Egyptian Pediatric
Association Gazette

Neonatal sepsis-a peek into our findings in Northwest Nigeria: a prospective study

Samaha S. Mustapha[1*], Aishatu Musa Zaidu[1], Nanret Tanko Azaria[2], Shamsudin Aliyu[3] and Isa Abdulkadir[4]

Abstract

Background   Neonatal sepsis is still a global health concern as it contributes to a high burden of neonatal morbidity and mortality especially in developing countries. The aim of the study is to give an insight into neonatal sepsis: risk factors, sepsis types, clinical features, pathogen burden with their antibiotic sensitivities, and outcome of admission in our facility. The study was a prospective hospital-based study conducted over 10 months, October 2018–July 2019.

Result   Of the 248 term neonates with features of sepsis enrolled in the study 94 (37.9%) were confirmed to have sepsis. Late-onset sepsis LOS (68%) was found to be the most common, and most of the neonates were delivered elsewhere. Clinical features were non-specific for both early-onset (EOS) and LOS and include fever, jaundice, poor suck, and depressed primitive reflexes. Infections were mostly caused by gram-negative bacteria, and while *Staphylococcus aureus* was the single most common isolate for both EOS and LOS. Antibiotic sensitivity was highest with ciprofloxacin for both EOS and LOS. Mortality was high at 14.9% and was mostly contributed to by *Staphylococcus aureus* infection.

Conclusion   Neonatal sepsis is still a burden with mostly non-specific clinical features. The local prevalent organisms were *Staphylococcus aureus*, *Enterobacter agglomerans* and *Klebsiella pneumonia* with good antibiotic susceptibility to ciprofloxacin. Most presented with late-onset sepsis and therefore infection is likely to be community-acquired which to a great extent can be prevented with robust public health interventions.

Keywords   Neonatal sepsis, Late-onset sepsis, Early onset sepsis, Gram-negative bacteria, Gram-positive bacteria, Antibiotic sensitivity

Background

The definition of neonatal sepsis is heterogenous and has undergone through a lot of metamorphosis over the years. The term neonatal sepsis ((NS) is used to designate a systemic condition of bacterial, viral, or fungal origin that is associated with haemodynamic changes and other clinical manifestations and results in substantial morbidity and mortality [1]. In 2005, Goldstein et al. defined NS as systemic inflammatory response syndrome (SIRS) in the presence or as a result of suspected or proven infection occurring in the first 28 days of life and paediatric SIRS with accompaning temperature or leukocyte abnormalities [2]. Therefore, NS encompasses various systemic infections of the newborn such as meningitis, pneumonia, arthritis, osteomyelitis, and urinary tract infections [3, 4]. Seventy-five percent of global neonatal mortality burden is caused by prematurity and low birth weight, infections, asphyxia, and birth trauma with neonatal infection alone contributing 18% [5, 6]. The low-income earning countries account for 80% of the world's neonatal death burden [7], and in Nigeria, the Northwest and Kaduna state has the highest burden of mortality with Neonatal Mortality Rate (NMR) of 46 and 63 per 1000 live births, respectively [8]. Serious infections

*Correspondence:
Samaha S. Mustapha
samahamustapha@yahoo.com
[1] Department of Paediatrics, Abubakar Tafawa Balewa University, Bauchi, Nigeria
[2] Department of Medical Microbiology, Ahmadu Bello University Teaching Hospital, Zaria, Nigeria
[3] Department of Medical Microbiology Ahmadu, Bello University, Zaria, Nigeria
[4] Department Paediatrics Ahmadu, Bello University, Zaria, Nigeria

(sepsis, pneumonia, and meningitis) accounted for 44% of such deaths with NS alone accounting for 23–30% [9]. Neonatal sepsis is broadly classified into early or late-onset based on the age at onset of clinical features. This classification helps to guide antibiotic therapy as it implies differences in the presumed mode of transmission, differing aetiology, and pathophysiology of the pathogens [10–12].

Early-onset sepsis (EOS) is variably defined as sepsis within zero to 48–72 h of birth, while some define it as that which occurs within the first 7 days of life [3, 13, 14] It may present with subtle early signs or as a fulminating septicaemic illness with pneumonia being the commonest focal infection [3]. It reflects transplacental or more frequently, ascending infections from the maternal genital tract [3, 4, 15].

Infection occurring 48–72 h after birth [3, 11, 15] or after 7 days and up to 30 days of life [14, 16] is termed late-onset sepsis (LOS). It is acquired either as nosocomial (hence the term "Health Care Acquired Infection" HCAI) or community-acquired infection and is frequently associated with meningitis [3, 4, 14].

