis* are the two most common cause of co-infection in HIV-seropositive patients in Sub-Saharan Africa and highly contribute to the mortality and morbidity rates of HIV/AIDS globally, they further have similar clinical features and radiological appearances (Enitan Seyi et al., 2019). (Seyi et al., 2019), conducted a study on the prevalence of *Streptococcus pneumoniae* and *Mycobacterium tuberculosis* co-infection in HIV positive adult patients that were on Highly Active Antiretroviral Therapy (HAART) in Nigeria, they reported a prevalence rate of 8.8% (*Streptococcus pneumoniae* mono infection), 21.5% (*Mycobacterium tuberculosis* mono infection) and 2.7% (*Streptococcus pneumoniae* and *Mycobacterium tuberculosis* co-infection) among 260 patients. Antimicrobial susceptibility testing is important in prescribing an effective drug regime for TB patients, especially in areas where drug resistance is high (Gashaw et al., 2021). The global mortality rate of TB is reducing by 3% annually, however, the threat of its drug resistance is increasing (Gashaw et al., 2021). The cumulative effects of treatment interruption like lack of awareness about the nature of the bacteria, shortage and lack of WHO's recommended diagnostic tools and prolonged drug consumption period for treatment increases the risk (Gashaw et al., 2021).

As mentioned previously, microbial infections cause a high mortality rate in immunocompromised patients, therefore the study will also look at the mortality rate caused by opportunistic microorganisms globally. Infections due to *Campylobacter* are one of the most common causes of bacterial enteritis globally and there are about 1.3 million cases of *Campylobacter* infections reported each year (Sunnerhagen et al., 2024;Baek et al., 2024), however, the cases reduced in 2020 when social distancing measures were implemented during the new Coronavirus disease 2019 pandemic in some countries such as United States and Spain (Baek *et al.*, 2024). The disease usually comprises abdominal pain, fever and watery or bloody stools (Sunnerhagen et al., 2024). Bloodstream infection with *Campylobacter* species has been commonly reported in immunocompromised patients (Nielsen *et al.*, 2010). The mortality rate associated with *Campylobacter* bacteremia is estimated to range from 2.5% to 15% (Sunnerhagen et al., 2024). (Sunnerhagen et al., 2024), reported that a study that was conducted in France observed that *Campylobacter* bacteremia most often occurs in immunocompromised cases with a 30-day mortality rate of 11.7% (Sunnerhagen et al., 2024). (Zayet *et al.*, 2023), reported that in France, *Campylobacter fetus* is the most common isolated *Campylobacter* species after *Campylobacter jejini* and *Campylobacter coli*, therefore, the risk for death from *Campylobacter fetus* systemic infection are a huge concern for clinicians as the fatality rate is about 15% (Zayet *et al.*, 2023). A study conducted by (Baek *et al.*, 2024), showed that in-hospital mortality occurred at the rate of 13% and the risk factors associated with in-hospital mortality were male sex, cancer, liver disease and septic shock.

Clostridium difficile is among the normal flora of the gastrointestinal tract, however, it becomes pathogenic if the normal intestinal flora is disturbed (Seugendo *et al.*, 2015). It is the most common cause of infectious diarrhoea in North America and Europe (Olanipekun et al., 2016). There are few studies that have been done on the *Clostridium difficile* prevalence in Sub-Saharan Africa and the prevalence rate of *Clostridium difficile* infection in Sub-Saharan Africa from previous studies has been reported to range between 4% to 43% (Seugendo *et al.*, 2015). Zimbabwe reported a prevalence rate of *C. difficile* infection of 8.6% (Seugendo *et al.*, 2015). (Seugendo *et al.*, 2015) further stated that HIV positive individuals were significantly more positive for *C. difficile* than individuals that are HIV negative. A study conducted by (Solanki *et al.*, 2021) showed that the mortality rate was higher in *C. difficile* hospitalization with the rate of 6.1% than the mortality rate due to all other hospitalization (1.9%), furthermore, *C. difficile* patients were more than two times at major chances of dying (Solanki *et al.*, 2021). *Escherichia coli* is part of the normal commensal gut of microbes in a healthy human being, however, some of the strains can cause intestinal or extraintestinal infections due to specific virulence factors (Daga *et al.*, 2019). (Tao et al., 2020) stated that in the study that they conducted, the mortality rate cohort was 21.3% which is similar to the mortality rates reported by other researchers from the rate of 10.3 to 33.3%. (Daga *et al.*, 2019) stated that the mortality associated with bacteremia due to *E. coli* was 33.3%. *Pseudomonas aeruginosa* is the third frequently identified gram-negative microorganisms that cause bloodstream infection (BSI) and it carries a very high mortality rate (Ioannou *et al.