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PREVALENCE OF MULTIDRUG-RESISTANT BACTERIA PNEUMONIA IN KADUNA, NIGERIA

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ABSTRACT

Background: studies have shown that pneumonia accounts for approximately 16-19% annual deaths, resulting in an estimated 162,000 annual deaths at 18 deaths per hour in Nigeria, and it's triggered by low vaccination coverage, antimicrobial resistance, indoor air pollution and malnutrition. As part of strategies to develop and implement effective pneumonia control that strives to reduce mortality and morbidity, it is important to assess the prevalence of bacterial pneumonia infection, which accounts for 35 – 60% pneumonia globally, and its susceptibility profile to commonly prescribed antibiotics within our locality. This mechanism has been linked to stimulate protective, cost-effective, treatment and preventative interventions that save lives and sustain children's health.

Aim: This study evaluated the prevalence of bacterial pneumonia in Kaduna and the susceptibility of the isolated bacteria against commonly prescribed antibiotics in Kaduna metropolis for a better treatment option.

Methods: A total of 250 samples (consisting of sputum (128)) and deep throat swab (122) suspected of pneumonia were randomly collected from patients attending Barau Dikko Teaching Hospital, Kaduna, after ethical approval was obtained from October, 2024 – March, 2025 (6 months). Bacteria were identified using microscopy, Gram staining and Microbat bacterial identification kits. Antimicrobial susceptibility of the isolates was carried out to determine the resistance profile and percentage multidrug resistance to conventional antibiotics.

Results: High percentages (62%) of the population with pneumonia cases at Barau Dikko Teaching Hospital were male, while 38% were female. Children aged 0-5 years (48%) were the most infected, followed by the elderly aged ≥70 (16%). The populations within the active life stage are 19 – 57 years old. Out of a total of 250 samples collected, 51.2% were from sputum, while 48.8% were obtained from a deep swab of the throat source. Sputum samples (43.8%) had more bacterial growth than the deep throat swab (36.1%). The prevalence of bacterial pneumonia was 40.8%. The highest occurring bacteria were *Streptococcus pneumoniae* (30.4%), followed by *K. pneumoniae* (22.6%), *E. coli* (16.7%), and *S. aureus* (11%), while the least isolated was *Pseudomonas aeruginosa* (5.9%). Significant percentages (13.7%) of the isolates were unclassified. Overall assessment of the isolated bacteria antimicrobial susceptibility profile showed that the isolates were most resistant to amoxicillin (71.6%), tetracycline (62.5%), amoxicillin-clavulanic acid (55.7%), cefotaxime (47.7%) and cotrimoxazole (43.2%) but highly susceptible to imipenem (85.2%), ciprofloxacin (73.9%), chloramphenicol (69.3%) and azithromycin (60.2%). Significant percentages of the isolates (57.9%) were multidrug resistant, while 82.9% had MARI of ≥ 0.2. *Ps. aeruginosa* isolates (83.3%) had the highest multidrug-resistant profile, followed by *K. pneumoniae* (82.6%), *Streptococcus pneumoniae* (71%) and *E. coli* (58.8%), while the least multidrug-resistant bacterium was *S. aureus* (45.5%).

Conclusion: The study recorded a 40.8% prevalence of bacterial pneumonia in Kaduna, consisting of a high multidrug-resistant profile with children ages 0-5 years and males being the most infected.

Keywords: Prevalence, bacterial pneumonia, Kaduna, antibiotics, multidrug resistance

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INTRODUCTION

One of the leading causes of death among children less than 5 years old globally is pneumonia. Recent clinical guideline has subdivided pneumonia into 3 categories, namely the ventilator-associated pneumonia [40], healthcare-associated pneumonia [9] and community-acquired pneumonia (CAP) [22]. Pneumonia infection is caused by viruses, bacteria or fungi. Two classes of bacteria have been noted to cause respiratory infection and pneumonia. They include those termed typical (predominant), which comprises *Staphylococcus* (24%) been the most prevalent, followed by *Streptococcus* spp. (13%) and other Gram-negative bacteria such as *Escherichia, Pseudomonas, Proteus, Klebsiella, Stenotrophomonas, Enterobacter, Acinetobacter, Legionella, Serratia and Citrobacter spp* [19]. The others are called atypical because they are rare and the frequency of occurrence is low compared to those known as typical. They include *Mycoplasma pneumoniae, Chlamydia pneumoniae, Legionella pneumophila* [10]. However, studies have shown that clinical examination and manifestation of pneumonia caused by both typical and atypical bacteria cannot be differentiated. Also, there have been reports of frequent coinfection by more than one bacterium in pneumonia cases [10]. The study conducted by [30] revealed that *M. pneumoniae* were the most occurring community-acquired pneumonia (CAP) especially in outpatient setting in both adult and children throat swabs; accounting for between 15 – 40% of the atypical bacterium followed by *L. pneumophila* (2–15%) while the least were *C. pneumoniae* (5–10%) in Iran. In India, [12] reported an occurrence of 11.4% *M. pneumoniae* and 11% *L. pneumophila*, while in Nigeria, paucity of studies exist on the incidence of this atypical pneumonia bacterium. However, [13] in China observed that isolation of *M. pneumoniae* and *C. pneumoniae* is most common in the summer season (April – October in Nigeria), hence, its temperature influenced. The report of [33] further justifies that pneumonia prevalence is always very high in the dry season, with a double peak in March and October. These pathogens induce inflammation of the lung, producing pus and fluids that block the airway, causing difficulty in breathing [44]. The report has shown that over 800,000 deaths globally were recorded in 2018, implying a child dies every 39 seconds, with Nigeria recording the highest (19% cause of child deaths), amounting to 162,000 child deaths in 2018 from Nigeria. This implies that 443 or 18 children die every day or hour, respectively [42]. Other reports further showed that the northern parts of Nigeria, especially states like Borno, Jigawa, Gombe, Kebbi, Sokoto, Zamfara, Kaduna and Kano, recorded the highest cases of mortality of pneumonia [18]. Pneumonia could be community-acquired, and such had been recorded as the highest cause of death among children less than 5 years in Nigeria in 2017. Approximately 140,520 children died, accounting for 15% deaths globally in 2017 [11]. This has led the government of Nigeria to introduce pneumococcal and *Haemophilus influenzae* type b conjugate vaccines or Pneumococcal Conjugate Vaccine (PCV), which has approximately 70% efficacy and protective ability against 13 different strains of pathogenic pneumococcal bacterium among the children's routine immunisation exercise [29]. This proactive approach has significantly lowered the rising incidences of pneumonia and other bacterial respiratory tract infections [20]. For example, there was a drastic decline in mortality to 51% (i.e.

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from 13.6 per 1000 live births in 2000 to 6.6 per 1000 live births in 2015) after the UNICEF outcry of deaths associated with pneumonia globally [43]. Although the vaccine is available, it's not evenly distributed effectively in Nigeria; this sadly influenced Nigeria's high mortality rate of 19% in 2018, with a slight decline by 8% in 2020 [47]. Although [20] study further showed that there was no correlation between the immunisation status of a child and the development of pneumonia, which makes the infection still progressive. The study conducted by [25] reported 1.3% prevalence and 0.6% severity of pneumonia among children (aged 0–5 years) living in Kiyawa village of Jigawa State. [20] also observed 12.7% prevalence, implying that 1 out of every 8 children <5 years is infected with pneumonia. This study was carried out in a Primary Health Care (PHC) clinic in Amuwo Odo, Local Government Area of Lagos State. Risk factors such as malnutrition accounted for 15.6% prevalence, and this served as one of the major contributory factors to pneumonia mortality and morbidity in Nigeria [41]; [25]. Other risk factors observed to contribute to high severity pneumonia as published in other studies include lack of 6 months exclusive breastfeeding and vaccination, low socioeconomic status, parental smoking and coughing siblings, children cohabiting in overcrowded rooms such as house, prison and school, altered conscious state, HIV/AIDS, poverty, low birth weight, measles, hypoxaemia and age[39]; [21]; [38]).Also, a 2-week report of pneumonia prevalence of 2.6% in 2018 justifies the high incidence rate of this disease [51]. The study conducted by [4] reported that among children less than 5 years, the global indices showed that Nigeria has the highest yearly paediatric pneumonia mortality, and it accounts for approximately 20% deaths in children [45]. Although accurate data on pneumonia prevalence, health systems burden, or incidence are limited to periodic Demographic Health Surveys (DHS) without clinical assessments, the mortality report from these studies is significant and requires urgent response [21]. Also, the study by [25] further identified significant challenges in early/proper diagnosis of integrated management of childhood illness or defined pneumonia. Reasons could be due to non-classical presentation of illness, lack of clinical awareness, delayed seroconversion and extrapulmonary manifestation. This study, therefore, assessed the incidence of multidrug-resistant bacteria pneumonia in Kaduna, Nigeria, using Barau Dikko Teaching Hospital as a case centre to better understand the best treatment options available using commonly prescribed antibiotics.