The risk factors for NS are numerous and are dependent on the type of sepsis and environment, while in developed countries, factors such as maternal GBS colonization and advanced invasive procedures are top-most; developing countries are still battling with factors related to poor hygiene.

Several pathogens have been associated with sepsis in the neonatal period. The predominant agents are bacterial, but viruses have also been associated with fulminant infection with high mortality [17]. In most developing countries, gram-negative bacteria remain the major source of infection, while in developed countries, it is gram-positive bacteria [18].

The common organisms implicated in EOS include *Group B streptococci, Escherichia coli, Streptococcus viridans, Enterococci, Staphylococcus aureus, Pseudomonas aeruginosa*, and other gram-negative bacilli, while for LOS, it includes *Coagulase-negative Staphylococci (CoNS), Staphylococcus aureus, Escherichia coli, Klebsiella pneumonia, Enterococci, Pseudomonas aeruginosa*, and *Group B streptococci* [14]. Work done by various authors in different parts of the world shows differences in the frequency of causative organisms. The pathogenesis of sepsis is complex, and the prevailing, although debated theory, is that sepsis occurs when the host response overwhelms the protective mechanisms in place, resulting in a superimposing injury to the patient in addition to the infection that initially triggered this response [18]. Clinical symptoms and signs of sepsis in newborns vary with gestational age and severity of the infection. However, in most cases, features of both EOS

and LOS are subtle and non-specific and may evolve [19]. Sepsis may be fulminant, leading to death in several hours from multiorgan failure, or maybe more protracted. The most frequent features are lethargy, poor feeding, abdominal distention, prolonged capillary filling time, glucose intolerance, and unexplained persistent acidosis [20]. The gold standard investigation for diagnosis of NS remains blood culture although it is time-consuming, cumbersome [15, 21], and has low sensitivity (25%) [22]. Supporting investigations include culture of bloody fluids, complete blood count, inflammatory markers, and advanced tests like polymerase chain reaction and MALDI-TOF Mass Spectrometry. Prompt and effective therapy is important as neonates with infection often deteriorate rapidly. It involves supportive care, antimicrobial therapy, and host defence modulation [20].

The aim of the study is to determine the sepsis type, risk factors, mode of presentations, implicated organisms and their sensitivities, and the outcome of proven neonatal sepsis in term neonates in our centre.

Methods
Study location
The study was conducted at the neonatal unit of Ahmadu Bello University Teaching Hospital (ABUTH)—a tertiary hospital located in Zaria, Kaduna State. The unit has a 30-bed capacity across its in-born and out-born wards and an average number of 900 admissions per year over serving Kaduna and other neighbouring states.

Study design
It was an observational prospective cross-sectional study conducted over a 10-month period from October 2018 to July 2019 of term neonates that were evaluated for sepsis.

Study population
Consecutive term neonates presenting with at least three or more risk factors and/or clinical features suggestive of sepsis and admitted into the neonatal unit were recruited for the study.

Ethics
Ethical approval for the study was obtained from Ahmadu Bello University Teaching Hospital Health Research Ethics Committee with ref no *ABUTH/HREC/ CL/05*. Parental consent was obtained for all neonates before recruitment.

Data collection
A structured questionnaire was used to obtain the socio-demographic characteristics and details of perinatal events from patients' relatives/carers. Their samples were taken at admission for blood culture, complete blood

count (CBC), C-reactive protein (CRP), and procalcitonin (PCT).

Bacterial identification and susceptibility testing

Blood specimen (3 ml) from neonates with presumptive bloodstream infections were taken under aseptic condition and immediately transferred blood culture bottle containing 15 ml of Brain Heart Infusion (BHI) and incubated aerobically at 37 °C for 24 h. Broth with signs of growth were immediately removed and sub-cultured on 5% Sheep blood and MacConkey agar plate and incubated in the same condition as the broth above. Growths from both culture plates were examined and gram-stained. Isolates were sub-cultured on Nutrient agar (NA) for further identification and biochemical testing. Microbact™ 24E (Oxiod UK) and Staph ID were used to identify the organisms according to the manufacturer's instructions.

Antimicrobial susceptibility testing (AST) for every organism isolated was done and interpreted using the modified Kirby–Bauer single disk diffusion technique with the following antibiotics: amoxicillin/clavulanate (20/10 µg), ceftriaxone (30 µg), cefoxitin (30 µg), ceftazidime (30 µg), chloramphenicol (30 µg), ciprofloxacin (5 µg), gentamicin (10 µg), and meropenem (10 µg) according to the Clinical and Laboratory Standards Institute (CLSI) guidelines [23].

Data analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS) version 22 IBM SPSS Inc, Chicago, IL, USA. Values were expressed as count/percentages and mean/standard deviation. Data was presented in frequency tables.