*, 2023). The prevalence of *P. aeruginosa* in Europe is 6.1%, which is like Spain at the rate of 5.9% (Callejas-Díaz et al., 2019). Previous studies have shown that *P. aeruginosa* bacteraemia could trigger severe septic shock and multiple organ failure which result in high mortality rate and substantial medical costs (Zhang *et al.*, 2020). In some hospital settings, such as in Intensive Care units, the rate of *Pseudomonas* species isolation as pathogens that causes bloodstream infection is reported to be higher (Ioannou *et al.*, 2023). (Gomes *et al.*, 2011) noted that the high mortality rates in the study that they conducted demonstrated the burden of multi-resistant *Pseudomonas aeruginosa* infections in immunocompromised patients. In a study that was conducted in India, 48.2% of 593 blood cultures were determined to be positive for *P. aeruginosa* and 63.6% of which were multidrug resistance (de Matos *et al.*, 2018). *P. aeruginosa* usually cause multi-site infections, of which bacteremia is fatal, with the mortality rate ranging from 18% to 61% (Zhang *et al.*, 2020). The mortality rate is estimated to be 30% after 30 days from the BSI episode (Ioannou et al., 2023; Callejas-Díaz et al., 2019;Ferreiro et al., 2017). . (Callejas-Díaz *et al.*, 2019) stated that in their study, the overall mortality was 37.3%, while the mortality directly caused by bacteremia was 29.1%. (Callejas-Díaz *et al.*, 2019) further stated that the mortality was higher during the first days after bacteremia onset. Before the Covid-19 era, bacterial infections represented one of the leading causes of death (Bongiovanni and Barda, 2023), furthermore, (Bongiovanni and Barda, 2023) stated that the global mortality in 2019 was associated with 33 bacterial pathogens and *P. aeruginosa* was responsible for more than 50% of the overall cases of death.

Staphylococcus aureus is the second major cause of bloodstream infections (Bello-Chavolla *et al.*, 2018). A person that has a chronic illness may interact with the health care system on a regular basis than those in general population, and physicians may be more likely to admit a patient that is immunocompromised on suspicions of infection compared to patients that don't have chronic diseases (Smit et al., 2016). *S. aureus* Bacteremia (SAB) is the most serious cases in *S. aureus* infections and is related to mortality rates between 15-60% (Li et al., 2021). The general 30-day mortality of MRSA BSIs is between 16 to 44% in general hospital population (Li et al., 2021). (Boison *et al.*, 2022), reported that in Ghana, there have been reports of *S. aureus* and MRSA carriage prevalence, although the prevalence of *S. aureus* and MRSA carriage was found to be 13.9% and 13%, respectively, among inpatients and they were found to be 44.9% and 5.6%, respectively, among HIV- infected individuals (Boison et al., 2022). (Kang *et al.*, 2012), reported that the mortality rate of *S. aureus* bacteremia in their study of cancer patients was about 50%, they further concluded that the results in their study indicate that *S. aureus* continues to be a significant cause of invasive infection in cancer patients and Methicillin resistance was found in more than 50% of the cases. A study conducted by (Li *et al.*, 2021) in cancer patients reported that the 60-day mortality in adult cancer patients with MRSA BSIs was 12% and the 6-month overall mortality was 43.2% (Cusumano et al., 2020), conducted a study about Covid-19, and *S. aureus* has been described as the primary causative pathogen of secondary bacterial infections, therefore, onset of secondary bacterial infections with influenza is seen within

the first 6 days of influenza infection when viral shedding is the highest (Cusumano et al., 2020). Bacteria has been associated with mortality that ranges to 50% compared with 1.4% in patients with influenza but without bacteremia (Cusumano et al., 2020), Cusumano et al., 2020), reported that in the study that they conducted during Covid-19 era, the 14 day hospital mortality rate from the first positive blood culture was 54.8%, while the 30 day hospital mortality rate was 66.7%. (Smit et al., 2016), also stated that *S. aureus* bacteremia has a 30-day mortality that ranges between 20-40% in developed countries and patients with Diabetes Mellitus (DM) experience higher mortality from *S. aureus* bacteremia when compared to patients without Diabetes Mellitus because of their decreased immunity (Smit et al., 2016). (Smit et al., 2016), study reported that a thirty-day cumulative mortality was 25.8% in patients with DM and about 24.3% in patients without DM, therefore patients with DM experienced no increased risk of dying within 30 days of blood culture when compared to patients without DM. *Enterobacteriaceae* are the most observed hospital acquired drug resistant gram-negative bacteria (Alkofide *et al.*, 2020) and drug resistance GNB differs from one hospital to another (Alkofide *et al.*, 2020). Multi-drug resistant *Enterobacteriaceae* (MRDE) infections are associated with poor outcome and high cases of mortality rates, especially in low- and middle-income countries (Ballot et al., 2019).