MATERIALS AND METHODS

Materials, Reagents and Bacteriological Media

Light Microscope (wild mill Switzerland), sterile petri dishes, glass cylinders, conical flasks, test tubes, Test tube rack, Staining Tray, glass rod, Bunsen burner, face mask, hand gloves, wire loop, laboratory incubator (Baird and Tatlock ltd Essex), beakers, glass slide, sterile syringe and needle, sterile swab stick, weighing balance (W & T every limited Birmingham), micropipette (Huawei chemical Zheilang chin), Hot air oven (Baird and Tatlock ltd Essex), glass spreader, and an autoclave (Adelphi mfg Co Ltd UK).Crystal violet, iodine, Ethanol, Safranin, Normal

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saline, Acetic acid (Avondale Laboratory, England), Chloral hydrate (BDH Laboratory Chemicals Division, Poole, England), Drangendroff's reagent, Picric acid reagent, Mayers reagent, Phloroglucinol, Sudan red solution, and methylene blue. Blood agar, Muller-Hinton agar (oxoid), Mueller-Hinton broth (oxoid).

Antibiotics Disc: ciprofloxacin, imipenem, amoxicillin, cefotaxime, chloramphenicol, amoxicillin\clavulanate, azithromycin, tetracyclines.

Determination of Pneumonia Sample Size

Using the Cochran's formula below and a prevalence of 20% according to the Pharmaceutical Society of Nigeria – Partnership for advocacy in children and family health [52]. Where z is the confidence level score (1.96), p is the percentage (0.2), and e is the margin of error (5%).

$$n = \frac{z^2 p(1-p)}{d^2},$$

$$= (1.96)^2 (0.2)(1\text{-}0.2) \Big/ (0.05)^2$$

$$= \frac{3.8416 \text{ X } 0.8 \text{ X } 0.2}{0.0025} = \frac{0.614656}{0.0025} = 245.9$$

≈ 250 samples

Sample Collection and Processing

A total of 250 samples of sputum and deep throat swabs from suspected pneumonia patients for the period of 6 months (October 2024 – March, 2025) were randomly collected from patients attending Barau Dikko Teaching Hospital, Kaduna, after ethical approval. All samples were emulsified with phosphate normal saline buffer and transported to the Central lab of the Pharmaceutical Microbiology Laboratory in the Faculty of Pharmaceutical Sciences, Kaduna State University, in a cold-chained cooler and further stored at 4 °C until required, where a bacteriological study was carried out. All samples were treated according to the method described by the [49].

Bacteria Isolation and Identification

Bacteria were identified using Gram staining as described by [50] and Microgen biochemical kits as described by the manufacturer. Gram staining was performed by making a smear of a pure colony on a clean and grease-free slide. A drop of normal saline was added and then allowed to air dry. The air-dried inoculated slide was then passed across a flame three times. The heat-fixed slide was then placed on a staining tray and flooded with crystal violet for 30 seconds, rinsed with water and allowed to drain. Methyl red was also added and washed off with water after 30 seconds. The slide was then held at an angle, and acetic acid was dropped on the slide and then washed off immediately. Furthermore, the slide was flooded with safranin and allowed to stand for 30 seconds. It was then rinsed with water and allowed to drain. The slide was blotted with blotting paper and then allowed to dry completely before the microscopic examination. A magnification of 100X in oil immersion was used to observe the colour of the individual bacterial cells. The isolates were then classified as either Gram-positive or Gram-negative. The collected specimens were further inoculated onto two separate blood agar plates per sample, and then incubated aerobically at 37 °C for 24 hours to provide a 5-10% CO_2 concentration for isolation of *Streptococcus pneumoniae* and *Haemophilus influenzae*, and anaerobically cultured in an incubator to isolate other

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bacteria using standard microbiological techniques.

Antibiotic Susceptibility Testing

Antibiotic susceptibility testing was performed using the Kirby-Bauer disc diffusion method to determine the resistance profile of the isolates and multidrug resistance to conventional antibiotics. The following antibiotics were tested: Ciprofloxacin, Amoxicillin, Chloramphenicol, Cefotaxime and Imipenem. This was achieved by inoculating/seeding 200µl of 0.5 McFarland standard of an overnight culture of the bacteria isolated from pneumonia patients into 20ml melted Mueller Hinton agar. The admixture was then mixed thoroughly and poured aseptically into a sterile plate and covered with a lid. This was allowed to stand on the bench for 20 minutes to set and dried at room temperature. The antibiotics were placed on the media with the aid of forceps, pressed down to ensure complete contact with the agar surface, then allowed for 15 minutes pre-diffusion time before being incubated for 24 hours.

RESULTS

Assessment of Socio-Demographic Data

From the 250 samples collected 62% of the population infected with pneumonia at Barau Dikko Teaching Hospital were male while 38% were female (Fig. 1). More so, age distribution among the affected patients showed that children age 0-5 had 48% occurrence followed by the elderly age ≥70 with 16% and adolescence of ages 6 – 18 years having 15%. Fewer infected were populations within the active life stage, 19 – 57 years (Figure 2).

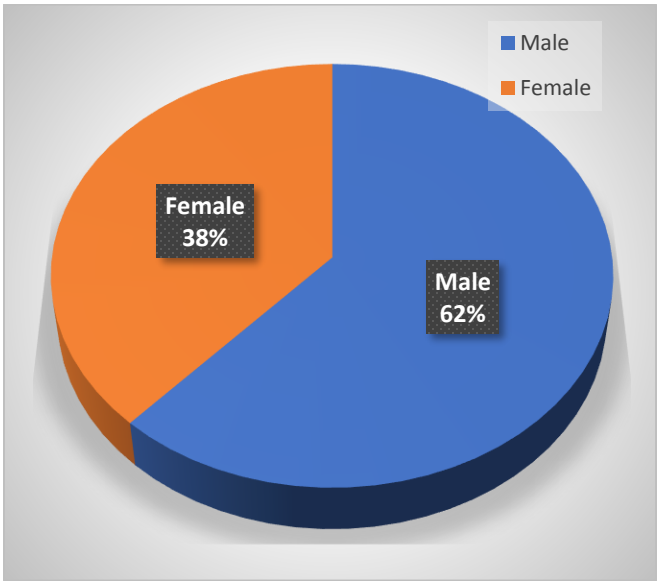

Figure 1: Gender distribution of Pneumonia cases in BDTH, Kaduna

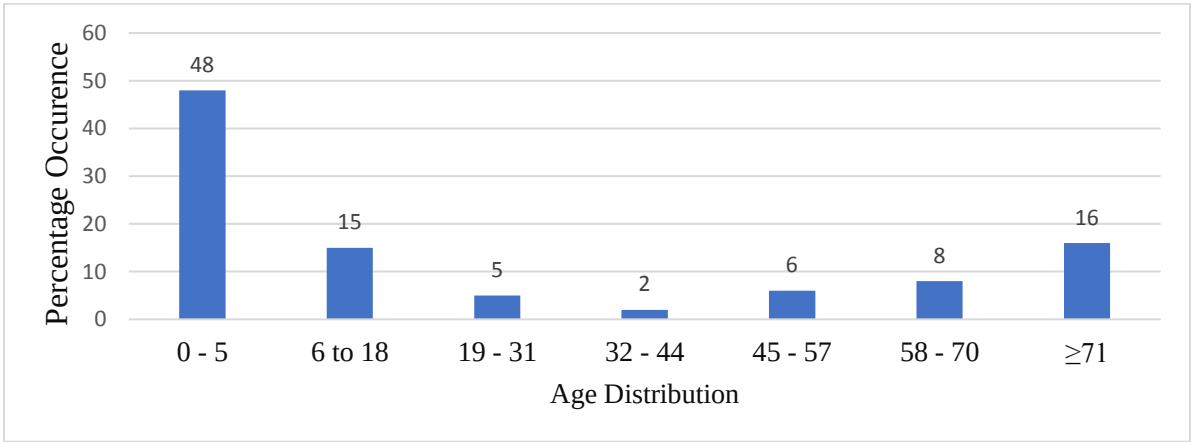

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Figure 2: Age Distribution of Pneumonia cases in BDTH, Kaduna

Assessment of Sample Distribution from Different Sources

Out of a total of 250 samples collected, 51.2% percentage of the samples were obtained from sputum, while 48.8% was obtained from deep swab throat source. Out of the number of sputum and deep swab throat samples collected, 43.8% (56/128) and 36.1% (44/122) had bacterial growth on blood agar, respectively. Further assessment showed that 40.8% incidence of bacterial pneumonia among patients attending Barau Dikko Teaching Hospital, Kaduna, was recorded in this study (Table 1).

