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(RESEARCH ARTICLE)

Antibiogram profile of *Pseudomonas aeruginosa* isolated from wounds of patients attending some selected hospitals in Sokoto metropolis, Nigeria

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Abstract

Pseudomonas aeruginosa is an important opportunistic human pathogen that is found in most communities in Nigeria. One hundred and sixty-five (165) wound swabs specimens were aseptically collected from three hospitals (Specialist Hospital, Maryam Abacha Women and Children Hospital and Noma Children Hospital, Sokoto) and investigated for the possible presence of *P. aeruginosa.* The swabs were aseptically cultured on MacConkey agar, organisms identified using standard biochemical tests and Muller Hinton agar for sensitivity. A prevalence rate of *Pseudomonas aeruginosa* isolates amounting to 32(19.4%) was obtained from the wound sites investigated, out of which 14(8.5%) were multi-drug-resistant. Statistically, Chi square analysis showed that there was no significant difference in the number of isolates from SHS, MAWCHS and NCHS and in the occurrence of organism in relation to gender and age ($p>0.05$). The incidence of *P. aeruginosa* was highest (10.9%) at Specialist Hospital, Sokoto, compared with other collection points investigated. Antibiogram studies revealed that *P. aeruginosa* was most resistant to colistin, aztreonam and ceftazidime to a magnitude of 87.5%, 40.6% and 37.5% respectively, while the organism was most susceptible to imipenem (90.6%) followed by piperacillin-tazobactam (78.1%) and ciprofloxacin (56.3%). Antibiogram becomes very important in clinical cases to forestall possible recrudescence of infection. However, there is need for routine antibiotic sensitivity check.

Keywords: Antibiogram profile; *Pseudomonas aeruginosa*; Wounds; Sokoto metropolis

1. Introduction

Pseudomonas aeruginosa is an opportunistic pathogen notable as a leading cause of wound infections and is responsible for at least 10% of all wound infections and ranking second among Gram-negative pathogens associated with wound infections [1]. *P. aeruginosa* is an aerobic Gram negative rod-shaped opportunistic bacterium that can cause disease in plants and animals, including humans [2]. It is a highly versatile microorganism capable of tolerating low oxygen condition and can survive with low nutrients and grow in temperature ranging from 4°C-42°C. This characteristic allows it to be associated with wound and hospital-acquired infections [3]. Despite introduction of a wide variety of antimicrobial agents with anti-*pseudomonal* activity, life-threatening infections caused by *Pseudomonas aeruginosa* contribute to morbidity and mortality in patients with wound infections [4]. The ability of this organism to develop resistance to antimicrobial agents makes it a main culprit in numerous infections especially in wound infection and Hospital-acquired infections. The capabilities to colonize rapidly in an immune compromised host make it very difficult to deal with. In such an eventuality antibiotic stand ineffective [5].

Drug resistance is the reduction in effectiveness of a drug such as an antimicrobial agent in curing a disease or condition. Antibiotic resistance is a world-wide problem of major importance and new form of antibiotics resistance can cross

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international boundaries and spread between continents with ease [6]. Many forms of resistance spread with remarkable speed. The use of antibiotics is the single most important factor leading to antibiotics resistance around the world. Antibiotics are among the most commonly prescribed used in human medicine [7]. However, up to 50% of all the antibiotics prescribed for people are not needed or are not optimally effective as prescribed. Multi-drugs-resistant organisms are pathogens that have become resistant to more than one class of antibiotics and these antibiotics can no longer be used to control or eliminate the pathogen [16]. *P. aeruginosa* produces various mechanisms of resistance to antibiotics such as broad spectrum β-lactamases, metallo-β-lactamases (MβL), alteration of protein binder of penicillin, penicillin binding protein (PBP), porin mutations, plasmid enzymatic modification, DNA-gyrase mutation and active expulsion (efflux) pumps [3]. Generally, antibiotics resistance mechanism of *P. aeruginosa* can be divided into intrinsic and acquired resistance. Intrinsic refers to resistance that is a consequence of a large selection of generally encoded mechanisms and acquired refers to resistance that is achieved via the acquisition of additional mechanism or is a consequence of mutational event under selective pressure [8]. The genome of this microorganism is among the largest in the bacterial world, allowing for great genetic capacity and high adaptability to environmental changes. The widespread use of antibiotics, together with the length of time over which they have been available have led to major problems of resistant pathogens in wound infections thus contributing to morbidity and mortality [4].