Enterobacteriaceae are the most observed hospital acquired drug resistant gram-negative bacteria (Alkofide *et al.*, 2020) and drug resistance GNB differs from one hospital to another (Alkofide *et al.*, 2020). Multi-drug resistant *Enterobacteriaceae* (MRDE) infections are associated with poor outcome and high cases of mortality rates, especially in low- and middle-income countries (Ballot et al., 2019). Studies that were conducted in Africa showed that ESBL-E prevalence rate is increasing and it varies from 0.7% in Malawi to 75.8% in Egypt (Ndir et al., 2016), however, the burden of ESBL-E has not been clearly established in Sub-Saharan African countries (Ndir et al., 2016). (Ndir *et al.*, 2016) reported that sixty-nine (37.1%) patients with an infection caused be *Enterobacteriaceae* died during their study period, furthermore, the case fatality rate was higher in ESBL positive patients with the rate of 47.3% compared to ESBL negative patients with the rate of 22.4% (Ndir et al., 2016). In the study conducted by (Alkofide *et al.*, 2020), in the total of 227 *Enterobacteriaceae* cultures identified, 130 (57.3%) were MDR and 8 (3.5%) were XDR cultures and there were no PDR cultures isolated. (Alkofide *et al.*, 2020) mentioned that about 84.1% (116/138) mortality was reported during the hospital stay. Sabino *et al.*, 2019 evaluated the epidemiology of Carbapenem-resistant *Enterobacteriaceae* (CRE) infections in patients with sepsis and organ dysfunction or septic shock, they further compared the bacteria presenting different resistance phenotypes and CRE infections were the ones with higher 30-day mortality with the following rates; CRE (63.8%), Carbapenem-resistant non-fermentative Gram-negative bacteria (60.7), ESBL-producing *Enterobacteriaceae* (36.4%), MRSA (33.3%) and other pathogens (31.6%) (Sabino et al., 2019).

GAPS IN SUB-SAHARAN AFRICAN COUNTRIES

South Africa is one of the developing countries in sub-Saharan countries with many people suffering from TB (87%) and HIV (7.9 million) (Matakanye *et.al.,* 2021; Inbarani et al., 2022). Microorganisms such as bacteria, fungi, viruses and parasites cause opportunistic infections in immunocompromised people and that results in a huge challenge for the healthcare system with an increase in morbidities, mortalities and cost of healthcare (Nazeerah *et al.*, 2022). Early diagnosis and treatments of microorganisms in immunocompromised patients are important to reducing morbidity and mortality rate. Gaps exist regarding the scientific documentation about the prevalence of microorganisms that infect hospitalized patients and their antibiotic susceptibility in the different regional/provincial hospitals of the Free state and Northern Cape province of South Africa. This calls for scientific studies in the sub-Saharan countries and globally to have diseases monitoring and drugs surveillance so that we are better informed for any emerging or reemerging of infections.

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REFERENCES

1. Abotsi, R. E., Nicol, M. P., McHugh, G., Simms, V., Rehman, A. M., Barthus, C., Mbhele, S., Moyo, B. W., Ngwira, L. G., Mujuru, H., Makamure, B., Mayini, J., Odland, J., Ferrand, R. A., & Dube, F. S. (2021). Prevalence and antimicrobial resistance profiles of respiratory microbial flora in African children with HIV-associated chronic lung disease. BMC Infectious Diseases, 21(1). https://doi.org/10.1186/s12879-021-05904-3
2. Alem, K. (2021). Prevalence of bacterial pneumonia among HIV-Seropositive patients in East Africa: Review. Cogent Medicine, 8(1). https://doi.org/10.1080/2331205x.2021.2015883
3. Alkofide, H., Alhammad, A. M., Alruwaili, A., Aldemerdash, A., Almangour, T. A., Alsuwayegh, A., Almoqbel, D., Albati, A., Alsaud, A., & Enani, M. (2020). Multidrug-resistant and extensively drugresistant enterobacteriaceae: Prevalence, treatments, and outcomes – a retrospective cohort study. Infection and Drug Resistance, 13. https://doi.org/10.2147/IDR.S283488
4. Archary, M., Adler, H., La Russa, P., Mahabeer, P., & Bobat, R. A. (2017). Bacterial infections in HIV-infected children admitted with severe acute malnutrition in Durban, South Africa. Paediatrics and International Child Health, 37(1). https://doi.org/10.1080/20469047.2016.1198561
