Scientific Research Publishing

Open Journal of Medical Microbiology, 2022, 12, 184-203
https://www.scirp.org/journal/ojmm
ISSN Online: 2165-3380
ISSN Print: 2165-3372

Transitioning to Automated Microbiologic Era: Blood Culture Isolates in Children and Adults in Federal Teaching Hospital in Gombe, North East Nigeria 2016-2020

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How to cite this paper: Isaac, E.W., Jalo, I., Manga, M.M., Difa, A.J., Poksireni, M.R., Christianah, O., Mohammed, I. and Charanci, M.S. (2022) Transitioning to Automated Microbiologic Era: Blood Culture Isolates in Children and Adults in Federal Teaching Hospital in Gombe, North East Nigeria 2016-2020. *Open Journal of Medical Microbiology*, **12**, 184-203.
https://doi.org/10.4236/ojmm.2022.124016

Received: November 29, 2022
Accepted: December 27, 2022
Published: December 30, 2022

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Abstract

Introduction: Automated blood culture systems for incubation and growth monitoring have become the standard in high-income countries (HICs), but are still relatively expensive and not universally available for implementation in most low- and middle-income countries (LMIC). We aimed to report blood culture isolates using Automated technique in children and adults admitted into the Federal Teaching Hospital Gombe from 2016 to 2020. **Materials and Methods:** Blood Culture Isolates in children (0 - 18 years) and adults (>19 yrs) by Bactec 9050 Automated culture system from 2016-2020 were retrieved from the medical and laboratory register. Information analyzed included, age, sex, month, and year and culture growth and reported antibiotic sensitivity. A Bactec Blood culture tests is $20 in this facility. In Nigeria, the minimum monthly wage is $70 (Official currency exchange rate is N423/US Dollar). **Results:** Of the 1713 blood cultures performed, children 0 - 18 years were 1322 (77.2%) and adult (19 years above) (22.8%). Overall positivity was 733 (42.2%) with males 385 (52.5%). Of the 1322 Blood cultures (BC) in children 615 (46.5%) were positive for isolates and adults 118 (30.2)%. Blood culture positivity decreased with increasing age with newborns 251 (34.5%) and adults > 65 years 18 (2.5%). *Staphylococcus aureus* constituted 61.3% of all isolates and was the leading isolates in all age groups; *Alkaligenes* (9.1%); *Citrobacter* 8.1%, *Klebsiella* 6.7%; *Pseudomonas* 6.1%; *E. coli* 2.7%; *Enterococcus* 2%;

Proteus 1%. Of the Antimicrobial resistance priority isolates *E. coli* susceptibility ranged from 71% to Gentamycin and 100% to Cefixime; *Klebsiella* from 25% sensitivity to Amikacin to 78% each to chloramphenicol and ciprofloxacin; *Salmonella* was 100% sensitive to chloramphenicol, ciprofloxacin and cefuroxime. *Klebsiella* was 100% sensitive to Cefoxitin; *Proteus* sensitivity ranged from 35% to ampicillin and 100% to ciprofloxacin and cefuroxime. *Staph aureus* sensitivity was 35% to cefoxitin, 70% to amoxicillin/clavulanate and 70% to cefuroxime. **Conclusion:** Blood culture yield by Automated method was high. *Staph aureus* was the predominant pathogen and bacterial yield reduced with increasing age. Antibiotic sensitivity was variably reduced against gram negative bacteria.

Keywords

Children, Adults, Blood Culture Isolates, Bactec, Sensitivity

1. Introduction

Blood culture is the laboratory gold standard for the diagnosis of blood stream infection; it guides antimicrobial treatment and monitoring of antimicrobial resistant patterns [1]. BSI has emerged as a public health concern with especially rising drug resistance, morbidity and mortality worldwide [2]. Low- and middle-income countries bear disproportionately the burden of BSI [3] [4] [5]. Globally, there is some variation in key pathogens among regions. Studies [6] [7] [8] [9] from high income countries have reported *S. aureus*, *Escherichia coli*, *Klebsiella spp.*, *Pseudomonas aeruginosa* as some of the key pathogens of BSI in general while common BC isolates reported in Africa include *Salmonella enterica*, *Streptococcus pneumoniae*, *Staphylococcus aureus* and *Escherichia coli* [1] [10]. In Nigeria, a nationally representative epidemiologic data on BSI is lacking [11] and few BCI reports have used automated blood culture methods [12] [13] [14] [15] [16].