Each year in the United States, at least two million people acquire serious infections with bacteria that are resistant to one or more of the antibiotics designed to treat those infections [7]. A recent report by Centre for Disease Control and Prevention (CDC) around 51,000 health care associated *P. aeruginosa* infections occur every year in United States, of which around 6,000 (13%) are caused by multi-drug-resistant (MDR) *P. aeruginosa* strains which account for roughly 400 deaths every year. Recent reports on the antibiotic sensitivity pattern of *P. aeruginosa* in the United Kingdom have highlighted the problem of antibiotic resistance in cystic fibrosis (CF) strains in comparison with hospital isolates. Antibiotic resistance infections add considerable and avoidable cost to the already overburdened health care system [7]. The total economic cost of antibiotic resistance to the Nigerian economy has been difficult to calculate. Due to paucity of information on antimicrobial resistance in the country. Estimate vary but have range as high as 12 trillion naira [9].

The development of wound infection depends on the integrity and protective function of the skin [10]. It has been shown that wound infection is universal and the bacterial type varies with geographical location, resident flora of the skin, clothing at the site of wound, time between wound and examination [6]. In general, a wound can be considered infected if purulent materials drain from it, even without confirmation of positive cultures. Also, many wounds are colonized by bacteria, whether infected or not. Infected wounds may not yield pathogens by culture owing to the fastidious nature of some pathogens, or if the patient has received an antimicrobial therapy [4]. Many bacterial agents are known to cause wound infections. Initial injury to the skin triggers coagulation and an acute inflammatory response followed by exposure of subcutaneous tissue following loss of skin integrity which provides a moist, warm, and nutritive environment that is conducive to microbial colonization and proliferation [11].

The rapid increase of drug resistance in clinical isolates of this opportunistic human pathogen is of world-wide concern which is not only related to high morbidity and mortality but its significant influence on the economy [12]. The overall prevalence of antibiotic-resistant *P. aeruginosa* is increasing with up to 10% of global isolate found to be multi-drug-resistant. This represents a major treatment challenge as *P. aeruginosa* is the second leading cause of Gram-negative wound infections [13].

MDR *P. aeruginosa* has been given a serious threat level in the CDC antibiotic resistance report. As a consequence of multi-resistant-strains evolving, there has been a search for new antibiotics agent. Aerosolized azetreonam was approved in 2010 and some other old antibiotics but the available antibiotics with which to treat *Pseudomonas aeruginosa* still remain limited [14]. This is because *Pseudomonas aeruginosa* is a notoriously difficult organism to control with antibiotics or disinfectant [15]. Paucity of information on the prevalence of *P. aeruginosa* in wound infections in Sokoto State necessitated this study.

This study may help to know the burden of *Pseudomonas aeruginosa* infection with respect to wound. Understanding of Antibiogram profile of *Pseudomonas aeruginosa* in wound infections may also be essential in the treatment and control of the infections, the study may also help to reduce the unnecessary economical wastages on the cost of treatment of wound infection caused by *Pseudomonas aeruginosa.* This may also provide useful information about distribution of multi-drugs-resistance *Pseudomonas aeruginosa* in wound infections in Sokoto State, Nigeria.