Table 1: Sample Collection and Assessment

S/N	Sampling	Sputum (%)	Deep Swab throat (%)	Total	Percentage
1	Samples collected	128 (51.2)	122 (48.8)	250	100
2	Bacteria grow on blood agar	58(43.8)	44(36.1)	102	40.8
3	Samples without growth	67(52.3)	81 (66.4)	148	59.2

Further sample analysis showed that *Streptococcus pneumoniae* (30.4%) had the highest percentage occurrence among bacterial pneumonia isolated from BDTH, Kaduna, followed by *K. pneumoniae* (22.6%), *E. coli* (16.7%), *S. aureus* (11%), while the least isolated was *Pseudomonas aeruginosa*, 5.9%. A significant percentage (13.7%) of the isolates were unclassified by the kit used (Table 2).

Table 2: Percentage occurrence of Bacteria from pneumonia samples

S/N	Bacteria isolated	Frequency	Percentage
1	*S. pneumoniae*	31	30.4
2	*K. pneumoniae*	23	22.6
3	*S. aureus*	11	10.7
4	*E. coli*	17	16.7
5	*P. aeruginosa*	6	5.9
6	Unclassified bacteria	14	13.7
Total		102	100

Evaluation of the Antimicrobial Susceptibility Profile of the Bacterial Isolates

Overall assessment of the isolated bacteria antimicrobial susceptibility profile showed that the isolates were most resistant to amoxicillin (71.6%), tetracycline (62.5%), amoxicillin-clavulanic acid (55.7%), cefotaxime (47.7%) and cotrimoxazole (43.2%) but highly susceptible to imipenem (85.2%), ciprofloxacin (73.9%), chloramphenicol (69.3%) and azithromycin (60.2%). Significant percentages of the isolates (57.9%) were multidrug resistant, while 82.9% had MARI of ≥0.2 (Table 3).

Table 3: Antimicrobial Susceptibility Profile of Bacteria Pneumonia Isolated from Clinical Samples in Kaduna, Nigeria

S/N	Isolate Code	Bacteria isolated	AZT	C	AMC	AMX	IMP	CTX	CIP	SXT	TET	NART	MARI	CRP
1	DS2	*S. pneumoniae*	R	R	S	R	R	S	S	S	R	5	0.6	MDR

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2	DS6	*S. pneumoniae*	R	S	S	R	S	S	S	S	R	3	0.3	NMDR
3	DS8	*S. pneumoniae*	R	S	S	R	S	S	S	S	R	3	0.3	NMDR
4	DS9	*S. pneumoniae*	S	S	S	S	S	S	S	S	S	0	0	NMDR
5	DS12	*S. pneumoniae*	R	R	S	R	S	S	S	R	R	5	0.6	MDR
6	DS15	*S. pneumoniae*	R	S	S	R	S	S	S	S	S	2	0.2	NMDR
7	DS17	*S. pneumoniae*	S	S	S	S	S	S	S	S	S	0	0	NMDR
8	SPT3	*S. pneumoniae*	S	R	S	R	S	S	S	S	S	2	0.2	NMDR
9	SPT4	*S. pneumoniae*	R	S	R	R	S	S	S	S	S	3	0.3	NMDR
10	DS20	*S. pneumoniae*	S	S	S	S	S	R	S	S	S	1	0.1	NMDR
11	SPT5	*S. pneumoniae*	S	S	R	R	S	S	R	R	R	5	0.6	MDR
12	DS21	*S. pneumoniae*	S	S	R	R	S	R	S	S	R	4	0.4	NMDR
13	DS23	*S. pneumoniae*	R	R	S	R	S	R	R	R	S	6	0.7	MDR
14	DS25	*S. pneumoniae*	S	R	R	S	S	S	S	S	R	3	0.3	MDR
15	SPT7	*S. pneumoniae*	R	S	R	R	S	S	S	S	R	4	0.4	NMDR
16	SPT10	*S. pneumoniae*	R	S	R	R	S	R	S	S	R	5	0.6	MDR
17	DS27	*S. pneumoniae*	S	R	S	R	S	R	S	S	S	3	0.3	NMDR
18	SPT11	*S. pneumoniae*	R	S	R	S	S	S	R	R	S	4	0.4	MDR
19	SPT14	*S. pneumoniae*	S	S	R	R	S	S	R	S	S	3	0.3	NMDR
20	DS29	*S. pneumoniae*	R	S	R	R	S	S	S	R	R	5	0.6	MDR
21	SPT16	*S. pneumoniae*	S	S	R	R	S	R	S	S	R	4	0.4	NMDR
22	SPT18	*S. pneumoniae*	S	R	R	R	S	R	R	S	R	6	0.7	MDR
23	DS31	*S. pneumoniae*	S	S	R	R	S	S	S	S	S	2	0.2	NMDR
24	DS32	*S. pneumoniae*	R	S	R	R	S	S	S	R	S	4	0.4	NMDR
25	SPT24	*S. pneumoniae*	R	S	R	S	S	S	S	R	R	4	0.4	MDR
26	SPT28	*S. pneumoniae*	S	S	R	R	S	R	R	S	S	4	0.4	NMDR
27	DS37	*S. pneumoniae*	R	S	R	R	S	S	S	R	R	5	0.6	MDR
28	DS39	*S. pneumoniae*	S	S	R	R	S	R	S	S	R	4	0.4	NMDR
29	SPT30	*S. pneumoniae*	S	S	R	R	S	R	R	S	R	5	0.6	MDR
30	SPT33	*S. pneumoniae*	S	S	R	R	S	S	S	S	S	2	0.2	NMDR
31	DS40	*S. pneumoniae*	R	S	R	R	S	S	S	R	S	4	0.4	NMDR
32	SPT35	*K. pneumoniae*	S	R	S	S	S	R	S	S	R	3	0.3	NMDR
33	SPT36	*K. pneumoniae*	S	S	R	R	S	S	R	R	R	5	0.6	MDR
34	DS41	*K. pneumoniae*	R	R	R	S	R	R	S	R	S	6	0.7	MDR
35	DS43	*K. pneumoniae*	R	R	R	S	S	S	R	R	R	6	0.7	MDR
36	SPT37	*K. pneumoniae*	S	R	S	S	R	R	S	S	R	4	0.4	MDR
37	SPT42	*K. pneumoniae*	S	S	S	R	S	S	R	R	R	4	0.4	MDR
38	DS45	*K. pneumoniae*	R	R	R	S	R	R	S	R	S	6	0.7	MDR
39	DS47	*K. pneumoniae*	S	R	R	S	S	S	R	R	R	5	0.6	MDR
40	DS49	*K. pneumoniae*	S	S	R	R	S	S	R	R	R	5	0.6	MDR
41	SPT51	*K. pneumoniae*	R	R	R	S	R	R	S	R	S	6	0.7	MDR
42	SPT54	*K. pneumoniae*	R	R	R	S	S	S	R	R	R	6	0.7	MDR
43	SPT56	*K. pneumoniae*	R	S	S	R	S	R	R	S	S	4	0.4	MDR
44	DS50	*K. pneumoniae*	R	S	S	R	S	R	S	S	R	4	0.4	NMDR
45	SPT58	*K. pneumoniae*	S	S	S	S	S	S	R	R	S	2	0.2	NMDR
46	SPT59	*K. pneumoniae*	S	S	S	R	S	R	R	R	S	4	0.4	MDR
47	SPT62	*K. pneumoniae*	R	R	R	R	S	R	R	S	S	6	0.7	MDR
48	SPT65	*K. pneumoniae*	S	R	S	S	S	R	S	S	R	3	0.3	MDR
49	SPT67	*K. pneumoniae*	S	S	R	R	S	S	R	R	S	4	0.4	MDR
50	SPT70	*K. pneumoniae*	S	S	R	R	S	R	R	R	S	5	0.6	MDR
51	SPT73	*K. pneumoniae*	R	S	S	R	S	R	R	S	S	4	0.4	MDR
52	SPT74	*K. pneumoniae*	S	S	R	S	S	R	S	S	R	3	0.3	NMDR
53	SPT75	*K. pneumoniae*	S	R	R	R	S	S	R	R	S	5	0.6	MDR