In earlier [11] and recent studies [17] in Nigeria, Obaro *et al.* [11] [17] reported *Staph aureus*, *Salmonella* and *Acinetobacter* and *Salmonella* respectively as leading isolates in children less 59 months in North central and North west Nigeria. The large sample size of this study is worth noting; however, it was limited by the age spectrum [11] [17]. Automated blood culture systems for incubation and growth monitoring have become the standard in high-income countries (HICs), but are still relatively expensive and not universally available for implementation in most LMICs [18]. Studies [19] [20] [21] from developing countries showed that automated systems show better performance than manual systems in terms of yield, sensitivity and especially speed of growth and overall turnaround time. We had earlier reported higher pathogen yield with Bactec compared to manual culture method in children in our facility [22].

Implementing automated blood culture in a resource-limited setting is possi-

ble and improves microbiological diagnostic performance [23]. In general, community acquired BSI are different from hospital acquired forms [24] [25] [26]. Yet of greater concern is rising to dangerously high levels of antibiotic resistance in all parts of the world. New resistance mechanisms are emerging and spreading globally, threatening the ability to treat common infectious diseases. Sub-Saharan Africa has the least comprehensive antimicrobial surveillance strategies of all world regions, alongside scarce infection prevention and control programmes [27]. A national reference laboratory for antimicrobial resistance and surveillance systems have become top priority for Nigeria [28]. With few reports of blood culture using automated systems in the country and paucity of similar reports in the North East Nigeria, we aimed to describe antibiotic susceptibility of blood culture isolates by automated system in children and adults in a tertiary health facility in Gombe North East Nigeria between 2016-2020.

2. Methodology

The Federal Teaching hospital Gombe is a 500-bed health facility; which started providing health services to the public in 2000. The hospital receives referral of patients from 5 neighbouring states in the North East subregion. The use of automated blood culture system in the microbiology department started in 2015.

Subjects

Blood culture samples from consecutive children and adult admissions from 2016 to 2020 with suspected blood stream infections or sepsis were obtained using the Hospital standard operation procedure which was communicated regularly to the departmental staff by Infectious Disease Training and Research Group and the Microbiology Department.

Blood culture isolates in children (0 - 18 years) and adults (19 years and above) (or rather, lets us ≥ sign) by Bactec 9050 Automated culture system from 2016-2020 were retrieved from the medical register. Information analyzed included, age, sex, month, and year of admission and culture growth.

The BD Bactec (R) 9050 instrument is designed for the rapid detection of microorganisms in clinical cultures of blood [29]. From 2021 Bactec FX40 was introduced in the microbiology unit to replace the Bactec 9050 equipment and Vitek II automated platform for identification and antimicrobial susceptibility testing (ID/AST) was introduced in 2022.

Principle

The Blood sample to be tested was inoculated into the vial which was entered into the Bactec 9050 for incubation and periodic reading. Each vial contains a sensor which detects increases in carbon dioxide, produced by the growth of microorganisms. The sensor was monitored by the instrument every ten minutes for an increase in its fluorescence, which was proportional to the amount of carbon dioxide present. A positive reading indicates the presumptive presence of viable microorganisms in the vial which are subsequently sub cultured for identification and antibiotic susceptibility testing. Clinical and Laboratory Standards Institute (CLSI) guideline for antibiotic susceptibility testing was used.

Quality Assurance was ensured and maintained in accordance with our hospital laboratory standard protocol for quality control and assurance.

3. Data Analysis

Data were entered into the EPInfo version 3.5.1 software and analyzed. Statistical significance was calculated using chi square and Fischer's exact test where appropriate. A p-value below 0.05 was considered as statistically significant.

4. Ethical Approval

Approval for this study was received from the Ethical Research Committee of the Federal Teaching Hospital Gombe.

5. Results

Figure 1 is the outcome of blood cultures during the study period between 2016 and 2020. There were 52,448 admissions between 2016 to 2020 with children and adults constituting 10,472 (20%) 41,976 (80%) respectively. The total number of blood cultures performed was 1767 giving an overall culture sampling rate of 0.06/patient admission. In children this was 0.1/patient admission and in adults this was 0.009/patient admission. Overall, 42.8% (733/1713) of the blood cultures in children and adults were positive for bacterial isolates.