The main aim of this research is to determine the prevalence and antimicrobial susceptibility profile of *Pseudomonas aeruginosa* isolated in wound infections of patients attending some selected Hospital in Sokoto metropolis, Nigeria. However, the specific objectives are as follows:

- To isolate and identify strains of *Pseudomonas aeruginosa* from the collected wounds using standard bacteriologic techniques.
- To determine the antimicrobial susceptibility profile of the isolates.
- To identify isolates exhibiting multi-drug resistance (MDR).
- To determine the relationship between *Pseudomonas aeruginosa* and socio demographic factors.

2. Material and methods

2.1. Study area

Sokoto State is located within the North-Western geopolitical zone of Nigeria, carved out of the defunct North Western State on 3RD February 1976. Sokoto State lies in the (longitude 11˚ - 30˚ to 13˚ - 50˚ East and Latitude 4 – 6˚ North), According to the National Population Commission (2010), population figures stand at 3,7026,76 persons spread over an area of 33,776.89 square kilometres of land. Sokoto state has an annual temperature of 28oC (82.9oF). Sokoto as a whole is a very hot area, however, maximum daytime temperature is most of the year generally under 40oC (104.0oF). The warmest months are February to April when daytime temperature can exceed 45oC (113.0oF). The population mainly consists of the Hausa/Fulani ethnic groups. The major occupation of the people is farming (rainy season and irrigation in the dry season) and animal husbandry. The two major seasons in Sokoto are the dry and wet seasons. The wet season spans between May and October, with an annual rainfall of between 50cm to 130cm.The dry season starts around October and may last up to May. Socio cultural characteristics is homogenous as majority of its indigenes are Muslims [17].

2.2. Study sites

The study was carried out in three hospitals located within Sokoto metropolis, Specialists Hospital Sokoto, Maryam Abacha Women and Children Hospital Sokoto and Noma Children Hospital Sokoto. These hospitals span within two Local Government Areas of the state Sokoto North and Sokoto South Local Government Areas.

Specialists Hospital Sokoto and Maryam Abacha Women and Children Hospital Sokoto are the apex State Government owned healthcare centre while the Noma Children Hospital is specialist medical centre that serves mainly children healthcare needs.

2.3. Study population

A total of one hundred and sixty-five (165) subjects with wounds were recruited for this study. These consist of both inpatients and outpatient attending some selected Hospitals in Sokoto metropolis, Nigeria.

2.4. Study design

The research is a cross-sectional observational study on patients with wound infections.

2.5. Sample size determination

Sample size for this study was calculated based on the prevalence reported from initial studies carried out around north central of Nigeria using the following formula for calculating minimum sample size (18). Sample size n is given by the formula below: $n = \frac{Z^2 pq}{d^2}$

The calculated sample size was 150. In order to enhance precision, 165 samples were collected.

2.6. Ethical consideration

Ethical permission was sought from the Ethics and Research committee of Sokoto State Ministry of Health and the selected hospitals before commencing the study. Informed consent was also obtained from each of the patient before enrolment in the study.

2.7. Sampling method

Simple random sampling method was used.

2.8. Instruments of data collection

2.8.1. Consent Form

Informed consent of the subjects was sought prior to sample collection.

2.8.2. Questionnaire

The selected patients who were willing to participate were interviewed using detailed interviewer administered questionnaire that gives information on demographic data and some clinical variables.

2.8.3. Sample collection

A sterile swab stick was used to obtain each sample from the site of wound, first cleansing the wound with sterile saline to wash off any debris. The swab was then rotated over a 1-cm square area with sufficient pressure to express fluid from within the wound tissue. Care was taken to avoid contaminating the specimen with commensal organisms from the skin (20). Specimens were then transported immediately to the laboratory for further processing.

2.9. Specimen analysis

2.9.1. Culture

At the laboratory the specimens were cultured on MacConkey Agar (Oxoid, U.K), each sample on a half section of the culture plate. Briefly, the swab was used to make a well of inoculum on the plate and a sterile wire loop was used to streak out from the well onto the remaining half of the media. Plates were then incubated at 37^0C aerobically for 24 hours and examined for bacterial growth (20).