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54	SPT80	*K. pneumoniae*	S	S	R	R	S	R	R	R	S	5	0.6	MDR
55	SPT82	*S. aureus*	S	S	S	R	S	R	S	S	S	2	0.2	NMDR
56	SPT84	*S. aureus*	S	S	R	S	S	R	S	R	R	4	0.4	MDR
57	DS53	*S. aureus*	S	S	R	R	S	R	S	R	R	5	0.6	MDR
58	DS57	*S. aureus*	S	S	R	R	S	S	S	S	R	3	0.3	NMDR
59	DS72	*S. aureus*	S	S	R	R	S	R	S	S	S	3	0.3	NMDR
60	DS77	*S. aureus*	S	R	R	R	S	R	S	R	R	6	0.7	MDR
61	SPT90	*S. aureus*	S	S	R	R	S	R	S	R	R	5	0.6	MDR
62	SPT92	*S. aureus*	S	S	S	S	R	S	S	S	R	2	0.2	NMDR
63	SPT94	*S. aureus*	S	S	R	R	S	R	S	R	R	5	0.6	MDR
64	SPT105	*S. aureus*	S	S	R	R	S	S	S	S	R	3	0.3	NMDR
65	SPT108	*S. aureus*	R	S	S	R	S	R	S	S	S	3	0.3	NMDR
66	DS86	*E. coli*	S	S	S	S	S	R	S	S	R	2	0.2	NMDR
67	SPT126	*E. coli*	S	S	S	R	S	R	S	R	R	4	0.4	MDR
68	SPT128	*E. coli*	R	S	R	R	S	S	S	S	R	4	0.4	NMDR
69	DS89	*E. coli*	S	S	S	S	S	R	S	S	S	1	0.1	NMDR
70	SPT140	*E. coli*	S	R	S	R	R	R	S	S	R	5	0.6	MDR
71	SPT146	*E. coli*	S	S	S	S	R	R	S	R	R	4	0.4	MDR
72	DS92	*E. coli*	R	R	S	R	S	S	S	S	R	4	0.4	MDR
73	SPT152	*E. coli*	S	R	S	R	R	S	S	R	S	4	0.4	MDR
74	SPT156	*E. coli*	S	R	S	R	R	R	S	R	R	6	0.7	MDR
75	SPT169	*E. coli*	S	S	R	R	S	R	S	R	R	5	0.6	MDR
76	SPT182	*E. coli*	R	S	S	R	S	S	S	S	S	2	0.2	NMDR
77	DS95	*E. coli*	R	S	S	S	S	R	S	S	R	3	0.3	NMDR
78	SPT187	*E. coli*	R	S	R	R	R	S	R	S	R	6	0.7	MDR
79	SPT192	*E. coli*	R	S	S	R	S	S	S	S	R	3	0.3	NMDR
80	DS102	*E. coli*	R	S	R	R	S	S	S	R	R	5	0.6	MDR
81	SPT208	*E. coli*	S	S	S	R	S	S	S	S	R	2	0.2	NMDR
82	SPT224	*E. coli*	R	S	R	R	S	S	S	R	R	5	0.6	MDR
83	DS202	*P. aeruginosa*	R	R	S	R	R	S	S	S	R	5	0.6	MDR
84	SPT232	*P. aeruginosa*	S	R	S	R	R	R	S	S	R	5	0.6	MDR
85	SPT238	*P. aeruginosa*	S	S	R	S	S	R	S	R	R	4	0.4	MDR
86	SPT42	*P. aeruginosa*	R	S	S	S	S	S	S	S	R	2	0.2	NMDR
87	SPT250	*P. aeruginosa*	S	R	R	R	S	R	S	R	R	6	0.7	MDR
88	DS247	*P. aeruginosa*	S	R	S	R	S	S	S	S	R	3	0.3	MDR
Percentage Resistance			39.8	30.7	55.7	71.6	14.8	47.7	26.1	43.2	62.5			
Percentage susceptible			60.2	69.3	44.3	28.4	85.2	52.3	73.9	56.8	37.5			
Percentage MDR														57.9
Percentage NMDR														42.1
Multiple antibiotic resistant index (percentage of isolates resistant to more than 2 antibiotics)												82.9		

Keys: AZT = Azithromycin, C= Chloramphenicol, AMC = Amoxicillin clavulanic acid, AMX = Amoxicillin, IMP = imipenem, CTX = Cefotaxime, CIP = Ciprofloxacin SXT = cotrimoxazole, TET = Tetracycline, MDR = multidrug resistant, NMDR = not multidrug resistant, NART = number of antibiotics resistant to, MARI = Multiple antibiotic resistant index, CRP = Classification of resistant profile

Streptococcus pneumoniae was most susceptible to imipenem (96.8%), ciprofloxacin (77.4%) and Chloramphenicol (77.4%) and highly resistant to beta-lactams (Amoxicillin (80.6%), Amoxicillin-clavulanic acid (64.5%)), and Tetracycline (51.6%) (Figure 3).

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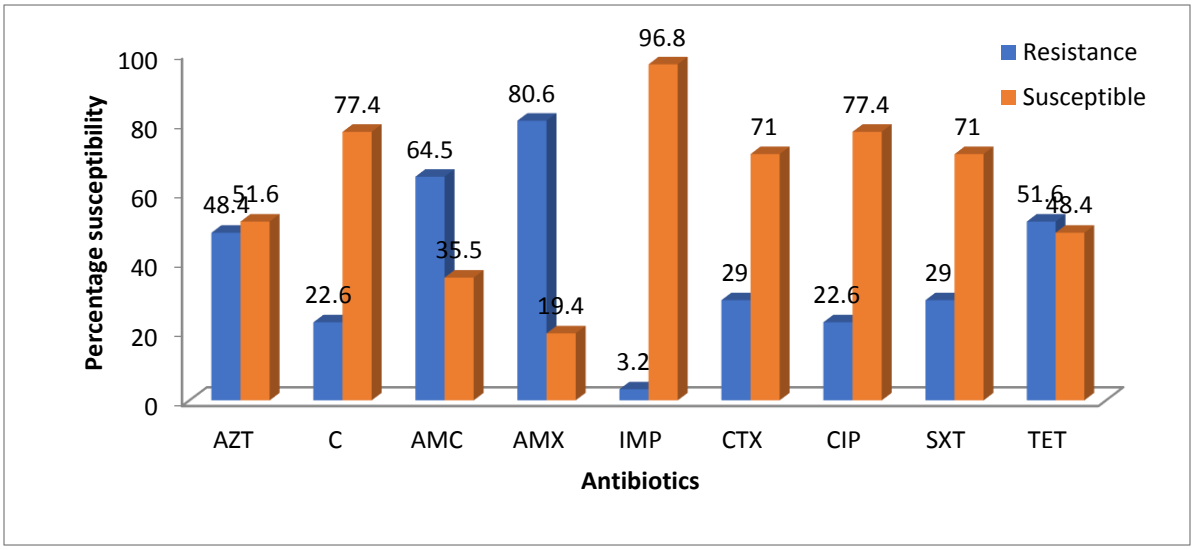

Figure 3: Antimicrobial susceptibility profile of *Streptococcuspneumonia* isolated from Pneumonia patients in Kaduna

Keys: Ciprofloxacin = CIP, Imipenem = IMP, Amoxicillin = AMX, Cefotaxime = CTX, Chloramphenicol = C, amoxicillin\clavulanate = AMC, azithromycin = AZT, tetracycline = TET, cotrimoxazole = SXT

Klebsiella pneumoniae was most susceptible to imipenem (82.6%), Azithromycin (60.9%) and Chloramphenicol (52.2%) and Tetracycline (52.2%), but resistant to ciprofloxacin (65.2%), cotrimoxazole (65.2%), beta-lactams (Amoxicillin-clavulanic acid (60.9%), Cefotaxime (60.9%) and Amoxicillin (52.2%)) (Figure 4).

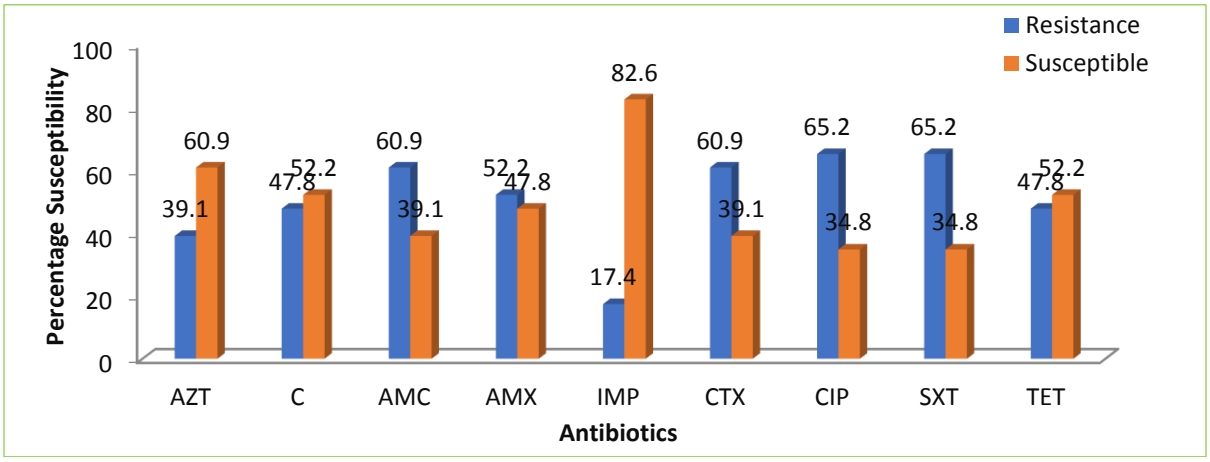

Figure 4: Antimicrobial susceptibility profile of *Klebsiellapneumonia* isolated from pneumonia patients in Kaduna

Keys: Ciprofloxacin = CIP, Imipenem = IMP, Amoxicillin = AMX, Cefotaxime = CTX, Chloramphenicol = C, amoxicillin\clavulanate = AMC, azithromycin = AZT, tetracycline = TET, cotrimoxazole = SXT

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Staphylococcus aureus was most susceptible to ciprofloxacin (100%). Imipenem (90.9%), Azithromycin (90.9%) and Chloramphenicol (90.9%) had the same activity profile against the isolates, while the isolates were mildly susceptible to cotrimoxazole (54.5%). *Staphylococcus aureus* isolates were also observed to exhibit resistance against beta-lactams (Amoxicillin (81.8%), Cefotaxime (72.7%) and Amoxicillin-clavulanic acid (72.7%)) and Tetracycline (72.7%) (Figure 5).