5. Baek, Y. J., Song, J. E., Kim, E. J., Choi, H., Sohn, Y., Jeon, Y. D., Lee, E. H., Ahn, J. Y., Jeong, S. J., Ku, N. S., Choi, J. Y., Yeom, J. S., Song, Y. G., & Kim, J. H. (2024). Trends, clinical characteristics, antimicrobial susceptibility patterns, and outcomes of Campylobacter bacteraemia: a multicentre retrospective study. Infection, 52(3). https://doi.org/10.1007/s15010-023-02118-4
6. Ballot, D. E., Bandini, R., Nana, T., Bosman, N., Thomas, T., Davies, V. A., Cooper, P. A., Mer, M., & Lipman, J. (2019). A review of -multidrug-resistant Enterobacteriaceae in a neonatal unit in Johannesburg, South Africa. BMC Pediatrics, 19(1). https://doi.org/10.1186/s12887-019-1709-y
7. Belay, A., Ashagrie, M., Seyoum, B., Alemu, M., & Tsegaye, A. (2020). Prevalence of enteric pathogens, intestinal parasites and resistance profile of bacterial isolates among HIV infected and non-infected diarrheic patients in Dessie Town, Northeast Ethiopia. PLoS ONE, 15(12 December). https://doi.org/10.1371/journal.pone.0243479
8. Bello-Chavolla, O. Y., Bahena-Lopez, J. P., Garciadiego-Fosass, P., Volkow, P., Garcia-Horton, A., Velazquez-Acosta, C., & Vilar-Compte, D. (2018). Bloodstream infection caused by S. aureus in patients with cancer: a 10-year longitudinal single-center study. Supportive Care in Cancer, 26(12). https://doi.org/10.1007/s00520-018-4275-1
9. Bhat, S., Muthunatarajan, S., Mulki, S. S., Archana Bhat, K., & Kotian, K. H. (2021). Bacterial Infection among Cancer Patients: Analysis of Isolates and Antibiotic Sensitivity Pattern. International Journal of Microbiology, 2021, 1–7. https://doi.org/10.1155/2021/8883700
10. Blot, S. (2008) 'Limiting the attributable mortality of nosocomial infection and multidrug resistance in intensive care units', Clinical Microbiology and Infection. Available at: https://doi.org/10.1111/j.1469-0691.2007.01835.x.
11. Boison, D., Akwetey, S. A., Osei, S. A., Kelechi, S., & Barnie, P. A. (2022). Nasal colonization of methicillin-resistant Staphylococcus aureus in HIV-infected patients at the Cape Coast Teaching Hospital, Ghana. Frontiers in Tropical Diseases, 3. https://doi.org/10.3389/fitd.2022.976567
12. Bongiovanni, M., & Barda, B. (2023). Pseudomonas aeruginosa Bloodstream Infections in SARS-CoV-2 Infected Patients: A Systematic Review. In Journal of Clinical Medicine (Vol. 12, Issue 6). https://doi.org/10.3390/jcm12062252
13. Callejas-Díaz, A., Fernández-Pérez, C., Ramos-Martínez, A., Múñez-Rubio, E., Sánchez-Romero, I., & Vargas Núñez, J. A. (2019). Impact of Pseudomonas aeruginosa bacteraemia in a tertiary hospital: Mortality and prognostic factors. Medicina Clinica, 152(3). https://doi.org/10.1016/j.medcli.2018.04.020
14. Carrim, M., Tempia, S., Thindwa, D., Martinson, N. A., Kahn, K., Flasche, S., Hellferscee, O., Treurnicht, F. K., McMorrow, M. L., Moyes, J., Mkhencele, T., Mathunjwa, A., Kleynhans, J., Lebina, L., Mothlaoleng, K., Wafawanaka, F., Gómez-Olive, F. X., Cohen, C., Von Gottberg, A., & Wolter, N. (2023). Unmasking Pneumococcal Carriage in a High Human Immunodeficiency Virus (HIV) Prevalence Population in two Community Cohorts in South Africa, 2016-2018: The PHIRST Study. Clinical Infectious Diseases, 76(3). https://doi.org/10.1093/cid/ciac499
15. Cerini, P., Meduri, F. R., Tomassetti, F., Polidori, I., Brugneti, M., Nicolai, E., Bernardini, S., Pieri, M., & Broccolo, F. (2023). Trends in Antibiotic Resistance of Nosocomial and Community-Acquired Infections in Italy. Antibiotics, 12(4). https://doi.org/10.3390/antibiotics12040651
16. Chabala, F., Madubasi, M., Mutengo, M. M., Banda, N., Yamba, K., & Kaonga, P. (2020). Escherichia coli antimicrobial susceptibility reduction amongst HIV-infected individuals at the University Teaching Hospital, Lusaka, Zambia. International Journal of Environmental Research and Public Health, 17(10). https://doi.org/10.3390/ijerph17103355

17. Cohen, T., Murray, M., Wallengren, K., Alvarez, G. G., Samuel, E. Y., & Wilson, D. (2010). The prevalence and drug sensitivity of tuberculosis among patients dying in hospital in kwazulu-natal, South Africa: A postmortem study. PLoS Medicine, 7(6). https://doi.org/10.1371/journal.pmed.1000296