Of the 1713 blood cultures 1322 (77.2%) were in children while 391 (22.8%) were in adults. Of the 1322 children, 615 (46.5%) tested positive while 118 (30.2%) out of 391 adult samples were positive and the difference was statistically significant ($p = 0.000$). Of the 932 males, 385 (41.3%) had positive culture results while 348 (44.6%) of 781 females tested positive. When children were compared based on gender, 286 (49.1%) females tested positive compared to male group, similarly in adult population, 62 (31.3%) females group tested positive compared to their male counterparts. However, the difference was not statistically significant ($p = 0.176$), ($p = 0.101$) and (0.621) respectively (Table 1).

Table 2 shows *Staph aureus* was the most prevalent bacterial isolate at 61.4% (450/733) and the most prevalent in all age groups too with the highest percentage (83.2%) in those > 65 years and the lowest among the newborns (49.4%). *Alcaligenes* and *Citrobacter* both gram negative pathogens were the second and third most common isolates in children and adults and the table shows the distribution of other isolates and their proportions across the age groups. Salmonella constituted 0.4% (3/733) of isolates; all in adolescents and young adults.

In Table 2, 63% of *Staph. aureus* isolates were in children 5 years and Eighty-four percent 84% (379/450) were in children 0 - 18 years; and decreased with age with those > 65 years having the lowest prevalence at 3.2% (15/450). *Alcaligenes* was most commonly isolated in the newborn period 41/67 (61.1%) with a second peak in those 19 - 46 years old 11/67 (16.4%).

Of the 59 isolates of *Citrobacter*, the newborn period had the peak isolation 27 (45.8%) with 88% (52) of *Citrobacter* found in children 0 - 18 years. Gram positive

Table 1. Blood culture results distribution among children and adults in Federal Teaching Hospital Gombe 2016 to 2020.

	Blood culture results		X^2	P-value
	Positive (%)	Negative (%)		
Characteristics				
Children	615 (46.5)	707 (52.5)	32.9	0.000*
Adults	118 (30.2)	273 (69.8)		
Sex				
Male	385 (41.3)	547 (58.7)	1.83	0.176
Female	348 (44.6)	433 (55.4)		
Children				
Male	329 (44.5)	410 (55.5)	2.694	0.101
Female	286 (49.1)	297 (50.9)		
Adult				
Male	56 (29.0)	137 (71.0)	0.245	0.621
Female	62 (31.3)	136 (68.7)		

Table 2. Distribution of blood culture isolates across age groups in FTH Gombe 2016-2020.

Isolate	0 - 28 days	29 days - 1yr	>1 yr - 5 yrs	6 - 9 yrs	10 - 18 yrs	19 - 45 yrs	46 - 65 yrs	>65 yrs	Total
S. aureus	124 (49.4)	80 (80.8)	102 (66.2)	30 (63.0)	43 (67.1)	42 (60.9)	14 (45.1)	15 (83.2)	450 (61.4)
Alkaligenes	41 (16.3)	0	6 (3.9)	1 (2.1)	4 (6.2)	11 (15.9)	4 (12.9)	0	67 (9.1)
Citrobacter	27 (10.7)	6 (6.1)	10 (6.5)	8 (17.0)	1 (1.6)	4 (5.8)	2 (6.5)	1 (5.6)	59 (8.1)
Klebsiella	21 (8.4)	4 (4.0)	12 (7.8)	2 (4.3)	5 (7.8)	2 (2.9)	2 (6.5)	1 (5.6)	49 (6.7)
Pseudomonas	14 (5.6)	1 (1.0)	10 (6.5)	6 (12.8)	6 (9.4)	2 (2.9)	5 (16.1)	1 (5.6)	45 (6.1)
E. coli	7 (2.8)	-	5 (3.2)	-	1 (1.6)	5 (7.2)	2 (6.5)	-	20 (2.7)
Enterococcus	7 (2.8)	4 (4.0)	3 (1.9)	-	1 (1.6)	-	-	-	15 (2.0)
Enterobacteriaceae	5 (2.8)	-	3 (1.9)	-	-	-	-	-	8 (1.1)
Salmonella	-	-	-	-	2 (3.1)	1 (1.4)	-	-	3 (0.4)
Proteus	5 (2.0)	1 (1.0)	1 (1.9)	-	-	1 (1.4)	-	-	8 (1.1)
S. saprophyticus	-	1 (1.0)	1 (1.9)	-	1 (1.6)	-	1 (3.2)	-	4 (0.5)
Strep faecalis	-	1 (1.0)	1 (1.9)	-	-	1 (1.4)	-	-	3 (0.4)
Strep viridans	-	-	-	-	-	-	1 (3.2)	-	1 (0.1)
Diphtheroid	-	1 (1.0)	-	-	-	-	-	-	1 (0.1)
TOTAL	251 (34.2)	99 (13.5)	154 (21.0)	47 (6.4)	64 (8.7)	69 (9.4)	31 (4.2)	18 (2.5)	733 (100.0)