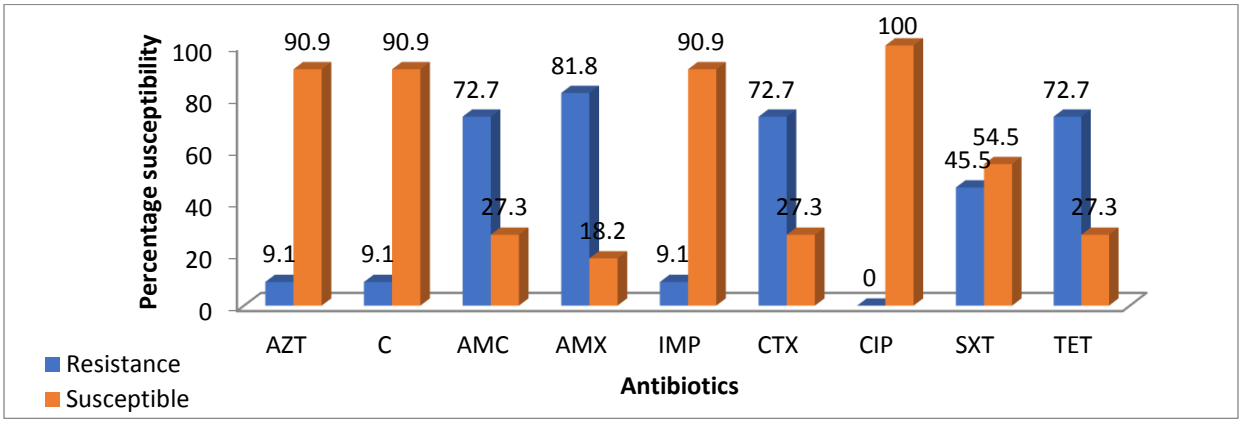

Figure 5: Antimicrobial susceptibility profile of *Staphylococcus aureus* isolated from pneumonia patients in Kaduna

E. coli was most susceptible to ciprofloxacin (94.2%), Chloramphenicol (76.5%), Imipenem (70.6%), and amoxicillin-clavulanic acid (70.5%), while the isolates were mildly susceptible to cotrimoxazole (58.8%), cefotaxime (52.9%) and Azithromycin (52.9%). *E.coli* isolates were also observed to exhibit resistance against Tetracycline (82.4%) and Amoxicillin (76.5%) (Figure 6).

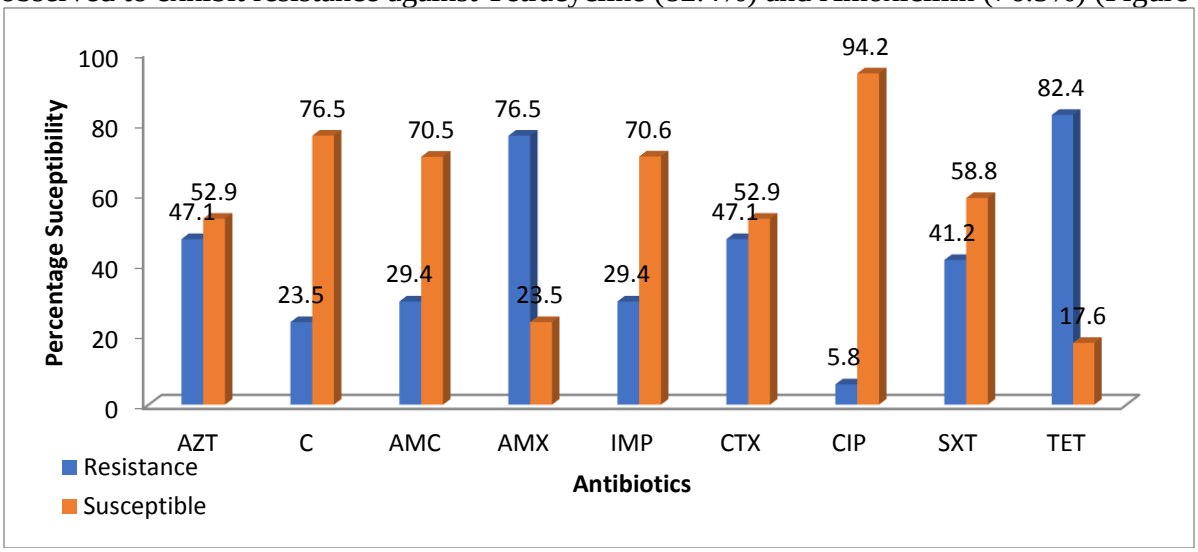

Figure 6: Antimicrobial susceptibility profile of *E. coli* isolated from pneumonia patients in Kaduna

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Pseudomonas aeruginosa was most susceptible to ciprofloxacin (100%), Imipenem (66.7%), Amoxicillin-clavulanic acid (66.7%), cotrimoxazole (58.8%), Azithromycin (66.7%) and cefotaxime (50%). *Pseudomonas aeruginosa* isolates were also observed to exhibit absolute resistance against Tetracycline (100%) and showed significant resistance against Chloramphenicol (66.7%), Amoxicillin (66.7%) and cefotaxime (50%) (Figure 7).

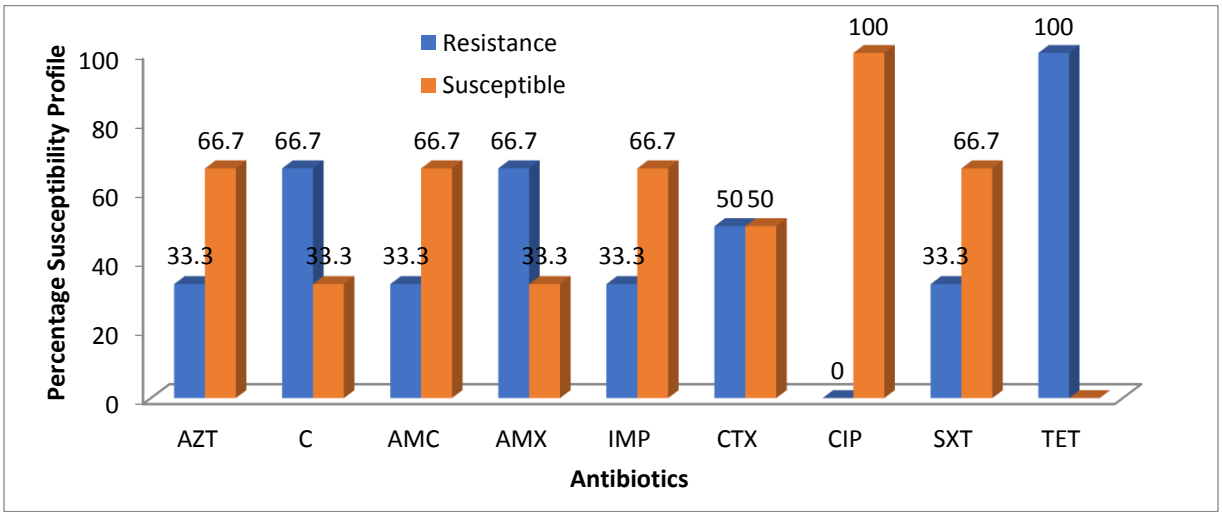

Figure 7: Antimicrobial Susceptibility Profile of *Pseudomonas aeruginosa* Isolated from Pneumonia Patients in BDTH, Kaduna

Ps. aeruginosa isolates (83.3%) had the highest multidrug-resistant profile among the isolates identified, followed by *K. pneumoniae* (82.6%), *Streptococcus pneumoniae* (71%) and *E. coli* (58.8%), while the least multidrug-resistant bacterium was *S. aureus* (45.5%) (Figure 8).