Results

Table 1 shows the general characteristics of the neonates with proven sepsis. Ninety-four (37.9%) of the 248 subjects recruited into the study had proven sepsis out of whom 68% had -LOS with a male-to-female ratio of 1:1 and 2:1 for EOS and LOS, respectively. Babies delivered outside the facility and admitted into the out-born unit accounted for 66.7% EOS and 96.7% LOS, respectively. The most common maternal risk factor for sepsis is prolonged (premature rupture of membranes) PROM of > 18 h (26.7%) followed by peripartum fever and dysuria which were all seen in EOS, while for LOS, there were no significant maternal risk factors as shown in Table 2.

Table 3 the presenting symptoms; while respiratory difficulty followed by fever, convulsion, and poor suck were the most common symptoms in EOS, in LOS, it was fever followed by poor suck, yellowish discoloration of the body, and convulsion. The most common signs for EOS were tachypnoea, depressed primitive reflexes, dyspnoea, and pyrexia, while for LOS, it was pyrexia, jaundice, depressed reflexes, and abnormal tone. This is shown in Table 4.

Table 1 General characteristics of studied neonates

Parameter	EOS	LOS
	Number (%)	Number (%)
Time of onset		
< 72 h	30 (32)	
> 72 h		64 (68)
Sex		
Male	15 (50)	40 (62.5)
Female	15 (50)	24 (37.5)
Age at admission in hours[a]	31 ± 18	237 ± 177
Weight at admission (kg)[a]	2.8 ± 0.41	2.8 ± 0.7
Length (cm)[a]	49.1 ± 2.5	49.0 ± 3.4
Source of admission		
In-born	10 (33.3)	1 (3.3)
Out-born	20 (66.7)	63 (96.7)

[a] Mean and standard deviation

Table 2 Maternal risk factors identified

Maternal risk factors	EOS		LOS	
	Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)
Maternal fever	5	16.7	6	9.4
Dysuria	5	16.7	4	6.3
Foul smelling vaginal discharge	3	10.0	0	0.0
Foul smelling liquor	2	6.7	4	6.3
Prolonged PROM	8	26.7	0	0.0
MSAF	2	6.7	0	0.0
Multiple VE	1	3.3	1	1.6
Urinary frequency	3	10.0	0	0.0

MSAF meconium-stained amniotic fluid, *VE* vaginal examination, *PROM* premature rupture of membranes

Mustapha *et al. Egyptian Pediatric Association Gazette*   (2024) 72:53

Page 4 of 9

Table 3 Presenting symptoms in neonates with proven sepsis

Symptoms	EOS		LOS	
	Frequency (*n*)	Percentage (%)	Frequency (*n*)	Percentage (%)
Fever	15	50.0	46	71.9
Convulsion	15	50.0	24	37.5
Abnormal cry	3	10.0	7	10.9
Irritability	4	13.3	6	9.4
Lethargy	3	10.0	14	21.9
Vomiting	0	0.0	5	7.8
Abdominal distension	1	3.3	15	23.4
Poor suck	14	46.7	40	62.5
Respiratory difficulty	23	76.7	16	25.0
Cessation of breathing	0	0.0	3	4.7
Yellowish discoloration of the body	7	23.3	40	62.5
Abnormal bleeding	1	3.3	3	4.7
Poor weight gain	0	0.0	3	4.7

Table 4 Presenting signs in neonates with proven sepsis

Signs	EOS		LOS	
	Frequency (*n*)	Percentage (%)	Frequency (*n*)	Percentage (%)
Pyrexia[a]	14	46.7	42	65.6
Hypothermia	2	6.7	3	4.7
Pallor	5	16.7	15	23.4
Jaundice	11	36.7	39	60.9
Lethargy	8	26.7	19	29.7
Depressed reflexes	17	56.7	33	51.6
Altered consciousness	4	13.3	2	3.1
Bulging fontanelle	1	3.3	1	1.6
Hypotonia	4	13.3	12	18.8
Hypertonia	10	33.3	25	39.1
Dyspnoea	13	43.3	12	18.8
Tachypnoea	17	56.7	15	23.4
Apnoea	0	0.0	3	4.7
Crepitations	6	20.0	6	9.4
Hypoxaemia	12	40.0	16	25.0
Abdominal distension	3	10.0	10	15.6
Hepatomegaly	3	10.0	4	6.3
Hypoglycaemia	6	20.0	6	9.4

[a] Axillary temperature ≥ 38 °C

Overall gram-negative bacteria were the most common group of isolates in both types of sepsis, and the pool is largely contributed to by the Enterobacteriaceae. While there were diverse isolates, *S.aureus* remained the most common isolate for both EOS and LOS. This was followed by *Enterococcus* spp, *E. coli*, and *P. mirabilis* for EOS, and *E. agglomerans* and *K.pneumoniae* for LOS as depicted in Table 5.