2.9.2. Direct Gram Stain

An evenly spread smear was made on a cleaned grease free glass slide and allowed to air dry, smear was then fixed by passing through the flame briefly. It was then stained using the Gram staining technique.

Briefly, the slide was placed on a staining rack and flooded with crystal violet and stained for 1 minute. Stain was then washed off with water and smear covered with Lugol's iodine solution, and allowed to stay for 1 minute. The smear was then rinsed again with water. Next, the smear was decolourised briefly with acetone solution which was then washed off with water immediately. The smear was finally counterstained with neutral red solution for 2 minutes. It was then rinsed in running tap water, allowed to air dry and viewed under the microscope using the 100X oil immersion objective [20].

2.10. Characterization of bacterial isolates

Isolates of Gram-negative bacilli and gave typical *Pseudomonas aeruginosa* characteristics on MacConkey Agar (Oxoid, U.K) were subjected to motility test and biochemical tests that included sugar utilization tests, catalase and oxidase test as described by [21]. A secondary gram staining was also performed on any bacterial colonies for morphologic identification of suspect colonies.

2.10.1. Motility Testing

This was performed using the hanging-drop technique from an overnight broth culture in peptone water. Briefly, a ring of plasticine was made around the edges of the centre of a clean grease-free cover slip. A drop of the broth culture was then transferred to the centre of the ring and a glass slide was then press on top of the ring. The entire preparation was then inverted quickly so that the cover slip becomes above the glass slide and examined under the microscope with the 40X objective lens to identify the motile organism [21].

2.10.2. Sugar Utilisation Tests

Pseudomonads are oxidative in their respiratory strategy, unlike the Enterobacteriaceae. The organisms do not ferment sugars that include glucose, fructose, lactose or sucrose. Thus, in media that detect pH change by acid production like MaConkey, Kligler Iron Agar (KIA) and Cysteine Lactose Electrolyte Deficient Agar (CLED) *Pseudomonas aeruginosa* forms pale coloured colonies with no indication of fermentation (acid or gas) [20].

2.10.3. Catalase Test

Catalase produced by the organism breaks down hydrogen peroxide into water and oxygen, bubbles of oxygen are observed in positive organisms like *Pseudomonas aeruginosa*. Two drops of 3% hydrogen peroxide (H_2O_2) solution were placed on the ends of a clean glass slide. A colony of the organism was collected using a sterile glass rod and emulsified in the drop of H_2O_2. Bubbles of gas indicate a catalase positive test, while absence of bubbles indicated a catalase negative test. No colony was emulsified in one of the drops, served as a negative control [21].

2.10.4. Oxidase Test

Cytochrome oxidases produced by positive organisms (e.g*Pseudomonas*organisms) oxidises the filter paper soaked in 1% tetramethyl-*p*-phenylene-diamine-dihydrochloride to a deep purple colour (indophenols). *Pseudomonas aeruginosa* are oxidase positive and this is an important feature of this organism that simplifies its differentiation from the members of the Family Enterobacteriaceae, which are commonly isolated in mixed culture with Pseudomonads but are all negative for the oxidase test.

A colony of the test organism was picked using a wire loop and smeared on the oxidase strip paper. The smeared area of the oxidase strip paper was observed for colour change to deep blue or purple within 10 seconds which indicates a positive reaction while the absence of blue-purple colour change was considered a negative test [20].

2.11. Antibiotic susceptibility testing (AST)

AST was performed in accordance with 2017 Clinical and Laboratory Standard Institute modified Kirby-Bauer disk diffusion on Muller Hinton Agar (MHA) [22]. This involves the use of antibiotic discs impregnated with the test antibiotics. The Inoculating suspensions were prepared by making direct saline suspensions of isolated colonies from 18-hours culture plates on MHA. The suspension was adjusted to achieve a turbidity equivalent of a 0.5 McFarland (1-2 $x10^8$ colony forming units CFU per ml). A sterile swab stick was dipped into the bacterial suspension and excess fluid removed by pressing the swab stick against the wall of the tube, the swab was then used to carefully swab the entire surface of MHA plates. The surface was then allowed to dry for 3 minutes. Commercially prepared antibiotic discs (Oxoid, UK) of selected antibiotic agents were then placed on the inoculated MHA 25mm away from each other.