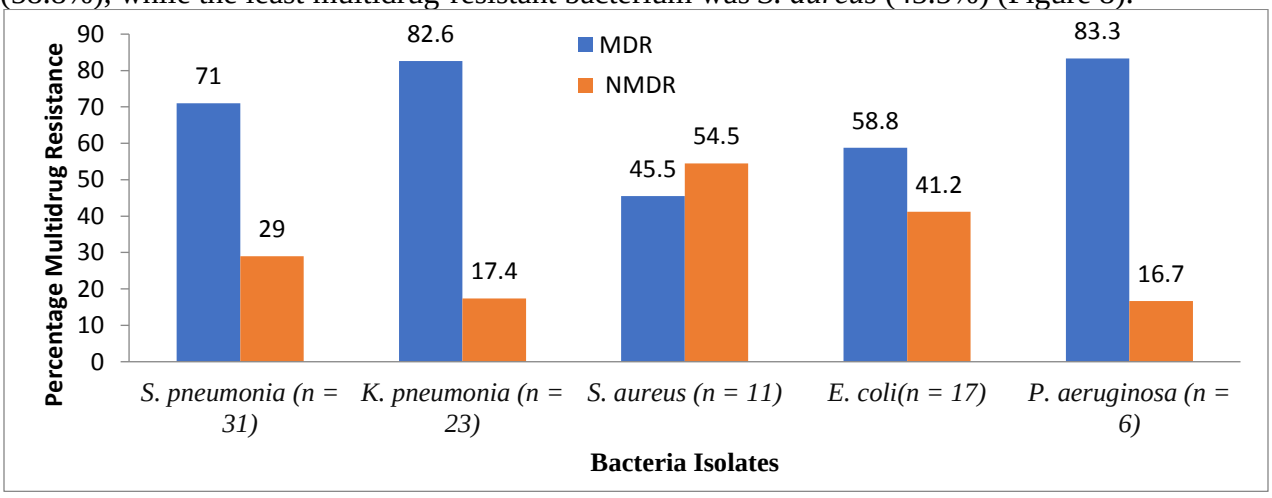

Figure 8: Comparative Assessment of Percentage Multidrug Resistance among Bacterial Isolates from Pneumonia Samples in BDTH, Kaduna

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DISCUSSION

Various studies have shown the deadly impact of pneumonia infection, accounting for one of the world's most common causes of mortality and morbidity in children, especially in Nigeria [37]). Demographic assessment in this study showed that male patients (62%) at Barau Dikko Teaching Hospital, Kaduna (BDTH) were more infected with pneumonia than females (38%). This finding is consistent with the study of [37], who reported an incidence of 68.42% male pneumonia infection at Kanti Children Hospital in the Department of Medicine in Nepal and [8], who also reported 50.7% incidence of pneumonia among male children at Dhaka Shishu (Children) Hospital in Bangladesh. Local comparison with other studies, such as, [27], who documented a male predominance among pneumococcal pneumonia patients in North-western Nigeria, a finding consistent with trends across sub-Saharan Africa and similarly, [15] study in a hospital-based pneumonia surveillance in rural Kenya found that pneumonia incidence peaked at 698 per 100,000 person-years among children under 5 years of age, a pattern directly comparable to the age distribution observed in the present study. The high occurrence of pneumonia in male children may be attributed to the possession of lower cellular immune and humoral responses to infections/antigenic stimulants compared to females [17]), giving their female counterparts a higher level of immunity that protects them against infection and inadvertently increases clearance of pathogens [26].[46] study involving 300 paediatric patients with severe pneumonia reported a 61% male predominance, supporting the recurrent pattern across diverse settings. [35], studying acute respiratory infections in children in a Nigerian tertiary hospital, confirmed that males are mostly infected with pneumonia and identified immunological differences as a key underlying mechanism. The high vulnerability of children under five years reported in this study is further corroboratedby [39], who documented that pneumonia is the leading cause of death among children under five globally, with the highest burden borne by sub-Saharan Africa due to socio-economic factors, poverty, exposure to hazards such as smoke, dust, etc. Among adults in low- and middle-income countries such as Nigeria, [23] had described that males are disproportionately affected by pneumonia partly due to immunological differences associated with the occupational exposure, X chromosome, and higher rates of tobacco use. From a public health standpoint, this sex disparity suggests the need for targeted health education campaigns that should be directed at male adults and caregivers of male children, emphasising early health-seeking behaviour and reducing risk factors such as indoor smoke exposure and tobacco use.

The high percentage of pneumonia infections among children aged 0–5 years (48%) as observed in this study further underscores a critical window for preventive intervention. Children under five years of age have immature immune systems and underdeveloped airways, rendering them particularly susceptible to lower respiratory tract pathogens. Similarly, the secondary peak among the elderly (≥70 years, 16%) reflects age-related immune senescence and comorbidities. These findings collectively point to the importance of targeted vaccination programmes, nutritional support, and improved access to paediatric and geriatric care in Kaduna State and similar settings across Northern Nigeria.

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The study recorded a 40.8% incidence of bacterial pneumonia among patients attending BDTH, with sputum samples yielding a higher bacterial growth rate (43.8%) than deep throat swabs (36.1%). This relatively high incidence rate highlights the considerable burden of bacterial pneumonia in the hospital's catchment population and raises concerns about diagnostic capacity and case management. The higher yield from sputum compared to deep throat swabs reinforces the importance of proper sample collection in clinical microbiology. From a public health perspective, an incidence of 40.8% in a tertiary care hospital suggests that bacterial pneumonia constitutes a major driver of hospital admissions, stretching already limited healthcare resources. This demands investment in diagnostic laboratory infrastructure, standardised specimen collection protocols, and the development of clinical guidelines tailored to local microbial epidemiology. Hospital-based incidence rates of bacterial pneumonia in similar African settings confirm the magnitude of the burden reported in this study. A retrospective study by [24] at Muhimbili National Hospital, Tanzania, found high rates of multidrug-resistant bacteria in sputum samples from pneumonia patients, with sputum identified as the most reliable specimen type for bacteriological diagnosis. [15] reported an 11.4% in-hospital mortality rate among 2,466 pneumonia inpatients in Kenya, underscoring the severity of the disease in resource-limited settings. [54] and global burden-of-disease estimates consistently identify sub-Saharan Africa as having among the highest rates of pneumococcal pneumonia, with Nigeria accounting for one of the largest absolute disease burdens on the continent. The World Health Organisation (WHO) has documented that pneumonia kills an estimated 2.5 million people annually, disproportionately affecting low- and middle-income countries where laboratory confirmation remains limited. Future research should employ standardised laboratory methods, including blood cultures and urinary antigen testing, alongside sputum microscopy and culture, to improve the sensitivity of pneumonia diagnoses. There is also a need for longitudinal, community-based incidence studies in Kaduna State and across Northern Nigeria to better characterise the epidemiological dynamics of bacterial pneumonia beyond hospital settings. Health facilities should be equipped with point-of-care diagnostics to reduce time-to-diagnosis and guide appropriate empirical treatment, while national and state health policies should prioritise infection prevention and control, including proper handwashing, respiratory hygiene education, and reduction of household indoor air pollution: all of which significantly modulate pneumonia incidence in low-income settings.

The dominance of *Streptococcus pneumoniae* (30.4%) as the leading pneumonia pathogen, followed by *Klebsiella pneumoniae* (22.6%), *E. coli* (16.7%), *S. aureus* (11%), and *Pseudomonas aeruginosa* (5.9%) at BDTH, Kaduna, mirrors global and regional patterns of bacterial pneumonia aetiology. The prominence of *S. pneumoniae* has critical public health implications, particularly given the availability of effective pneumococcal conjugate vaccines. A significant proportion (13.7%) of isolates remained unclassified by the identification kit used, pointing to diagnostic limitations in the laboratory. The presence of a diverse range of Gram-negative pathogens, including *Klebsiella*, *E. coli*, and *Pseudomonas*, alongside Gram-positives, suggests a mixed

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aetiology that complicates empirical treatment decisions and demands culture-guided therapy. The predominance of *S. pneumoniae* reinforces the urgency of robust pneumococcal vaccination campaigns in Nigeria, especially in Kaduna State, where vaccination coverage remains low. The preponderance of *S. pneumoniae* as the leading causative agent of bacterial pneumonia is well-established globally, as confirmed by [14], who note that *Streptococcus pneumoniae* has historically been the most common pathogen causing community-acquired pneumonia worldwide and currently accounts for up to 27% of pneumonia cases globally. [27] documented *S. pneumoniae* as the predominant pathogen in community-acquired pneumonia in North-western Nigeria, which is consistent with the present findings. [2,3] demonstrated that Nigeria bears the highest incidence of pneumococcal disease in Africa, with vaccine-type carriage declining significantly following the introduction of PCV10 in 2014–2016. [32], in a systematic review of East African studies, confirmed *S. pneumoniae* as the predominant opportunistic bacterial pneumonia pathogen across Sub-Saharan Africa. These convergent findings justify concerted efforts toward expanding pneumococcal vaccination in Kaduna and broader Northern Nigeria, while continued surveillance of bacterial aetiology of pneumonia in Kaduna is critical to tracking changes in pathogen distribution, especially in the post-PCV10 vaccination era. Future studies should employ molecular diagnostics such as PCR and whole-genome sequencing to accurately characterise unclassified isolates and monitor serotype replacements. Upgrading laboratory capacity at BDTH and similar secondary and tertiary care facilities across Northern Nigeria, including procurement of validated identification kits with broader speciation coverage, should be a priority for state health ministries. Collaboration with national reference laboratories (such as the Nigerian Institute of Medical Research) for serotyping of pneumococcal isolates would provide critical data to guide vaccine selection and procurement policies.