Most of the isolates in EOS were sensitive to ciprofloxacin followed by meropenem, while for LOS, it is ciprofloxacin followed by amoxicillin-clavulanate, gentamicin, chloramphenicol, and meropenem. This is shown in Tables 6 and 7, respectively.

Table 8 shows the outcome of admission of the neonates. The majority of neonates who had both types of sepsis were discharged from the hospital. Among these

Mustapha *et al. Egyptian Pediatric Association Gazette*   (2024) 72:53

Page 5 of 9

Table 5 Organisms isolated from blood cultures of studied neonates

Isolates	EOS		LOS	
	Frequency (*n*)	Percentage (%)	Frequency (*n*)	Percentage (%)
Gram-positive bacteria	**14**	**46.7**	**26**	**40.6**
Coagulase negative staph	0	0.0	2	3.1
Enterococcus spp	3	10.0	2	3.1
Staphylococcus aureus	3	10.0	6	3.0
Staphylococcus aureus MRSA	6	20.0	12	18.8
Staphylococcus spp	1	3.3	4	6.3
Streptococcus spp alpha haem	1	3.3	0	0.0
Gram-negative bacteria	**16**	**53.3**	**38**	**59.4**
Enterobacteriaceae	**14**	**46.7**	**32**	**50.0**
Citrobacter diversus	0	0.0	1	1.6
Citrobacter freundii	1	3.3	0	0.0
Citrobacter koseri	1	3.3	0	0.0
Citrobacter neteri	0	0.0	1	1.6
Enterobacter agglomerans	0	0.0	9	14.1
Escherichia coli	3	10.0	4	6.3
Escherichia vulneris	0	0.0	1	1.6
Gram negative bacilli	0	0.0	1	1.6
Klebsiella oxytoca	0	0.0	1	1.6
Klebsiella ozonae	1	3.3	0	0.0
Klebsiella pneumoniae	2	6.7	8	12.5
Proteus mirabilis	3	10.0	2	3.1
Salmonella chlorae sui	1	3.3	0	0.0
Serratia marcescens	1	3.3	3	4.7
Unidentified	1	3.3	1	1.6
Non-fermentative G- aerobes	**1**	**3.3**	**6**	**9.4**
Acinetobacter baumanii	0	0.0	1	1.6
Acinetobacter spp	0	0.0	2	3.1
Pseudomonas aeruginosa	1	3.3	1	1.6
Pseudomonas putida	0	0.0	1	1.6
Pseudomonas spp	0	0.0	1	1.6
Missing	1	3.3	0	0.0

neonates, those with EOS had a longer average hospital stay of 8.9 days. The overall mortality rate was largely attributed to *Staphylococcus aureus.*

Discussion

The prevalence of culture-proven sepsis from the study is 37.9%. This observation is similar to findings from earlier studies in the same centre by Onalo et al. [24] (35.5%) and Olorokooba et al. [25] (37.6%) which likely denotes poor public health interventions to reduce the prevalence of sepsis in society more so that most of the neonates came from within the metropolis. The observation is also similar to reports by Ekwochi [26] in Enugu (38.6%) and Mugalu [27] (37%) in Uganda but higher than what was found by Nwankwo [28] (27.8%), Ogundare [29] (16%), and Mhada [30] (26%). Late-onset sepsis was observed to be the most common type of sepsis (68%) similar to some reports [28, 31] as against other reports [32–36]. Most of the patients came through the out-born unit as was also reported by Nwankwo et al. [28] and this coupled with the preponderance of LOS implies the source of infections to be likely from the community. Though non-maternal factors associated with LOS were not evaluated in this study, factors such as poor personal hygiene/unhygienic practices, dirty environments, poor cord care, and exposure of neonates to well-wishers as is customary in our culture may have been contributory. Maternal risk factors for sepsis were mainly seen in EOS largely from prolonged PROM, and this is in keeping