The antibiotic discs used and their concentrations were ceftazidime 30 µg, Piperacillin 100 µg, Imipenem 10 µg, Ciprofloxacin 5 µg, Colistin 10 µg, Piperacillin-tazobactam 100/10 µg, Gentamicin 10µg, and Aztreonam 30µg. The plates were then incubated at 35 °C for 24hrs after which the zones of inhibition for each of the antibiotic was recorded. The diameter of zone of inhibition was measured in millimetres and interpreted as sensitive, intermediate or resistant based on the chart by CLSI [22]. Multidrug-resistant (MDR) strains (i.e. strains showing resistance to three or more antibiotics tested) were identified. For test result validation and Quality Control *P. aeruginosa* (ATCC® 27853) control strain was used.

2.12. Statistical analysis

All data obtained from this study was analysed using SPSS version 25.0 and was presented using tables and bar chart. Relationships between *Pseudomonas aeruginosa* isolated from wounds and socio-demographic factors was analysed using Chi square test (χ^2 test). Values were considered statistically significant at $p \leq 0.05$.

3. Results

From all the hospitals included as study sites during the period of the study, a total of 165 samples were collected and analysed between January and August 2018. Of these, 60(36.4%) samples were collected from female while 105(63.6%) samples from male patients. Out of these, 32(19.4%) yielded growth of *P. aeruginosa*.

Specialist Hospital Sokoto (SHS) has the highest prevalence of 18(10.9%) followed by Maryam Abacha Women and Children Hospital Sokoto (MAWCHS) with 10(6.1%) and Noma Children Hospital Sokoto (NCS) having the least, 4(2.4%) (Table 1).

Table 1 Distribution of *Pseudomonas aeruginosa* in the Study area by hospitals

Centre	Samples	Positive	Prevalence (%)	Chi (χ2) test	P-value
SHS	121	18	10.9		
MAWCHS	31	10	6.1	5.938	0.051
NCHS	13	4	2.4		
TOTAL	165	32	19.4		

Keys: **SHS** = Specialist Hospital Sokoto, **MAWCHS** = Maryam Abacha Women and Children Hospital Sokoto, **NCHS** = Noma Children Hospital Sokoto

Table 2 shows the distribution of *P. aeruginosa* according to age group of patients. Highest rate of isolates 8(4.8%) were found among the age group 31 to 40 years while the lowest rate of isolate 1(0.6%) was found among age group 71 to 80 years.

Table 2 Distribution of *Pseudomonas aeruginosa* in the Study Hospitals by age group

Age (years)	Frequency	Percent (%)	Chi (χ^2) test	P-value
1-10	5	3.0		
11-20	3	1.8		
21-30	4	2.4		
31-40	8	4.8	6.130	0.525
41-50	5	3.0		
51-60	3	1.8		
61-70	3	1.8		
71-80	1	0.6		
Total	32	19.4		

Table 3 shows a high prevalence of bacteria isolates among males than females as 18(10.9%) and 14(8.5%) respectively.

Table 3 Distribution of *Pseudomonas aeruginosa* in the study Hospitals by Gender

Gender	Frequency	Percent (%)	Chi (χ^2) test	P-value
Male	18	10.9		
Female	14	8.5	0.936	0.333
Total	32	19.4		

The result also shows high rate of isolates among business patients 13(7.9%) and least among farmers and civil servants 4(2.4%) (Table 5).

Table 4 Distribution of *Pseudomonas aeruginosa* in the study Hospitals by occupation

Occupation	Frequency	Percent (%)	Chi(χ^2) square value	P-value
Unemployed	11	6.7		
Farming	4	2.4		
Business	13	7.9	2.077	0.557
Civil servant	4	2.4		
Total	32	19.4		

The result also shows the distribution of isolates with respect to marital status in which married patients have high rate 23(13.9%) (Table 5).