The antimicrobial susceptibility profile observed in this study presents a serious public health crisis. The high resistance rates to amoxicillin (71.6%), tetracycline (62.5%), amoxicillin-clavulanic acid (55.7%), cefotaxime (47.7%), and cotrimoxazole (43.2%), which are drugs that are among the most commonly prescribed first-line agents in Nigerian primary and secondary healthcare indicate that empirical treatment regimens routinely deployed in the region may be clinically ineffective against these pneumonia-causing organisms. The finding that 57.9% of isolates were multidrug resistant (MDR) is alarming and suggests widespread antibiotic selection pressure in the community and hospital environment, likely driven by over-the-counter access to antibiotics and incomplete treatment courses. The relatively preserved susceptibility to imipenem (85.2%), ciprofloxacin (73.9%), chloramphenicol (69.3%), and azithromycin (60.2%) provides some guidance for clinicians in life-threatening cases, but the reliance on reserve antibiotics raises concerns about escalating treatment costs and future resistance development. The high MDR rates documented in this study are consistent with evidence from across sub-Saharan Africa. [31], in a 12-year analysis of*Klebsiella pneumoniae* AMR data from Nigeria and South Africa, found consistently high resistance to multiple antibiotic classes, with imipenem and meropenem consistently

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showing the lowest resistance rates, corroborating the high imipenem susceptibility observed in the present study. A systematic review by [24] on MDR bacteria in pneumonia patients at Muhimbili National Hospital, Tanzania, reported that high MDR prevalence was associated with intensive care unit admission, mirroring patterns observed at BDTH. The [48] AMR fact sheet acknowledges that antimicrobial resistance threatens effective prevention and treatment of infections globally, with sub-Saharan Africa particularly burdened due to poor antibiotic stewardship and limited access to diagnostics. [34] in an Ethiopian multisite study on S. pneumoniae confirmed widespread multidrug resistance and called for strengthening antimicrobial stewardship programmes (ASPs), a recommendation equally applicable to the Nigerian context. The high MDR prevalence demands the immediate implementation of formal Antimicrobial Stewardship Programmes (ASPs) at BDTH and across healthcare institutions in Kaduna State. ASPs should include antibiotic formulary management, mandatory culture-and-sensitivity-guided prescribing, and regular review of prescribing patterns by a multidisciplinary team of clinicians, pharmacists, and microbiologists. The Nigerian government, through the Federal Ministry of Health, should enforce regulations restricting over-the-counter sales of antibiotics without prescription. A national AMR surveillance platform, linked to regional and global databases, is urgently needed to produce timely, actionable data on resistance trends. Future research should investigate the molecular mechanisms of resistance (e.g., ESBL production, carbapenemase genes) in bacterial isolates from pneumonia patients in Kaduna to guide infection control policy.

Differential assessment of each isolate's resistant profile further substantiates the high resistance of *S. pneumoniae* isolates to amoxicillin (80.6%) and amoxicillin-clavulanic acid (64.5%), which are the globally recommended first-line agents for community-acquired pneumonia in children and deeply calls for concern. Tetracycline resistance at 51.6% further limits therapeutic choices in settings where these drugs are widely used. The good susceptibility to imipenem (96.8%), ciprofloxacin (77.4%), and chloramphenicol (77.4%) offers alternative therapeutic options, though imipenem is not readily available in most primary healthcare centres in Nigeria. The practical implication is that patients presenting with pneumococcal pneumonia in Kaduna State are at high risk of treatment failure when managed empirically with beta-lactam antibiotics, necessitating more widespread adoption of culture-directed therapy. Beta-lactam resistance in *S. pneumoniae* is driven by mutations in penicillin-binding proteins (PBPs), which reduce antibiotic affinity. This mechanism has been well characterised by [6], who reviewed antimicrobial resistance in pneumococcus globally, documenting escalating resistance to penicillins, cephalosporins, macrolides, and trimethoprim-sulfamethoxazole. In the Nigerian context, [2], using whole-genome sequencing, found high rates of beta-lactam resistance and multidrug resistance genes in *S. pneumoniae* isolates from children in Kano and Abuja settings, geographically comparable to Kaduna. [27] similarly observed resistance to commonly used antibiotics in pneumococcal isolates from North-western Nigeria. Resistance of *S. pneumoniae* to amoxicillin-clavulanate, as documented in the present study, has also

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been reported by [34], who noted that inappropriate use of antibiotics is the principal driver of resistance emergence in Ethiopia and Africa broadly. Therefore, Clinicians in Kaduna must be alerted through Continuing Medical Education (CME) programmes to the diminishing efficacy of beta-lactam antibiotics against pneumococcal pneumonia, and empirical treatment guidelines at BDTH should be revised to reflect local susceptibility data. Investment in rapid diagnostic tools, including pneumococcal urinary antigen tests, should be prioritised to facilitate faster identification and targeted treatment. Pneumococcal vaccination with PCV13 or PCV20 for high-risk adults, including the elderly and immunocompromised, should be actively promoted alongside the existing childhood PCV10 schedule. Nationally, policymakers should consider accelerating the introduction of higher-valent PCVs that offer broader serotype coverage against resistant strains.

The susceptibility pattern of *Klebsiella pneumoniae* observed in this study, with high resistance to ciprofloxacin (65.2%), cotrimoxazole (65.2%), and multiple beta-lactams, while retaining susceptibility to imipenem (82.6%), azithromycin (60.9%), and chloramphenicol (52.2%), is a hallmark of a multidrug-resistant Gram-negative pathogen increasingly prevalent in resource-limited settings. The resistance of *K. pneumoniae* to fluoroquinolones (ciprofloxacin) is particularly troubling because ciprofloxacin is frequently used as an empirical alternative in patients with beta-lactam allergy or resistance. The public health implication is that *K. pneumoniae* pneumonia patients in Kaduna may have very limited safe and affordable treatment options, potentially driving increased morbidity, prolonged hospital stays, and mortality. The AMR profile of *K. pneumoniae* documented in the present study is consistent with regional data. [31] in their 12-year multi-country AMR analysis found that *K. pneumoniae* from Nigerian clinical samples showed high resistance to most antibiotic classes except imipenem and meropenem. [1] studying *K. pneumoniae* in South African hospital effluents found high susceptibility to imipenem (94.5%) and marked resistance to ampicillin (86.2%), tetracycline (69%), and cefotaxime (48%), patterns that strongly parallel this study's findings. [5] at the University of Gondar Hospital, Ethiopia, reported 85.7% imipenem susceptibility but alarming multidrug resistance in *K. pneumoniae* isolates. These convergent findings from Nigeria and across Africa emphasise the growing threat of MDR *K. pneumoniae* and the urgency of surveillance and stewardship. Future studies should systematically screen *K. pneumoniae* isolates for ESBL (Extended-Spectrum Beta-Lactamase) and carbapenemase production using phenotypic and molecular techniques, as these mechanisms could explain the observed high-level resistance. Infection control practices at BDTH, including strict isolation precautions for MDR Gram-negative infections, should be strengthened. The availability of imipenem and other carbapenem-class antibiotics should be safeguarded through policy measures that restrict their use to cases where microbiological evidence justifies their prescription, preserving their clinical utility as last-resort agents. Pharmacovigilance programmes should monitor community-level antibiotic consumption patterns in Kaduna to identify and curb irrational use.

Staphylococcus aureus isolates in this study demonstrated 100% susceptibility to ciprofloxacin, 90.9% susceptibility to

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imipenem, azithromycin, and chloramphenicol, representing a relatively more favourable antibiotic profile compared to the Gram-negative isolates. However, the high resistance to beta-lactam antibiotics amoxicillin (81.8%), cefotaxime (72.7%), and amoxicillin-clavulanic acid (72.7%) combined with tetracycline resistance (72.7%) identifies this strain as likely methicillin-resistant *Staphylococcus aureus* (MRSA) or a community-acquired beta-lactam-resistant strain. In the context of pneumonia, MRSA infections are associated with high mortality and pose a significant hospital infection control challenge. The finding that 45.5% of *S. aureus* isolates were multidrug resistant, the lowest among all tested species, still represents a substantial proportion requiring careful management. [24] at Muhimbili National Hospital reported that *S. aureus* was the dominant Gram-positive pneumonia pathogen, with 82.4% penicillin resistance and 50% of the isolates being MRSA, paralleling the high beta-lactam resistance documented in the present study. [16] highlighted that antibiotic management of *S. pneumoniae* and *S. aureus* requires careful consideration of resistance patterns, with imipenem and vancomycin remaining the most reliable agents for highly resistant strains. [28], in a systematic review of bacterial agents in febrile neutropenia in Africa, reported 68.8% methicillin resistance in *S. aureus* isolates across the continent. [46] identified*S. aureus* as a significant bacterial pneumonia pathogen in paediatric patients, reinforcing the need for MRSA screening in hospital settings. A systematic programme for MRSA screening and surveillance should be established at BDTH, particularly in the ICU, paediatric wards, and medical wards where pneumonia cases are concentrated. Microbiological confirmation of methicillin resistance using cefoxitin disc diffusion tests should be made routine. Clinicians should be counselled against the use of beta-lactam antibiotics for suspected *S. aureus* pneumonia, and ciprofloxacin or chloramphenicol, which showed high in vitro activity in this study, should be considered as alternatives, pending culture confirmation. Long-term research should track whether the 100% ciprofloxacin susceptibility observed persists, as fluoroquinolone resistance in *S. aureus* is increasing globally.