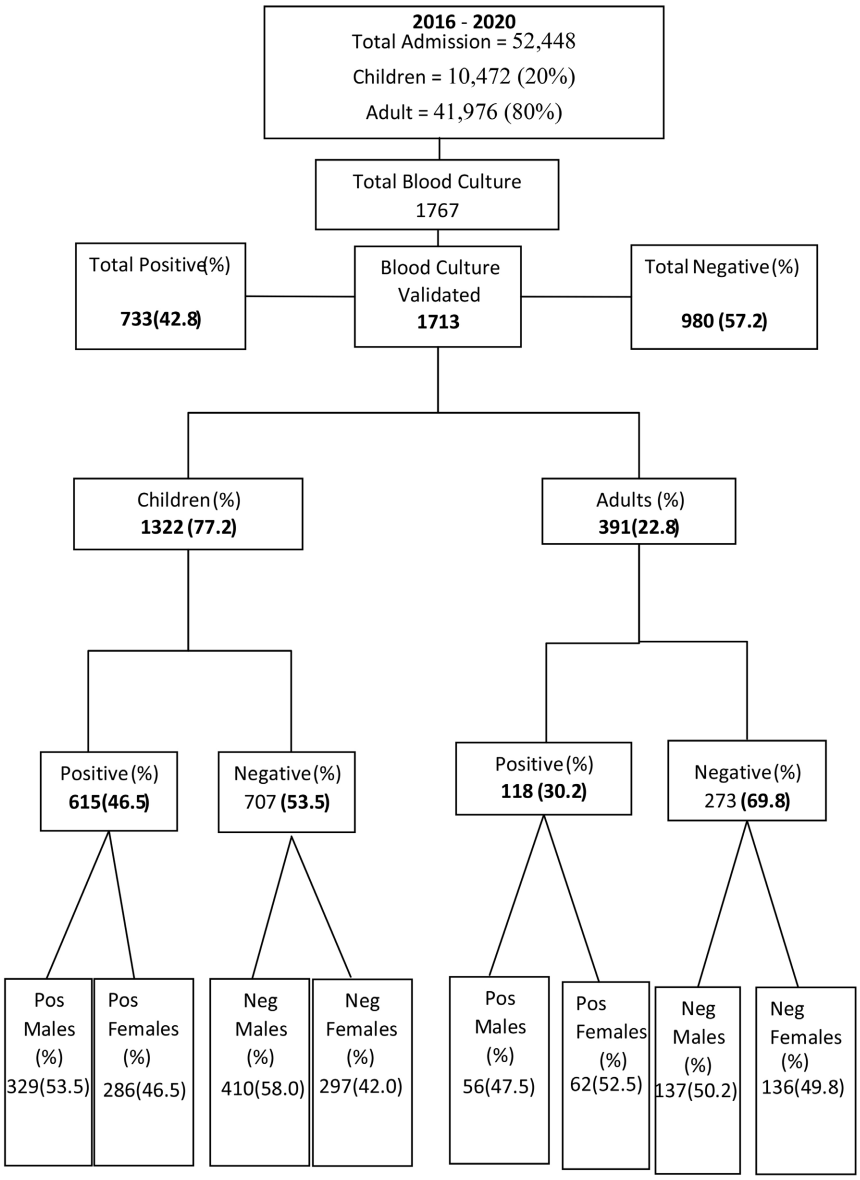

Figure 1. Flow chart of blood culture results of children and adults in federal teaching hospital, Gombe 2016-2020.

organisms constituted 63% (465) of isolates in all ages with *Staph aureus* being the most dominant at 96% (450/465). In the newborn period gram negative organisms predominated with 56% (14/251).

Table 1 and Table 2 showed the newborn period had the highest blood culture yield of 34.2% (251) with children under the age of five years contributing 69% (494) of bacterial isolates. Generally, Blood culture positivity decreased with decreasing age with those > 65 years having the lowest blood culture growth at 18 (2.5%). *Diphtheroid*, *viridans spp* and *Staph saprophyticus* were considered contaminants giving a contamination rate of 1.2%.