Table 5 Distribution of *Pseudomonas aeruginosa* in the study Hospitals by marital status

Marital status	Frequency	Percent (%)	Chi(χ^2)value	P-value
Single	8	4.8		
Married	23	13.9		
Widow	1	0.6	9.166	0.01
Divorce	0	0		
Total	32	19.4		

Statistically significant (P≤ 0.05)

Table 6 shows the distribution of isolate with respect to type of wound as; 3(1.8%) from surgical wounds, 9(5.5%) from traumatic wounds, 19 (11.5%) from non-traumatic wounds and 1(0.6%) from burns.

Table 6 Distribution of *Pseudomonas aeruginosa* in the Selected Hospitals by Wound type

Wound type	Frequency	Percent (%)	Chi (χ^2) test	P-value
Surgical	3	1.8		
Traumatic	9	5.5		
Non traumatic	19	11.5	0.271	0.965
Burns	1	0.6		
Total	32	19.4		

The result also shows high rate of isolate from clean contaminated wounds 18(10.9%) while infected wounds has least 3(1.8%) (Table 7).

Table 7 Distribution of *Pseudomonas aeruginosa* in the study Hospitals by nature of wound

Nature of wound	Frequency	Percent (%)	Chi(χ^2) value	P-value
Clean	4	2.4		
Clean contaminated	18	10.9		
Contaminated	7	4.2	1.613	0.656
Infected	3	1.8		
Total	32	19.4		

Antibiogram of isolates in the Study hospitals demonstrated highest sensitivity for imipenem with 29(90.6%) and this organism indicated strong resistance to colistin, aztreonam and ceftazidime with 28(87.5%), 13(40.6) and 12(37.5%) respectively (Table 8 and Figure 1). 14(8.5%) of the isolates were multi-drug-resistant, with equal distribution of 7(4.25%) among males and females (Table 9 and Table 10).

Table 8 Antibiogram pattern of *Pseudomonas aeruginosa* isolates

Antibiotic	Susceptible (%)	Intermediate (%)	Resistant (%)
Aztreonam	10(31.3)	9(28.1)	13(40.6)
Ceftazidime	16(50.0)	4(12.5)	12(37.5)
Ciprofloxacin	18(56.3)	6(18.8)	9(25.0)
Colistin	4(12.5)	0(0.00)	28(87.5)
Gentamicin	17(53.1)	6(18.8)	9(28.1)
Imipenem	29(90.6)	0(0.00)	3(9.4)
Piperacillin	17(53.1)	6(18.8)	9(28.1)
Piperacillin-tazobactam	25(78.1)	6(18.8)	1(3.1)