18. Cusumano, J. A., Dupper, A. C., Malik, Y., Gavioli, E. M., Banga, J., Berbel Caban, A., Nadkarni, D., Obla, A., Vasa, C. V., Mazo, D., & Altman, D. R. (2020). Staphylococcus aureus Bacteremia in Patients Infected with COVID-19: A Case Series. Open Forum Infectious Diseases, 7(11). https://doi.org/10.1093/ofid/ofaa518
19. Daga, A. P., Koga, V. L., Soncini, J. G. M., De Matos, C. M., Perugini, M. R. E., Pelisson, M., Kobayashi, R. K. T., & Vespero, E. C. (2019). Escherichia coli Bloodstream Infections in Patients at a University Hospital: Virulence factors and clinical characteristics. Frontiers in Cellular and Infection Microbiology, 9(JUN). https://doi.org/10.3389/fcimb.2019.00191
20. de Matos, E. C. O., Andriolo, R. B., Rodrigues, Y. C., de Lima, P. D. L., Carneiro, I. C. do R. S., & Lima, K. V. B. (2018). Mortality in patients with multidrug-resistant Pseudomonas aeruginosa infections: A meta-analysis. In Revista da Sociedade Brasileira de Medicina Tropical (Vol. 51, Issue 4). https://doi.org/10.1590/0037-8682-0506-2017
21. Dewi N. A. P. T. T., Mertaniasih N.M., Semedi N. B. P., Manik, N. and Koendhori, N.E.B. (2023). Bacterial profile and antimicrobial sensitivity pattern of blood specimen isolates in patients with bacteremia in the intensive care unit at Dr. Soetomo Hospital. Bali Medical Journal, 13(1), pp.148–153. doi:https://doi.org/10.15562/bmj.v13i1.4967.
22. Dube, F. S., Kaba, M., Robberts, F. J. L., Tow, L. A., Lubbe, S., Zar, H. J., & Nicol, M. P. (2016). Respiratory microbes present in the nasopharynx of children hospitalised with suspected pulmonary tuberculosis in Cape Town, South Africa. BMC Infectious Diseases, 16(1). https://doi.org/10.1186/s12879-016-1934-z
23. Enitan, Seyi, S., Adekunbi Oluyemisi, A., Ihonge John, C., & Olumide, A. (2019). Prevalence of Streptococcus Pneumoniae and Mycobacterium Tuberculosis Co-Infection among HIV Infected Adult Patients on HAART in Ogun State, Nigeria. International Journal of Virology and AIDS, 6(1). https://doi.org/10.23937/2469-567x/1510048
24. Ferreiro, J. L. L., Otero, J. Á., González, L. G., Lamazares, L. N., Blanco, A. A., Sanjurjo, J. R. B., Conde, I. R., Soneira, M. F., & De La Fuente Aguado, J. (2017). Pseudomonas aeruginosa urinary tract infections in hospitalized patients: Mortality and prognostic factors. PLoS ONE, 12(5). https://doi.org/10.1371/journal.pone.0178178
25. Franceschini, E., Santoro, A., Menozzi, M., Bacca, E., Venturelli, C., Zona, S., Bedini, A., Digaetano, M., Puzzolante, C., Meschiari, M., Cuomo, G., Orlando, G., Sarti, M., Guaraldi, G., Cozzi-Lepri, A., & Mussini, C. (2020). Epidemiology and outcomes of bloodstream infections in hiv-patients during a 13-year period. Microorganisms, 8(8). https://doi.org/10.3390/microorganisms8081210
26. Gashaw, F., Erko, B., Mekonnen, Y., Yenew, B., Amare, M., Gumi, B., & Ameni, G. (2021). Phenotypic and genotypic drug sensitivity profiles of Mycobacterium tuberculosis infection and associated factors in northeastern Ethiopia. BMC Infectious Diseases, 21(1). https://doi.org/10.1186/s12879-021-05961-8
27. Goel, N., Chaudhary, U., Aggarwal, R., & Bala, K. (2009). Antibiotic sensitivity pattern of gram negative bacilli isolated from the lower respiratory tract of ventilated patients in the intensive care unit. Indian Journal of Critical Care Medicine, 13(3). https://doi.org/10.4103/0972-5229.58540
28. Gomes, M. Z. R., Machado, C. R., De Souza da Conceição, M., Ortega, J. A., Neves, S. M. F. M., Da Silva Lourenço, M. C., & Asensi, M. D. (2011). Outbreaks, persistence, and high mortality rates of multiresistant Pseudomonas aeruginosa infections in a hospital with AIDS-predominant admissions. Brazilian Journal of Infectious Diseases, 15(4). https://doi.org/10.1016/S1413-8670(11)70198-2
29. Inbarani, N., Sinovuyo, T., Ronel, S., Sean, J., Zhou, S., Goitseone, M., Sizulu, M., Khangelani, Z., Musawenkosi, M. and Zungu, N. (2022). Past and current status of adolescents living with HIV in South Africa, 2005–2017. BMC Research Notes, 15(1). doi:https://doi.org/10.1186/s13104-022-06006-2.