Escherichia coli is not a classical pneumonia pathogen, but its isolation from 16.7% of pneumonia cases at BDTH is notable, possibly reflecting aspiration pneumonia, nosocomial infections, or mixed infections in immunocompromised patients. The susceptibility pattern, high susceptibility to ciprofloxacin (94.2%), chloramphenicol (76.5%), and imipenem (70.6%), with resistance to tetracycline (82.4%) and amoxicillin (76.5%), is consistent with ESBL-producing *E. coli* strains commonly documented in African hospitals. The high amoxicillin resistance in this study is particularly concerning, given that amoxicillin remains the WHO-recommended first-line agent for childhood pneumonia across low-income countries. The resistance of *E. coli* to amoxicillin and tetracycline has been well documented in sub-Saharan Africa. [7], in a systematic review of antimicrobial stewardship in sub-Saharan Africa, found that *E. coli* isolates had a median 88.1% resistance to amoxicillin and 80.7% resistance to trimethoprim across the continent, rates highly concordant with the BDTH findings. Similarly, [36] in Zambia documented *E. coli* and *K. pneumoniae* as the dominant multidrug-resistant Enterobacteriaceae in both inpatients and outpatients, accounting for 75% of resistant

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isolates. WHO's classification of antibiotics acknowledges that ciprofloxacin (a 'Watch' group antibiotic) should not be first-line treatment, and its high susceptibility rate in *E. coli* at BDTH is a temporary asset that must be protected through stewardship. Epidemiological studies should investigate the source of *E. coli* pneumonia at BDTH, particularly the role of aspiration events, ventilator-associated pneumonia, and underlying immunosuppression (e.g., HIV, diabetes mellitus). Phenotypic ESBL screening should be incorporated into routine diagnostic testing, while clinical guidelines should advise clinicians to avoid amoxicillin and tetracycline as empirical treatment of pneumonia where *E. coli* is a plausible aetiology agent, and local resistance data indicate unreliable activity. Cross-disciplinary infection control measures, including hand hygiene audits, care bundle implementation for ventilated patients, and environmental sampling, should be institutionalised at BDTH.

Pseudomonas aeruginosa exhibited absolute resistance to tetracycline (100%) and significant resistance to chloramphenicol (66.7%) and amoxicillin (66.7%), while maintaining susceptibility to ciprofloxacin (100%), imipenem (66.7%), azithromycin (66.7%), and amoxicillin-clavulanic acid (66.7%). As an intrinsically resistant and highly adaptive Gram-negative organism, *P. aeruginosa* poses a unique challenge in hospitalised pneumonia patients, particularly those requiring mechanical ventilation or with compromised immunity. The 83.3% MDR rate in *Pseudomonas* is the highest among all isolates, and thus underscores an alarming severity of this pathogen in the BDTH context and its capacity to evade most available antibiotics through multiple efflux pumps, outer membrane porin mutations, and enzymatic resistance mechanisms. The intrinsic and acquired multidrug resistance of *P. aeruginosa* is a globally recognised clinical challenge. The StatPearls review on Carbapenem-Resistant Enterobacterales [53] explains that *P. aeruginosa* resistance mechanisms include carbapenemase production, efflux pumps, and decreased porin expression, making it one of the most difficult-to-treat hospital pathogens. [24] at MNH Tanzania reported that *P. aeruginosa* showed minimal resistance to ciprofloxacin (12.5%), consistent with the 100% susceptibility observed in this study, while demonstrating substantial resistance to co-trimoxazole and augmentin. [28], in a systematic review of bacterial agents in febrile neutropenia in Africa, noted that *Acinetobacter* and *Pseudomonas* were among the Gram-negative bacteria with the highest resistance rates on the continent, reinforcing the need for targeted AMR surveillance. Given the extraordinary MDR rate of *P. aeruginosa* at BDTH, there is an urgent need for molecular resistance profiling of these isolates, including testing for metallo-beta-lactamase genes (e.g., VIM, NDM and IMP). Future studies should determine whether resistance to imipenem is increasing, as any emergence of carbapenem-resistant *P. aeruginosa* would represent an irreversible therapeutic dead end. Empirical use of ciprofloxacin should be guided by regular local susceptibility updates, as fluoroquinolone resistance in *Pseudomonas* is increasing globally. Novel combination therapy strategies, including newer beta-lactam/beta-lactamase inhibitor combinations (e.g., ceftazidime-avibactam, imipenem-relebactam, etc.), should be explored in clinical trials relevant to the Nigerian context.

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The species-specific MDR ranking showed that *P. aeruginosa* (83.3%), resistant profile was the highest, followed by *K. pneumoniae* (82.6%), then *S. pneumoniae* (71%), *E. coli* (58.8%) and *S. aureus* (45.5%). This finding reveals that Gram-negative organisms dominate the MDR landscape at BDTH. This distribution has far-reaching public health implications for treatment guidelines, hospital infection control, and antibiotic stewardship in Nigeria. The overall 57.9% MDR rate, with 82.9% of isolates having a Multiple Antibiotic Resistance Index (MARI) ≥0.2, indicates that while resistance is prevalent, most isolates are significantly exposed to high antibiotic-use environments, providing a window of opportunity for stewardship and intervention to preserve remaining antibiotic effectiveness. The MDR hierarchy observed in this study is consistent with published patterns from sub-Saharan Africa. [31] noted that *K. pneumoniae* MDR prevalence ranged from 57–83% across Nigerian and South African healthcare settings, a range encompassing the 82.6% observed at BDTH. [24] confirmed the highest MDR burden in Gram-negative bacteria in pneumonia patients, with *Pseudomonas* exhibiting the most extensive resistance phenotypes. WHO's 2023 AMR fact sheet warns that projections indicate a twofold surge in resistance to last-resort antibiotics by 2035 compared to 2005 levels, unless robust stewardship practices are implemented, a trajectory that the BDTH data clearly foreshadow if no action is taken. The MARI index, widely validated in the literature for assessing the level of antibiotic resistance in diverse environments, has been used in multiple Nigerian studies to benchmark resistance levels against the 0.2 threshold, where values above this indicate bacterial populations from high-risk antibiotic-use environments. To further control this, a coordinated national response to multidrug resistance in Nigeria that encourages the establishment of a functional national AMR surveillance network linking tertiary hospitals, the NCDC, and the Federal Ministry of Health is nonnegotiable. More so, mandatory reporting of MDR pathogens isolated in all tertiary hospitals and regular updating of national empirical treatment guidelines based on local resistance data are vital to keep track of surveillance. More so, dedicated training of laboratory scientists and clinicians in AMR detection and management and further investment in research and development of alternative therapeutic strategies, including phytotherapy, bacteriophage therapy, and novel antibiotic combinations, appropriate to the Nigerian resource context, are empirical.

CONCLUSION AND RECOMMENDATIONS

This study isolated bacteria with multidrug resistant profile from pneumonia samples in Barau Dikko Teaching Hospital, Kaduna, Nigeria. The incidence of bacterial-associated pneumonia from the samples collected was 40.8%. The most occurring bacteria were *S. pneumoniae, K. pneumoniae, E. coli, S. aureus* and *P. aeruginosa.* The most effective antibiotics were imipenem,ciprofloxacin, azithromycin and chloramphenicol, while the isolates were resistant to amoxicillin, amoxicillin-clavulanic acid and tetracycline. Future epidemiological studies are encouraged, and such studies should employ a population-based surveillance strategy rather than hospital-based sampling to produce more representative estimates of pneumonia incidence, resistant profile, predisposing factors, ages and sex distribution of

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pneumonia in Kaduna State. There is an urgent need for community-level sensitisation targeting parents and caregivers, particularly on the importance of pneumococcal vaccination, breastfeeding, and prompt care-seeking for febrile children. Nigeria introduced the Pneumococcal Conjugate Vaccine 10 (PCV10) into its National Programme on Immunization in 2014; however, vaccination coverage remains suboptimal, especially in the northern geopolitical zones. Intensified outreach to rural communities, combined with the reduction of socio-economic barriers to healthcare access, is essential to close these coverage gaps. Additionally, community health workers should be trained to screen and refer elderly patients with respiratory symptoms for early microbiological evaluation, as delayed treatment in this group is associated with high case fatality.

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