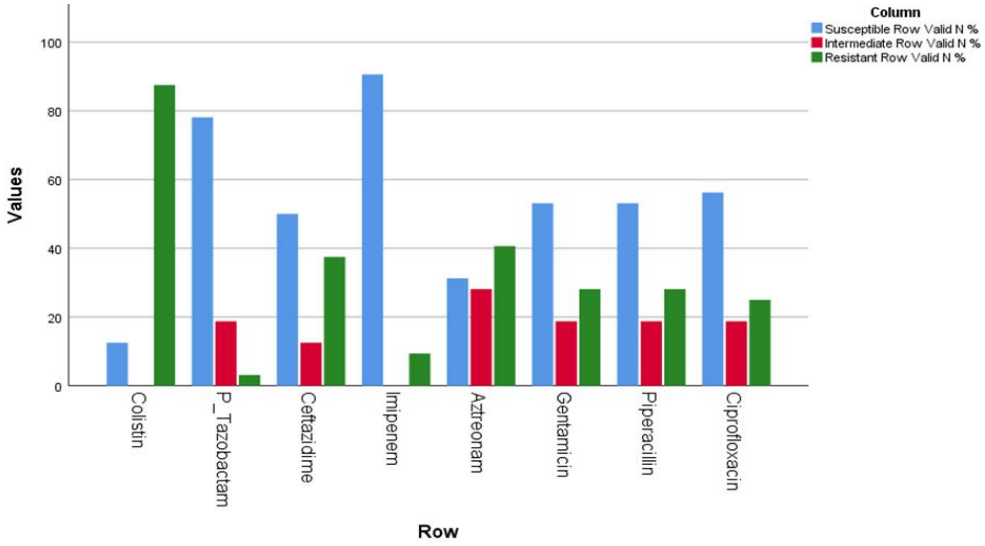

Figure 1 Graph showing Antibiogram pattern of the isolates
Key: P=Piperacillin

Table 9 Resistance pattern of MDR isolates

Resistance pattern	Number of isolates
CT, ATM, CN	2
CT, ATM, CN, CIP	1
CT, CAZ, ATM	1
CT, CAZ, ATM, CN, PRL	2
CT, CAZ, ATM, CN, PRL, CIP	3
CT, CAZ, IMP,ATM, CIP	2
CT, PRL, CIP	1
CT, TZP, CAZ, PRL	1
CAZ, ATM, CN, CIP	1
TOTAL	**14**

MDR: Multi-drug resistant, CT: Colistin, CN: Gentamicin, CAZ: Ceftazidime, CIP: Ciprofloxacin, TZP: Piperacillin-tazobactam, IMP: Imipenem, ATM: Aztreonam, PRL: Piperacillin

Table 10 Distribution of Multi-Drug-Resistant *Pseudomonas aeruginosa* by Gender

Gender	Frequency	Percent (%)	Chi (χ^2) test	P-value
Male	7	4.25		
Female	7	4.25	0.395	0.530
Total	14	8.50		

4. Discussion

Wound is considered one of the major health problems in the world and secondary bacterial infection is one of the most frequent and severe complications in patients who have sustained wounds [23]. *P. aeruginosa* is a common cause of wound infections, especially in clean contaminated non-traumatic wounds. This is because non-traumatic wounds are more open to the environment and has areas of dead tissue free of any defences thereby making them ideal sites for infection by bacteria from the environment or the normal microbiota.

The result of this research showed the prevalence rate of isolation of *P. aeruginosa*in wound specimens to be 32/165(19.4%) in three hospitals within Sokoto metropolis. This finding agrees with 18.5% of Dantas *et al.,* [24] in Karacchi city of Pakistan, 19.7% by Akinjogunlo *et al.,* [25] in Calabar, and 14.3% by Anjum [26] in South Eastern Nigeria. The rate of infection obtained in this study were, however, higher than the 10.5% reported by Joshi *et al.,* [27] in Benin City and another study with a prevalence of 8.6% reported from South Western Nigeria [28]. Our findings also disagree with the work done by Nwachukwu *et al.,* [4] in Abiah state, Nigeria who reported a high prevalence rate of 32.9%, Similarly, an earlier study in the U.A.E reported that out of 67 surgical wound patients examined microbiologically for surgical wound infection 35.6% had *P. Aeruginosa* infection, considerably higher than what this study found [29].

Other scientists have obtained increasing prevalence of *P. Aeruginosa* in wound infections especially in recent years. A research study carried out by Anupurba *et al.,* [10] showed that *P. Aeruginosa* had 32% isolation rate and a similar study from India showed that *P. Aeruginosa* was the most frequent pathogen isolated, accounting for 36% of the total number of the organisms [30]. It is thus clear that the prevalence of *P. Aeruginosa* obtained in this study is in agreement with what is obtained in some hospitals in Nigeria. The disparity in infection rate observed in relation to other studies could be attributed to differences in geographical location and possibly variations in wound hygiene practices.

Similar results were obtained by Kolmos *et al.,* [31] in Bombay town of India, Konno [32] and Akinjogunla *et al.,* [25]. Virulence and adaptability of the microorganism to the hospital environment may be responsible for its high infection rates [33].