30. Ioannou, P., Alexakis, K., Maraki, S., & Kofteridis, D. P. (2023). Pseudomonas Bacteremia in a Tertiary Hospital and Factors Associated with Mortality. Antibiotics, 12(4). https://doi.org/10.3390/antibiotics12040670
31. Javeri. J.R, Patel, S.M., Nayak, N. S., Kanan, D., & Parul, P. (2012). A Study on Bacteriological profile and Drug Sensitivity and Resistance Pattern of Isolates of the Patients Admitted in Intesive Care Units of a Tertiary Care Hospital in Ahmadabad. National Journal of Medical Research, 2(3).
32. Kamara,T.S., Banturaki, A., Ssenkumba, B., Pius, T., & Akaba, K. (2024) Bacterial Profile, Susceptibility Patterns, and Factors Associated with Culture-Positive Sputum Among HIV Patients Presenting with a Cough in Northern Uganda, HIV/AIDS - Research and Palliative Care, 16:, 355-366, DOI: 10.2147/HIV.S477096
33. Kang, C. I., Song, J. H., Ko, K. S., Chung, D. R., & Peck, K. R. (2012). Clinical features and outcomes of Staphylococcus aureus infections in non-neutropenic cancer patients. Supportive Care in Cancer, 20(3). https://doi.org/10.1007/s00520-011-1100-5
34. Katarzyna G., and Błaszkowska, J. (2015). Parasites and fungi as risk factors for human and animal health. PubMed, 61(4), pp.207–20. doi:https://doi.org/10.17420/ap6104.10.

35. Li, Z., Zhuang, H., Wang, G., Wang, H., & Dong, Y. (2021). Prevalence, predictors, and mortality of bloodstream infections due to methicillin-resistant Staphylococcus aureus in patients with malignancy: systemic review and meta-analysis. BMC Infectious Diseases, 21(1). https://doi.org/10.1186/s12879-021-05763-y
36. Lubega, G., Abaasa, A., Ochola, W., Kikaire, B., Lutaakome, J., Rugazira, E., & Mayanja, Y. (2023). The bacterial profile and antibiotic susceptibility pattern in respiratory tract samples from art-experienced HIV-positive adults in Uganda. PLoS ONE, 18(8 August). https://doi.org/10.1371/journal.pone.0282936
37. Marbou, W. J. T., & Kuete, V. (2017). Bacterial resistance and immunological profiles in HIV-infected and non-infected patients at Mbouda AD LUCEM Hospital in Cameroon. Journal of Infection and Public Health, 10(3). https://doi.org/10.1016/j.jiph.2016.04.009
38. Marwa, K. J., Mushi, M. F., Konje, E., Alele, P. E., Kidola, J., & Mirambo, M. M. (2015). Resistance to cotrimoxazole and other antimicrobials among isolates from HIV/AIDS and Non-HIV/AIDS patients at bugando medical centre, Mwanza, Tanzania. AIDS Research and Treatment, 2015. https://doi.org/10.1155/2015/103874
39. Matakanye, H., Tshitangano, T.G., Mabunda, J.T. and Maluleke, T.X. (2021). Knowledge, Beliefs, and Perceptions of TB and Its Treatment amongst TB Patients in the Limpopo Province, South Africa. International Journal of Environmental Research and Public Health, 18(19), p.10404. doi:https://doi.org/10.3390/ijerph181910404.
40. Mbim, E., Mboto, C. and Agbo, B. (2016). A Review of Nosocomial Infections in Sub-Saharan Africa. British Microbiology Research Journal, 15(1), pp.1–11. doi:https://doi.org/10.9734/bmrj/2016/25895.