Mustapha *et al. Egyptian Pediatric Association Gazette*   (2024) 72:53

Page 6 of 9

Table 6 Antibiotic sensitivity pattern of EOS isolates

Isolates	No	AMC	CRO	CAZ	CHL	DA	CIP	CN	MEM	P
Gram-positive bacteria										
Enterococcus spp	3	2 (66.7)			1 (33.3)		2 (66.7)			2 (66.7)
Staphylococcus aureus	3	1 (33.3)			2 (66.7)	1 (33.3)	3 (100)	2 (66.7)		
Staphylococcus aureus MRSA	6	1 (16.7)			5 (83.3)	3 (50.0)	1 (16.7)	2 (33.3)		
Staphylococcus spp	1					1 (100)				
Streptococcus spp alpha haem	1									1 (100)
Gram-negative bacteria										
Citrobacter freundii	1						1 (100)		1(100)	
Citrobacter koseri	1	1 (100)	1 (33.3)	1(100)			1 (100)	1 (100)	1(100)	
Escherichia coli	3	1 (33.3)	1 (33.3)	1(33.3)	2 (66.7)		2 (66.7)		3(100)	
Klebsiella ozonae	1								1	
Klebsiella pneumoniae	2			1(50)			2 (100)	2 (100)	1(50)	
Proteus mirabilis	3	3 (100)	1 (33.3)	3(100)	1 (33.3)		3 (100)		1(33.3)	
Pseudomonas aeruginosa	1			1(100)			1 (100)	1 (100)		
Salmonella chlorae sui	1						1 (100)		1(100)	
Serratia marcescens	1	1 (100)		1(100)			1 (100)		1(100)	
Unidentified	1						1 (100)			

AMC amoxicillin-clavulanate, *CRO* ceftriaxone, *CAZ* ceftazidime, *CHL* chloramphenicol, *DA* clindamycin, *CIP* ciprofloxacin, *CN* genticin, *MEM* meropenem, *P* penicillin

Table 7 Antibiotic sensitivity pattern of LOS isolates

	No tested	Number and (%) sensitive to									
		AMX	CRO	CAZ	CHL	DA	CIP	CN	MEM	P	TZP
Isolates											
Gram positive bacteria											
Coagulase negative staph	2		1 (50)			1 (50)	2 (100)	2 (100)			
Enterococcus spp	2			1 (50)	2 (100)				2 (100)		
Staphylococcus aureus	6	2 (33.3)	1 (16.7)			3 (50)	4 (66.7)	5 (83.3)			
S. aureus MRSA	12	1 (8.3)		2 (16.7)	6 (50)	2 (16.7	10 (83.3)	5 (41.6)			
Staphylococcus spp	3				3 (100)		2 (66.7)	3 (100)			
Gram negative bacteria											
Acinetobacter baumanii	1	1 (100)	1 (100)	1 (100)	1 (100)		1 (100)	1 (100)	1 (100)		
Acinetobacter spp	2	1 (50)		2 (100)			2 (100)	2 (100)	2 (100)		
Citrobacter diversus	1						1 (100)	1 (100)			1 (100)
Citrobacter neteri	1	1 (100)	1 (100)	1 (100)	1 (100)			1 (100)		1 (100)	
Enterobacter agglomerans	9	6 (66.7)	4 (44.4)	5 (55.6)	5 (55.6)		8 (88.9)	8 (88.9)	4 (88.9)		
Escherichia coli	4	2 (50)	3 (75)	4 (100)	4 (100)		4 (100)	2 (100)	4 (100)		
Escherichia vulneris	1							1 (100)	1 (100)		
Gram negative bacilli	1	1 (100)	1 (100)	1 (100)	1 (100)		1 (100)	1 (100)			
Klebsiella oxytoca	1	1 (100)	1 (100)	1 (100)	1 (100)		1 (100)	1 (100)	1 (100)		
Klebsiella pneumoniae	7	2 (28.6)	1 (14.3)		2 (28.6)		5 (71.4)		4 (57.1)		
Kebsiella spp	1						1 (100)				1 (100)
Proteus mirabilis	2				2 (100)		2 (100)	2 (100)			
Pseudomonas aeruginosa	1						1 (100)	1 (100)	1 (100		1 (100)
Pseudomonas putida	1			1 (100)			1 (100)	1 (100)			
Pseudomonas spp	1							1 (100)	1 (100)		
Serratia marcescens	3	2 (66.7)		1 (33.3)	2 (66.7)		3(100)	3 (100)	1 (100)		
Unidentified	1	1 (100)	1 (100)	1 (100)	1 (100)				1 (100)		

AMC amoxicillin-clavulanate, *AMP* ampicillin, *CRO* ceftriaxone, *CAZ* ceftazidime, *CHL* chloramphenicol, *DA* clindamycin, *CIP* ciprofloxacin, *ERY* erythromycin, *CN* genticin, *MEM* meropenem, *P* penicillin, *TZP* piperacillin-tazobactam