Table 3 presents the antibiotic susceptibility of the bacterial isolates to some commonly used antibiotics in all age groups with BSI. *Staph aureus* was 78%

Table 3. Percentage susceptibility of blood culture isolates in children and adults in Federal Teaching Hospital, Gombe 2016-2020.

	AMK	AMC	AMP	CRO	CIP	GEN	CTX	FOX	CXM	CHL
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
AMR priority pathogens										
E. coli	13 (56)	11 (46)	3 (15)	9 (38)	15 (64)	16 (71%	100%	12 (50)	8 (33)	15 (64)
S. aureus	282 (65)	338 (78	147 (34)	295 (68)	321 (74)	334 (77)	217 (50)	151 (35)	303 (70)	321 (74)
Klebsiella	1 (25	28 (56)	9 (17)	19 (38)	39 (78)	30 (60)	19 (38)	10 (20)	24 (48)	39 (78)
Salmonella	2 (67)	3 (100)	-	-	3 (100)	3 (67)	-	-	3 (100)	3 (100)
pseudomonas	7 (15)	14 (30)		35 (75)	38 (81)	25 (53)	15 (33)	47 (100)	18 (38)	40 (85)
Proteus	-	6 (80)	2 (33)	7 (100)	7 (100)	-	6 (50)	-	7 (100)	7 (100)
Non-AMR priority pathogens										
Citrobacter	25 (100)	31 (62)	7 (14)	50 (100)	44 (87)	36 (71)	33 (67)	25 (50)	39 (78)	41 (83)
Alkaligenes	35 (50	29 (42)	10 (15)	59 (85)	56 (81)	30 (43)	43 (62)	-	57 (82)	56 (81)
Enterococcus		-	13 (87)	-	-	-	-		100	-
Enterobacteriaceae	6 (67)		-	-	-	-	-	-	-	-
S faecalis	3 (100)	3 (100)	3 (100)		100	3 (100)	0	# (100)		3 (100)
S viridans	-	-	-		-	-		-		-
S saprophyticus	-	-	-		-	-		-		-

No data for blank cells. AMK: Amikacin; AMC: amoxycillin/clavulanate; AMP: Ampicillin; CRO: Ceftriaxone; CIP: Ciprofloxacin; GEN: Genticin; CFM: Cefixime, FOX: Cefoxitin, CXM: cefuroxime; CHL: chloramphenicol, CTX: cefotaxime.

susceptible to Amoxycillin-clavulanate, 74% to ciprofloxacin and 77% to Genticin. *Staph aureus* susceptibility to cephalosporins was between 50% - 70%. *E. coli* was 100% susceptible to CTX, 71% to Genticin and 64% to ciprofloxacin. Both *Citrobacter* and *Alkaligenes* had susceptibility to Ampicillin, ciprofloxacin, chloramphenicol and ceftriaxone that ranged from 81% to 100%. *Staph aureus*, the dominant Gram-positive bacteria had reduced susceptibility to cefoxitin which is a surrogate for testing susceptibility to oxacillin and in turn is a surrogate for testing reduced susceptibility or resistance to penicillin. *E. coli* had low susceptibility to ampicillin and cotrimoxazole but high sensitivity to ciprofloxacin and ceftriaxone. The cephalosporins, ceftriaxone and ceftazidime had reduced sensitivity to *Klebsiella*, however this priority pathogen was highly susceptible to the fluoroquinolone ciprofloxacin. *Pseudomonas* was not tested against meropenem; had reduced susceptibility to cephalosporins, moderately to cotrimoxazole susceptible to ciprofloxacillin and chloramphenicol. *Salmonella* was highly susceptible to ciprofloxacin, chloramphenicol, amoxicillin-clavulanate and the second-generation cephalosporin.

6. Discussion

While recommendations regarding the optimal sampling rate of blood cultures in children are not available [30], the blood culture sampling rate in this study is low and is even more so for adults compared to children. This is much lower than reports from South Africa [31] [32] and Gambia [33]. Studies have reported much higher blood culture rates [30] [31] [32] [33] [34]. While there is paucity of reports on sampling rates for blood culture, sampling of about 100 to 200 blood culture sets per 1000 patient-days is recommended as the target range for blood culture rates [35]. With blood stream infections strongly associated with HIV, malaria and malnutrition [3] [36] and other prevalent childhood conditions, blood culture sampling rate especially in sub-Saharan Africa should be a proxy and a clinical microbiology key performance indicator.