41. Mushunje, P. K., Dube, F. S., Olwagen, C., Madhi, S., Odland, J. Ø., Ferrand, R. A., Nicol, M. P., Abotsi, R. E., & Breathe Study Team (2024). Characterization of bacterial and viral pathogens in the respiratory tract of children with HIV-associated chronic lung disease: a case-control study. BMC Infectious Diseases, 24(1), 637. Article 637. https://doi.org/10.1186/s12879-024-09540-5
42. Nair, A., Steinberg, W., Habib, T., Saeed, H., & Raubenheimer, J. (2018). Prevalence of healthcare-associated infection at a tertiary hospital in the Northern Cape Province, South Africa. South African Family Practice, 60(5), 162–167. https://doi.org/10.1080/20786190.2018.1487211
43. Nazeerah, H., Oliveira Bianca, D., Simon, F., Sameshan, G., Maano, M., Nokolinah, M., Fathima-Zahra, R., Zahra, K., William Khabe, M., & Thifhelimbilu Emmanuel, L. (2022). Nosocomial Infections in Surgical Patients at a Central Academic Hospital in South Africa. Journal of Surgery, 10(1). https://doi.org/10.11648/j.js.20221001.19
44. Ndir, A., Diop, A., Ka, R., Faye, P. M., Dia-Badiane, N. M., Ndoye, B., & Astagneau, P. (2016). Infections caused by extended-spectrum beta-lactamases producing Enterobacteriaceae: Clinical and economic impact in patients hospitalized in 2 teaching hospitals in Dakar, Senegal. Antimicrobial Resistance and Infection Control, 5(1). https://doi.org/10.1186/s13756-016-0114-7
45. Nielsen, H., Hansen, K. K., Gradel, K. O., Kristensen, B., Ejlertsen, T., Østergaard, C., & Schønheyder, H. C. (2010). Bacteraemia as a result of Campylobacter species: A population-based study of epidemiology and clinical risk factors. Clinical Microbiology and Infection, 16(1). https://doi.org/10.1111/j.1469-0691.2009.02900.x
46. Nimer, N. A. (2022). Nosocomial Infection and Antibiotic-Resistant Threat in the Middle East. In Infection and Drug Resistance (Vol. 15). https://doi.org/10.2147/IDR.S351755
47. Okon, R. S., Onwuezobe, I., Edem, E. N., Akereuke, U. E., Bonne, S., & Bawonda, E. O. (2023). Bacterial Aetiologic Profile and Antibiotic Response Patterns of Lower Respiratory Tract Infection (LRTI) among HIV/AIDS Patients on Highly Active Antiretroviral Therapy (HAART) in Uyo, South-south Nigeria. Acta Microbiologica Hellenica, 68(3).
48. Olanipekun, T. O., Salemi, J. L., Mejia de Grubb, M. C., Gonzalez, S. J., & Zoorob, R. J. (2016). Clostridium difficile infection in patients hospitalized with type 2 diabetes mellitus and its impact on morbidity, mortality, and the costs of inpatient care. Diabetes Research and Clinical Practice, 116. https://doi.org/10.1016/j.diabres.2016.04.021
49. Owusu, M., Adu, E., Kalu, L. E., Martey, E., Acheampong, G., Enimil, A., Appiah, J. A., Badu-Peprah, A., Sylverken, J., Sylverken, A. A., Nguah, S. B., Westeel, E., Pouzol, S., Drosten, C., & Adu-Sarkodie, Y. (2024). Aetiological agents of pneumonia among HIV and non-HIV infected children in Ghana: A case-control study. PLoS ONE, 19(3 March). https://doi.org/10.1371/journal.pone.0299222
50. Sabino, S., Soares, S., Ramos, F., Moretti, M., Zavascki, A. P., & Rigatto, M. H. (2019). A Cohort Study of the Impact of Carbapenem-Resistant Enterobacteriaceae Infections on Mortality of Patients Presenting with Sepsis . MSphere, 4(2). https://doi.org/10.1128/msphere.00052-19
51. Sarmah, P., Meria M Dan, Dattatreya Adapa, & Sarangi TK. (2018). A Review on Common Pathogenic Microorganisms and Their Impact on Human Health. Electronic Journal of Biology, 14(1).