Table 8 Admission outcome of studied neonates

Parameter	EOS	LOS	
	Number (%)	Number (%)	Total
Outcome			
Discharged	20 (66.7)	42 (65.6)	62 (65.9)
Discharged against medical advice	4 (13.3)	3 (4.7)	7 (7.4)
Died	5 (16.7)	9 (14.1)	14 (14.9)
Missing	1 (3.3)	10 (15.6)	11 (10.3)
Duration of hospital stay (days)	8.9 (4.8)[b]	6.5 (3.8)[b]	
Implicated organisms			
Staphylococcus aureus	3 (60)	1 (11.1)	4 (28.5)
Klebsiella pneumoniae		2 (22.2)	2 (14.3)
Klebsiella oxytoca		1 (11.1)	1 (7.1)
Escherichia coli		1 (11.1)	1 (7.1)
Enterobacter agglomerans		1 (11.1)	1 (7.1)
Proteus mirabilis	1 (20)[a]		1 (7.1)
Pseudomonas spp		1 (11.1)[a]	1 (7.1)
Citrobacter koseri	1 (20)		1 (7.1)
Acinetobacter spp		1 (11.1)	1 (7.1)

[a] Had dual isolates

[b] Mean and standard deviation

with the well-documented fact that the source of infection in EOS is the mother as was reported by some. [24, 33]. Several studies [24, 28, 31, 34, 36] have shown sepsis to be more common in males as we have observed, and it is believed that males are more prone to infections because of the presence of a single X-chromosome. The clinical features observed were non-specific for both EOS and LOS, but while EOS was more associated with features of pneumonia, LOS was more associated with features of meningitis; however, the presence of fever and jaundice should raise the index of suspicion of infection as they were the most observed symptoms and signs. Mhada et al. [30] reported a similar observation. Looking at the isolate groups, gram negatives were observed to be the commonest aetiology for both EOS and LOS as reported by some authors [28, 32] but in contrast to findings by others [24, 26, 31]. Coming down to individual isolates, our findings were quite interesting as the organisms were diverse; some are rare/opportunistic, and for some, this may be their first documentation as a cause of NS. We also observed infection with dual organisms (5.4%). The single most common isolate was *Staphylococcus aureus* for both EOS and LOS as was documented by some authors [24, 30, 37] but in contrast to findings by others [28, 31–34, 36] and in developed countries where GBS and CoNS predominates. This has buttressed the fact that pathogen burden varies between within countries, and

variation is also seen from nursery to nursery [3]. Also, one organism or a group of organisms may over time replace another as the leading cause of NS in a particular region [18]. Most of the *S. aureus* isolates were methicillin resistant which signifies resistance to penicillin and cephalosporins likely from indiscriminate use of antibiotics. As the isolates vary from nursery-nursery so also will the antibiotic sensitivity. Ciprofloxacin from the study had the highest sensitivity across most of the isolates and should therefore be replaced as the antibiotic of first choice for both EOS and LOS, and more so that the risk of foetal arthropathy is no longer there. This observation was documented by Ekwochi et al. Mortality for both EOS and LOS was 16.7%, though high but it is lower than what was found in other studies [28, 31, 34, 36]. The mortality was majorly contributed by gram negatives likely because they are more virulent and stimulate a lot of inflammatory response but *S. aureus* and *Klebsiella* spp seem to be the most important culprits.

Conclusion
Neonatal sepsis still remains an important cause of morbidity and mortality. Clinical features are non-specific and are caused by diverse organisms; some of which are considered rare and opportunistic. As most of the cases were late-onset sepsis coming from the community, these infections can be preventable by deploying public health interventions: public enlightenment, improved personal hygiene especially hand hygiene, environmental sanitation, discouragement of harmful traditional practices, and rational use of antibiotics.

Abbreviations
ABUTH	Ahmadu Bello University Teaching Hospital
AST	Antibiotic susceptibility
BHI	Brain heart infusion
CBC	Complete blood count
CoNS	Coagulase negative *Staphylococcus aureus*
CRP	C-reactive protein
EOS	Early onset sepsis
GBS	Group B streptococci
HCAI	Healthcare-associated infection
LOS	Late-onset sepsis
MRSA	Methicillin Resistant *Staphylococcus aureus*
MSAF	Meconium-stained amniotic fluid
NA	Nutrient agar
NMR	Neonatal mortality rate
NS	Neonatal sepsis
PCT	Procalcitonin
PROM	Prolonged rupture of membranes
SIRS	Systemic inflammatory response syndrome

Mustapha *et al. Egyptian Pediatric Association Gazette*   (2024) 72:53

Page 8 of 9

and review of the manuscript. SA—analysis of samples and review of the manuscript. AI—work conception, design, review of data analysis and interpretation, and final review of the manuscript. All authors read and approved the final manuscript.

Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Health Research Ethics Committee of Ahmadu Bello University Teaching Hospital, Zaria with reference number ABUTH/HREC/CL/05.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

References
1. Shane AL, Sánchez PJ, Stoll BJ (2017) Neonatal sepsis. Lancet 390(10104):1770–1780
2. Goldstein B, Giroir B, Randolph A (2005) International pediatric sepsis consensus conference: definitions for sepsis and organ dysfunction in pediatrics. Pediatr Crit Care Med 6(1):2–8
3. Anderson-Berry AL, Ted R (2013) Neonatal sepsis. Paediatr Child Health (Oxford) 25(6):271–275
4. Samsygina GA, Shabalov NP, Talalaev AG, Milovanov AP, Glukhovets NG, Glukhovets BI (2002) Sepsis in the newborn. Indian J Pediatr 3:1007
5. WHO (2014) Delivering our future : survival and health for every newborn
6. (UNICEF) UNCF (2018) EVERY CHILD ALIVE The urgent need to end newborn deaths. Switzerland. Cited 2019 Oct 30. Available from: https://www.unicef.org/publications/files/Every_Child_Alive_The_urgent_need_to_end_newborn_deaths.pdf
7. United Nations Inter-agency Group for Child Mortality Estimation (UN IGME) (2020) Levels & Trends in Child Mortality: Report 2020, Estimates developed by the United Nations Inter-agency Group for Child Mortality Estimation. United Nations Children's Fund, New York
8. National Population Commission (NPC) [Nigeria], ICF (2019) Nigeria Demographic Health Survey 2018. The DHS Program ICF Rockville, Maryland. https://dhsprogram.com/publications/publication-fr359-dhs-final-reports.cfm
9. National Population Commission (NPC) [Nigeria] (2020) A verbal and social autopsy study to determine causes and determinants of deaths of neonates and children under-five years of age in Nigeria. Abuja, Nigeria
10. Shah BA, Padbury JF (2014) Neonatal sepsis: an old problem with new insights. Virulence. 5(1):170–8. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3916371&tool=pmcentrez&rendertype=abstract
11. Morioko I, Sota I, Koda T, Nagasaka M, Yamana K, Kurokawa D et al (2014) Recent epidemiology of neonatal sepsis in Japan: did the strategies to control and prevent MRSA transmission lead to a reduction in the incidence of late-onset sepsis? Dovepress Res Rep Neonatol 4:177–81
12. Voller SMB, Myers PJ (2016) Neonatal sepsis. Clin Pediatr Emerg Med 17(2):129–33. Available from: http://www.sciencedirect.com/science/article/pii/S1522840116300064
13. Camacho-gonzalez A, Spearman PW, Stoll BJ (2015) Neonatal infectious diseases: evaluation of neonatal sepsis. Pediatr Clin North Am 60(2):367–389
14. Stoll BJI in the neonatal infant (2011) Nelson Textbook of Pediatrics. 19th ed. Kliegman RM, Stanton BF, Gem III JW St., Schor NF, Behrman RE, editors. Philadelphia: Elsevier. p 629–647
15. Dong Y, Speer CP (2015) Late-onset neonatal sepsis: recent developments. Arch Dis Child Fetal Neonatal Ed 100(3):F257–F263
16. Mukhopadhyay S, Puopolo M (2016) Neonatal early-onset sepsis : epidemiology and risk. Infect Dis (Auckl) 16(4):221–230
17. Wynn JL, Wong HR (2010) Pathophysiology and treatment of septic shock in neonates. Clin Perinatol. 37:439–79
18. Nasir IA, Mele HU, Babayo A, Yahaya F (2015) Serum procalcitonin assay for investigations and clinical management of neonatal sepsis: a review. J Pediatr Infect Dis 1(1):3–11
19. Simonsen KA, Anderson-Berry AL, Delair SF, Dele DH (2014) Early-onset neonatal sepsis. Clin Microbiol Rev 27(1):21–47
20. McIntosh N, Stenson B, Heath Paul T (2008) Forfar et Arneil's Textbook of Pediatrics. 7th ed. McIntosh N, Helms PJ, Smyth RL, Logan S, editors. Philadelphia: Churchill Livingstone Elsevier. p 191–366
21. Ince Z (2014) Diagnosis of neonatal sepsis: what the clinician expects, what the laboratory tells. Clin Biochem. 47(9):754–5. https://doi.org/10.1016/j.clinbiochem.2014.05.045