Automated blood culture systems for incubation and growth monitoring show better performance than manual systems in terms of yield, sensitivity and especially speed of growth and overall turnaround time [18] [20] [22] [37]. Utilizing this method, the blood culture yield of 42.8% in children and adults in this study is similar to 42% from India [38] but higher than 23% from Ghana [39], 12% from Rwanda [40] 20.7% from Ethiopia [41] and 24.8% from Nigeria [42]. Studies in Nigeria using automated blood culture systems in different child populations have reported culture yield of 35% from Lagos [15], 45.6% [43] and 40% from Kano [44], 42.7% from Ife [45] and 31.8% from Maiduguri [46]. In large child population studies on bacteraemia in Nigeria, Obaro *et al.* [11] [17] reported positive blood culture range of 7.5% to 20.7% using automated methods.

While numerous factors such as prior antibiotic use, blood volume, blood stream infection periodicity, causative organism, bacteria density in the bloodstream, contribute to Blood Culture sensitivity, antibiotics prior to BC sampling decreases the rate of culture positivity by 45% - 50% [47] [48] [49].

This study did not report prior antibiotic use before blood culture, but over the-counter antibiotic use is very prevalent in Nigeria [15] [50] [51] and this is likely to impact the outcome of any study aimed at the determination of the causes of bacterial infection in children. It is possible that this healthcare seeking behavior may on itself modify the spectrum of prevalent bacteria pathogens and the overall yield [11]. Reports from sub-Saharan Africa showed high levels of antibiotic use before blood culture [52].

Children constituted majority of patients who had blood cultures in this all-age study. Similar reports from India [38], Ghana [39], Rwanda [40], Ethiopia [41] and Ibadan in Nigeria [42] showed that children constituted 73%, 60%, 56%, 63% and 82% respectively of all age group that had blood cultures. Invasive bacterial disease is the leading cause of mortality in children in developing countries especially sub-Saharan Africa related to child host factors, pathogen virulence, load and contextual factors [53] [54].

In this report, *Staph aureus* was the dominant isolate in both children and adults of all ages. Similar children and adult blood culture studies using auto-

mated method in Ghana [39] [55] Rwanda [40], Ethiopia [41] and Ibadan in Nigeria [42], *Staph aureus* was the leading isolate. Utilizing this method but in children, *Staph aureus* was the predominant isolates in reports from South Africa [56], Ethiopia [57], Afghanistan [58], Nepal [59], Guinea Bissau [60], Tanzania [61], India [62] and Gambia [63]. In a largely children blood culture report in Benin Republic [64] using automated method, *Klebsiella*, *Salmonella* and *Staph aureus* were the top three pathogens with higher pathogen rates among neonates and children between 5 and 15 years of age.

More males had positive blood cultures than females in children while in adults this was the reverse. There are reports of significant association between male gender and the development of community- and healthcare-associated BSI [65] [66]. The precise mechanisms by which gender might influence infection risk are unclear, but could possibly be related to differences in skin colonization or unknown anatomical differences between men and women [65].

While *Staphylococcus aureus* was the most commonly isolated specie in young bacteraemic infants followed by, *Escherichia coli and Klebsiella spp*. in six countries [67]; Mduma *et al.* [5] reported most frequent pathogens identified by blood culture were *Klebsiella pneumonia* and *Staphylococcus aureus*, followed by *Escherichia coli* in infants in Sub-Saharan Africa. A Systemic Review and Meta Analysis [10] in children 1 - 18 years old, whereas in Africa, *S. aureus* and *Streptococcus pneumoniae* were predominant isolates followed by *Escherichia coli* in the continent, in Asia, *Salmonella typhi* was the most commonly isolated pathogen, followed by *Staphylococcus aureus*. In an India neonatal and pediatric blood stream infection review report, *Staphylococcus aureus* and *Klebsiella pneumoniae* were the commonest reported Gram-positive and Gram-negative pathogens, respectively [68]. While the limitations of these studies [5] [10] [62] [63] were noted, nationally representative multicenter clinical microbiology laboratories in sub-Saharan Africa are urgently needed to provide coordination and management in this direction.