52. Seugendo, M., Mshana, S. E., Hokororo, A., Okamo, B., Mirambo, M. M., von Müller, L., Gunka, K., Zimmermann, O., & Groß, U. (2015). Clostridium difficile infections among adults and children in Mwanza/Tanzania: Is it an underappreciated pathogen among immunocompromised patients in sub-Saharan Africa? New Microbes and New Infections, 8. https://doi.org/10.1016/j.nmni.2015.09.016

53. Shahcheraghi, S. H., Ayatollahi, J., Niri, M. D., & Fazilati, A. (2016). The most common bacterial infections in HIV-infected patients. In Medical Journal of Dr. D.Y. Patil University (Vol. 9, Issue 6). https://doi.org/10.4103/0975-2870.194234
54. Singh, R., Jain, S., Chabbra, R., Naithani, R., Upadhyay, A., & Walia, M. (2014). Characterization and anti-microbial susceptibility of bacterial isolates: Experience from a tertiary care cancer center in Delhi. Indian Journal of Cancer, 51(4). https://doi.org/10.4103/0019-509X.175305
55. Smit, J., Thomsen, R. W., Schønheyder, H. C., Nielsen, H., Frøslev, T., & Søgaard, M. (2016). Outcome of community-acquired Staphylococcus aureus bacteraemia in patients with diabetes: A historical population-based cohort study. PLoS ONE, 11(4). https://doi.org/10.1371/journal.pone.0153766
56. Solanki, D., Kichloo, A., El-Amir, Z., Dahiya, D. S., Singh, J., Wani, F., & Solanki, S. (2021). Clostridium difficile Infection Hospitalizations in the United States: Insights From the 2017 National Inpatient Sample . Gastroenterology Research, 14(2). https://doi.org/10.14740/gr1371
57. Sunnerhagen, T., Grenthe, R., Kampmann, C., Söbirk, S. K., & Bläckberg, A. (2024). Campylobacter Infections With and Without Bacteremia: A Comparative Retrospective Population-Based Study. Open Forum Infectious Diseases, 11(3). https://doi.org/10.1093/ofid/ofae131
58. Szabó, S., Feier, B., Capatina, D., Tertis, M., Cristea, C., & Popa, A. (2022). An Overview of Healthcare Associated Infections and Their Detection Methods Caused by Pathogen Bacteria in Romania and Europe. In Journal of Clinical Medicine (Vol. 11, Issue 11). https://doi.org/10.3390/jcm11113204
59. Tao, X., Wang, H., Min, C., Yu, T., Luo, Y., Li, J., Hu, Y., Yan, Q., Liu, W. en, & Zou, M. (2020). A retrospective study on Escherichia coli bacteremia in immunocompromised patients: Microbiological features, clinical characteristics, and risk factors for shock and death. Journal of Clinical Laboratory Analysis, 34(8), e23319. https://doi.org/10.1002/jcla.23319
60. Temesgen, M., Kumalo, A., Teklu, T., Alemu, G., & Odoko, D. (2023). Bacterial Profile and Their Antimicrobial Susceptibility Pattern of Isolates Recovered from Intensive Care Unit Environments at Wachemo University Nigist Ellen Mohammed Memorial Comprehensive Specialized Hospital, Southern Ethiopia. Canadian Journal of Infectious Diseases and Medical Microbiology, 2023. https://doi.org/10.1155/2023/1216553
61. Tilahun, M., Gebretsadik, D., Seid, A., Gedefie, A., Belete, M. A., Tesfaye, M., Kebede, E., & Shibabaw, A. (2023). Bacteriology of community-acquired pneumonia, antimicrobial susceptibility pattern and associated risk factors among HIV patients, Northeast Ethiopia: cross-sectional study. SAGE Open Medicine, 11. https://doi.org/10.1177/20503121221145569
62. Ueckermann, V., Janse van Rensburg, L., Pannell, N., & Ehlers, M. (2022). Characteristics and outcomes of patients admitted to a tertiary academic hospital in Pretoria with HIV and severe pneumonia: a retrospective cohort study. BMC Infectious Diseases, 22(1). https://doi.org/10.1186/s12879-022-07522-z
63. Xia, J., Gao, J., & Tang, W. (2016). Nosocomial infection and its molecular mechanisms of antibiotic resistance. In BioScience Trends (Vol. 10, Issue 1). https://doi.org/10.5582/bst.2016.01020
64. Zayet, S., Klopfenstein, T., Gendrin, V., Vuillemenot, J. B., Plantin, J., Toko, L., Sreiri, N., & Royer, P. Y. (2023). Campylobacter fetus Invasive Infections and Risks for Death, France, 2000–2021. Emerging Infectious Diseases, 29(11). https://doi.org/10.3201/eid2911.230598
65. Zhang, Y., Li, Y., Zeng, J., Chang, Y., Han, S., Zhao, J., Fan, Y., Xiong, Z., Zou, X., Wang, C., Li, B., Li, H., Han, J., Liu, X., Xia, Y., Lu, B., & Cao, B. (2020). Risk factors for mortality of inpatients with Pseudomonas aeruginosa bacteremia in China: Impact of resistance profile in the mortality. Infection and Drug Resistance, 13. https://doi.org/10.2147/IDR.S268744