22. Arowosegbe A, Ojo D, Dedeke I, Shittu O, Akinloye O (2016) Diagnostic value of procalcitonin in neonatal sepsis. Niger J Paediatr. 43(1):15. Available from: http://www.ajol.info/index.php/njp/article/view/127951
23. Testing S (2018) Clinical and Laboratory Standards Institute. p 296
24. Onalo R, Ogala WN, Ogunrinde GO, Olayinka AT, Adama SA, Ega BA (2011) Predisposing factors to neonatal septicaemia at Ahmadu Bello University Teaching Hospital, Zaria Nigeria. Niger Postgrad Med J. 18:20–5. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=medl&AN=21445109.http://sfx.scholarsportal.info/uhn?sid=OVID:medline&id=pmid:21445109&id=doi:&issn=1117-1936&isbn=&volume=18&issue=1&spage=20&pages=20-5&date=2011&title=Nigerian+Postgrad
25. Olorukooba A, Ifusemu W, Ibrahim M, Jibril M, Amadu L, Lawal B (2020) Prevalence and factors associated with neonatal sepsis in a tertiary hospital, North West Nigeria. Niger Med J. 61(2):60. Cited 2020 Dec 2. Available from: http://www.nigeriamedj.com/text.asp?2020/61/2/60/283918
26. Ekwochi U, Ndu IK, Nwokoye IC, Ezenwosu OU, Amadi OF, Osuorah DIC (2014) Pattern of morbidity and mortality of newborns admitted into the sick and special care baby unit of Enugu State University Teaching Hospital. Enugu state Niger J Clin Pract 17(3):346–351
27. Mugalu J, Nakakeeto MK, Kiguli S, Kaddu-Mulindwa DH (2006) Aetiology, risk factors and immediate outcome of bacteriologically confirmed neonatal septicaemia in Mulago hospital. Uganda Afr Health Sci 6(2):120–126
28. Nwankwo E, Shehu A, Farouk Z (2011) Risk factors and bacterial profile of suspected neonatal septicaemia at a teaching hospital in Kano, Northwestern. Nigeria Sierra Leone J Biomed Res 3(2):104–109
29. Onipede AO, Onayade AA, Elusiyan JBE, Obiajunwa PO, Ogundare EOO, Olaniran OO et al (2009) Invasive bacteria isolates from children with severe infections in a Nigerian hospital. J Infect Dev Ctries 3(6):429–436
30. Mhada TV, Fredrick F, Matee MI, Massawe A (2012) Neonatal sepsis at Muhimbili National Hospital, Dar es Salaam, Tanzania; aetiology, antimicrobial sensitivity pattern and clinical outcome. BMC Public Health 12(1):1–6
31. Shehab El-Din EMR, El-Sokkary MMA, Bassiouny MR, Hassan R (2015) Epidemiology of neonatal sepsis and implicated pathogens: a study from Egypt. Biomed Res Int. 2015:1–11. Available from: http://www.hindawi.com/journals/bmri/2015/509484/
32. Boma Awoala W, Petronilla Nnenna T (2012) Clinico-Bacteriological profile of early and late onset sepsis in a tertiary hospital in Nigeria 1. J Med Med Sci. 3(2):107–11 . Cited 2016 Oct 15. Available from: http://www.interesjournals.org/JMMS
33. Olorukooba A, Ifusemu W, Ibrahim M, Jibril M, Amadu L, Lawal B (2020) Prevalence and factors associated with neonatal sepsis in a tertiary hospital, North West Nigeria. Niger Med J. 61(2):60. Cited 2020 Dec 2. Available from: https://www.nigeriamedj.com/article.asp?issn=0300-1652;year=2020;volume=61;issue=2;spage=60;epage=66;aulast=Olorukooba
34. Ahmed MA, Magzoub OS (2015) Risk factors for neonatal sepsis in paediatric ward at Khartoum North Teaching Hospital, Sudan. Basic Res J Med Clin Sci 4(1):37–43

Mustapha *et al. Egyptian Pediatric Association Gazette*   (2024) 72:53

Page 9 of 9

35. Sucilathangam G, Amuthavalli K, Velvizhi G, Ashihabegum MA, Jeyamuru-gan T, Palaniappan N (2012) Early diagnostic markers for neonatal sepsis: comparing procalcitonin (PCT) and C-reactive protein (CRP). J Clin Diagnostic Res 6(4):627–631
36. Verma P, Berwal PK, Nagaraj N, Swami S, Jivaji P, Narayan S (2015) Neonatal sepsis: epidemiology, clinical spectrum, recent antimicrobial agents and their antibiotic susceptibility pattern. Int J Contemp Paediatr 2(3):176–180
37. Ogundare OE, Akinsoji AA, Iyabode D, Florence O, Akintunde OJ, Ademola AL et al (2016) Neonatal septicaemia in a rural Nigerian hospital: aetiology, presentation and antibiotic sensitivity pattern. Br J Med Med Res 12(7):1–11

Publisher's Note