In Nigeria, *Staph aureus* was the most commonly reported isolate in paediatric studies from Central Nigeria [11], Lagos [15], Maiduguri [46], Kano [69], Ekiti [70], Uyo [71]. A recent study from Uganda [72] and a systemic review and meta-analysis of the aetiologic agents of neonatal sepsis in Sub-Saharan Africa [73] established *Staphylococcus aureus*, *Escherichia coli*, *and Klebsiella pneumoniae* respectively as the predominant aetiologic agents. In a Switz prospective population-based study involving children < 17 years *Staphylococcus aureus*, *Klebsiella spp*, and *Escherichia coli* were the commonest isolates reported [74]. While methodologic issues like inclusion criteria, population attributes vary significantly among these studies quality control and assurance are critical factors to be considered in any clinical microbiology laboratory, these factors affect pathogen identification and yield especially in sub-Saharan Africa where severe laboratory constraints and gaps exist [3] [10] [75].

Blood culture isolates were generally lower in adults compared to children in this study and the isolation rate declined with decreasing age. Immunologic im-

maturity, deficits in immunization, underlying clinical conditions and exposure to health facilities remain important risk factors for infection in children. Low socioeconomic status of parents, poor hygiene and sanitation standards, high incidence of home delivery and bottle feeding are also contributory factors [76].

Among adults, Blood culture isolates vary widely among patients, regions and settings; Sepsis in SSA is dominated by HIV and tuberculosis [77]. In an early SRMA by Reddy *et al.* [3] *Salmonella enterica* was the most prevalent isolate overall and in adults, and *Streptococcus pneumoniae*, was the most common isolate in children in sub-Saharan Africa however the methods of identification of organisms varied between the studies.

In a non nationally representative data from Mozambique, *S. aureus*, *E. coli and non-typhoidal salmonella* dominated [78], and in Ethiopia [79] with a positive culture yield of 40.6% with *Klebsiella* and *E. coli* being the commonest, while *Staph aureus* and *Klebsiella* predominated in a Uganda report [80].

As a principle, blood cultures positive for *S. aureus* always need to be respected as a clinically significant finding and should result in an appropriate treatment [81]. While S aureus may cause blood culture contamination, the observation of a single positive blood culture bottle for *S. aureus* should trigger a thorough investigation and clinical correlation is prudent as its associated mortality remained high, and complications, including infective endocarditis occur [82].

Klebsiella/*Alkaligenes* and *Citrobacter* were second and third leading blood isolates in this study and were most common in children. The prevalence of Alcaligenes of 9.1% in this study is comparable to 10.2% from Ghana [40] but much higher than the <1% reported by both Reddy *et al.* 3 in a Systemic Review and Meta Analysis in Sub-Saharan and Mordi *et al.* [83] in Nigeria. In Blood culture reports from Benin [84] and Abuja [85] in Nigeria a decade earlier using manual methods, *Alcaligenes* constituted 4.3% and 2% of isolates respectively. Both are potentially emerging pathogen and usually causes opportunistic infections in humans most commonly reported cases involved bacteremia, and most occurred in newborns and infants [86] [87].

Citrobacter is a gram-negative bacillus and constituted 1.3% [46], 1.9% [83] of blood cultures isolates in Nigeria studies; 0.3% each in Rwanda [40] and Uganda [72], 3% in Ethiopia [41] and 15% in Ghana [88]. While methodologic variations may account for these differences, *Citrobacter* spp. are opportunistic pathogens in humans that can lead to invasive disease, with sepsis and meningitis as the most common clinical manifestation in neonates and infants [89].

Salmonella is a major cause of bacteraemia in Africa especially in children. [90] [91]. *Salmonella* isolation in this study was low and was in older children and young adults. This is similar to studies from Kano [69], Uyo [71] and Ilorin [92] but in contrast to reports from North central and North western Nigeria where only children 5 years and below where studied [17]. *Salmonella* BSI was high in studies in children with protein energy malnutrition [43], Sickle Cell Disease [44] and HIV [69] in Nigeria. In a population based, multi-country Ty-

phoid fever Surveillance in Africa Programme [93] in which Nigeria was not included, the most frequent non-contaminant bacteria isolated were *S. typhi* 24%, *Non-Typhoidal Salmonella* 17%, *S. aureus* 12%, *E. coli* 8%, and *Streptococcus pneumoniae*. A well-coordinated multi centre and nationally representative bacteraemia surveillance programme is highly needed in Nigeria.