This study found the rate of *P. aeruginosa* to be higher at Specialist Hospital Sokoto than in other hospitals. In Specialist Hospital Sokoto, outpatients stay long in the overcrowded environment and move around freely, this could have exposed such patients group to cross infections from the hospital environment that has been shown to be likely sources of *P. aeruginosa*.

Incidence of *P. aeruginosa* was higher in Married and Business males than females. This finding is consistent with the reports of Kolmos *et al.,* [31] and Dulworth and Pyenson [35], however, it goes contrary to a study in which females were found to be more infected with *P. aeruginosa* [34]. Studies elsewhere have observed significant variations in hygienic practices between the male and female gender with females demonstrating significant compliance both in hospitals environments and community settings.

Patients within the age group31-40 years are at the highest risk of infections. Maltezou and Giamarellon [36] in southern Uganda had reported that the age groups 10-19 years and ≥50 years were the most infected. According to Joshi *et al.,* [27] in South East Nigeria, children less than 13 years old were the most infected. From this study also, the age group 71-80 years had the least rate of infection in most of the hospitals studied. This may be due to good hygienic practice and avoidance of cross-infection exhibited by this group of patients. The findings of this study on the rate of infection with *P. aeruginosa* according to marital status was statistically significant (P=0.01), this result indicated that there is a relationship between infection and this factor. However, the rate differs with respect to health facility, gender, age, type of wounds and nature of wounds which was found not to be statistically significant (P>0.05), indicating no relationship between infection and these factors.

The susceptibility profile of *P. aeruginosa* isolates to the eight antibiotics tested *in vitro* were relatively low compared to the sensitivity pattern to different anti pseudomonal [37]. Out of the 32 isolates of *P. aeruginosa* 14(8.5%) were MDR strains which demonstrated different resistance profile (Table 8 and Table 9).

Incidence of MDR strain *P. aeruginosa* was equal in females and males who were infected.This result is in contrast with the reports of Kolmos *et al.,* [31] and Dulworth and Pyenson [35] in which males were more infected with MDR strain *P. aeruginosa* (Table 10).

In this study, *P. aeruginosa* isolates were highly susceptible to imipenem (90.6%) followed by piperacillin-tazobactam (78.1%) and ciprofloxacin (56.3%) (Table 8 and Figure 1). Other drugs showed very low percentage of susceptibility. The non-hygienic measures in hospitals, the ability of some bacteria to grow in hospital materials or indiscriminate use of antibiotics, fake drugs, and self-prescription among patients are favourable conditions which overtime encourages the development of antibiotic resistance in bacteria. The isolates demonstrated high resistance to three of the antibiotics (colistin, aztreonam and ceftazidime) tested *in vitro*, which is much higher compared to a Belgian study by Prinsloo *et al.,* [38] but lower than the Turkish study where one third of the isolates were multidrug resistant. This could be due to misuse of these drugs without running antibiogram, thereby resulting to development of resistance in the organisms.

5. Conclusion and recommendations

Pseudomonas aeruginosa was isolated from wounds and has a frequency of occurrence of 19.4%. The sensitivity pattern of *Pseudomonas aeruginosa* showed that it is highly sensitive to Imipenem (90.6%), Piperacillin-tazobactam (78.1%) and Ciprofloxacin (56.3%). Colistin has the highest resistance of 87.5%. The prevalence rate of 8.5% MDR *P. aeruginosa* may have occurred as a result of widespread use and abuse of antibiotics.

Rigorous monitoring of the MDR in *P. aeruginosa* and the restriction of the inappropriate use of antimicrobial agents is recommended. Attention should be given to simple cost-effective infection control practices like hand hygiene that can substantially lower the risk of infection in our hospitals.

Compliance with ethical standards

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Disclosure of conflict of interest

This article is not the object of any conflict of interest and has not been submitted to other journal for publication. Consequently, we authorize the journal to publish it.

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