The absence of *Streptococcus pneumonia* as an isolate was worth nothing in this study. This is similar to recent reports from Maiduguri [46], Kano [66] and Ilorin [88] in Nigeria but in contrast to the studies from Central Nigeria [11] [17], Kano [43] [44] [89] and Ibadan [42] where the prevalence of *S. pneumoniae* bacteraemia was high. This contrasting finding in Nigeria has been demonstrated in the continent in reports from Benin Republic [18], South Africa [31], Ghana [39], Ethiopia [57], Guinea Bissau [60], and Tanzania [61]. While *Strep. pneumoniae* immunization coverage in Nigeria is very low with wide variation, prehospital antibiotic use, hosts and environmental factors could influence the prevalence of this pathogen [94].

The contaminant rate of 1.2% in our study is similar to report from Nigeria [14], Uganda [72] and Ghana [88] but lower than report from Nigeria [11], Gambia [33] and South Africa [56]. There is wide variation in both contamination frequency and pathogens considered to be contaminants [14] [57] [88].

With the increasing levels and growing threat of antimicrobial resistance globally, surveillance for bacterial resistance especially for priority pathogens becomes top items on the agenda of health [95]. A sharp surge in bacteria-encoding resistance is occurring worldwide, jeopardizing the efficacy of antibiotics that have saved millions of lives [96]. In general, knowledge of local organisms and their sensitivity and resistance profiles is invaluable for development and revision of antimicrobial guidelines in hospitals [56] [95].

In this study *Staph aureus*, the dominant Gram-positive bacteria had reduced susceptibility to cefoxitin which is a surrogate for testing for MRSA. We previously reported prevalence of MRSA of 84.6% in blood specimen in our centre [97].

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a well-recognized public health problem throughout the world and extended resistance to other non-β-lactams including vancomycin has only amplified the crisis [98].

Gram negative bacteria *E. coli*, *Klebsiella and Pseudomonas* had low to moderate sensitivity to cephalosporins and the penicillin especially the first line antibiotics. This was similar to an earlier report from our centre [99]. Duru *et al.* [87] showed resistance to commonly used antibiotics in bacteraemic infants caused by EBSL Enterobacteriaceae in Nigeria. This is similar to a finding in West African sub region [100] where common blood stream pathogens had moderate levels of AMR. In Sub-Saharan Africa among neonates, Gram-negative organisms were the predominant cause of early-onset neonatal sepsis, with a high prevalence of extended-spectrum β-lactamase-producing organisms and Gram-positive bacteria were responsible for a high proportion of infections among children beyond the neonatal period, with high reported prevalence of non-susceptibility to treatment advocated by the WHO therapeutic guidelines [101]. Gram-negative

bacteria are an important cause of neonatal sepsis in LLMICs and are associated with significant rates of resistance to WHO-recommended first- and second-line empirical antibiotics [102]. The looming threat of AMR is ominous. In 2019, sub-Saharan Africa (SSA) had the highest mortality rate (23.5 deaths per 100,000) attributable to AMR compared to other regions and it is estimated that by 2050, mortalities attributed to AMR will have increased to 10 million annually, with Africa and South Asia bearing the highest burden of deaths [103]. AMR surveillance globally and in sub-Saharan Africa especially have become medical microbiologic imperative and a public health priority.

Limitations of the Study

We were unable to disaggregate patients into community or hospital acquired blood stream infection and also determine prehospital treatment with antibiotics. Only one blood culture bottle was used on account of cost. Significantly, we could not establish individual blood culture procedure in the ward and laboratory even when infectious disease technical working group and IPC committee exists in the hospital.

7. Conclusion

Blood culture isolation yield by automated method was high in children and adults in our health facility and this decreased with increasing age. In all ages, staph aureus was the predominant bacterial isolate. Susceptibility of some common blood pathogens to penicillin and some cephalosporins is low to moderate.

8. Recommendations

Continuous standardization of blood culture methods should be sustained and communicated regularly to all health staff involved in the procedure. Nationally representative multicenter AMR surveillance clinical microbiology laboratories require establishment in Nigeria.

Acknowledgements

Hajiya Fatima and Hafsat Sabo of the Paediatric Data unit for extraction of data from the clinic and laboratory registers.

Funding

No funding was received for this study.

Author Contribution

WEI conceived of the study and study design, developed the first manuscript draft, and critically reviewed all drafts of the manuscript.

IJ, MM and IM critically reviewed bacterial isolates and reviewed draft manuscript.

AJD and CO conducted quantitative analysis and critically reviewed the final manuscript.

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