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Original Article

Prevalence And Microbial Spectrum Of Patients With Spontaneous Bacterial Peritonitis In Northeast Nigeria – A Cross-Sectional Multi-Centre Study

Alkali Mohammed,[1] *Auwal Adamu,[2] Mairo Usman Kadaura,[3] Musa Abubakar Garbati,[1] Mustapha Sabo Umar,[4] Garba M. Fika,[5] Baba Rimamtso Shamaki,[4] Hashiya Gunguru Mohammed,[6] Bala Mohammed Audu,[7] Kefas Zawaya,[8] Faruq Umar Faruq,[1] Nazeef Mohammed,[9] Isa Mustapha.[10]

[1]Department of Internal Medicine, Federal University of Health Sciences, Azare, Nigeria. https://orcid.org/0000-0002-0473-6125, [2]Department of Otorhinolaryngology, Federal University of Health Science, Azare, Nigeria. https://orcid.org/0000-0002-9939-3806, [3]Department of Medical Microbiology, Federal University of Health Sciences, Azare, Nigeria, [4]Department of Internal Medicine, Abubakar Tafawa Balewa University Teaching Hospital, Bauchi, Nigeria, [5]Department of Internal Medicine, Yobe State University Teaching Hospital, Damaturu, Nigeria, [6]Department of Pharmacy, Abubakar Tafawa Balewa University Teaching Hospital, Bauchi, Nigeria, [7]Department of Obstetrics and Gynaecology, Federal University of Health Sciences, Azare, Nigeria. [8]Department of Internal Medicine, Federal Teaching Hospital, Gombe, Nigeria, [9]Department of Community Medicine, Federal University of Health Sciences, Azare, Nigeria, [10]Department of Internal Medicine, Federal Medical Center, Nguru, Nigeria

Abstract

Background: Spontaneous bacterial peritonitis (SBP) is the most common infectious complication of cirrhosis, requiring prompt recognition and treatment. It is a recognized cause of death. Normal ascitic fluid is sterile, spontaneous presence of bacteria in this fluid is detrimental and needs to be investigated. This study aimed to determine the prevalence of primary ascitic fluid infection, the microbial agents involved, and their antibiotic sensitivity pattern among patients with cirrhosis and ascites seen at our facilities.
Methodology: A cross-sectional multi-centre study among patients diagnosed with liver cirrhosis and ascites who presented at four major tertiary institutions in Northeastern Nigeria from January 2024 to December 2024. All eligible participants underwent abdominal paracentesis under aseptic conditions and were subjected to microscopy, culture, and sensitivity using the BACT Alert 3D automated method. The data were analysed using SPSS version 26 (IBM SPSS Inc., Chicago, Illinois, USA).
Results: A total of 150 cirrhotic patients were studied, among whom 97 (64.7%) were males, with a male-female ratio of 1.8:1. The age of the patients ranged from 22 to 86 years, with a mean of 53.9 ± 13.4 years. The prevalence of primary ascitic fluid infection was 64%. All the positive culture samples were monomicrobial, and the most commonly isolated organisms were *Escherichia coli* (43.8%), *Staphylococcus aureus* (26.0%), and *Klebsiella spp.* (13.5%). The most sensitive antibiotics were levofloxacin (92 -100%), gentamicin (76.9 – 100%), imipenem (76.9 – 100%), piperacillin-Tazobactam (75.0 – 100%), and ciprofloxacin (69.0 – 100%). *Escherichia coli, Klebsiella spp., Pseudomonas aeruginosa, Streptococcus spp., and Enterobacter spp.* were found to be 100% resistant to cotrimoxazole. More specifically, *Enterobacter spp.* was found to be multidrug-resistant (MDR).
Conclusion: The prevalence of primary ascitic fluid infection among the cirrhotic patients was high. It is therefore recommended that prophylactic antibiotics be given to any patient with ascites and cirrhosis to prevent fatal complications of SBP.

Keywords: Spontaneous bacterial peritonitis, liver cirrhosis, ascites, prevalence, antibiotic sensitivity, antibiotic resistance.

***Correspondence:** Dr. Auwal Adamu, Department of Otorhinolaryngology, Federal University of Health Science, Azare, Nigeria, auwalu.adamu@fuhsa.edu.ng

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Introduction

Spontaneous bacterial peritonitis (SBP) is a primary bacterial infection of ascitic fluid and a common complication in patients with liver cirrhosis, occurring in about 10–40% of all hospitalized patients globally [1-3]. Being an infection of the ascitic fluid, SBP is a recognized cause of morbidity and mortality in cirrhotic patients. Normal ascitic fluid is sterile, spontaneous presence of bacteria in this fluid is detrimental and needs to be investigated. There are many predisposing factors for the development of SBP, but what contributes most is the translocation of intestinal flora into the ascitic fluid [4,5]. A variety of other factors are also associated with the development of SBP, including lifestyle changes, immunocompromised state, and background comorbid conditions [4,5].

Ordinarily, ascitic fluid is primarily a transudate with poor opsonic activity, which provides a favorable environment for the growth of bacteria. Studies have shown that SBP invariably occurs in patients with liver cirrhosis. However, only a few cases of SBP from cardiac, renal, portal vein thrombosis, malignancy, and autoimmune disease ascites have been reported [5].

The incidence of SBP in patients with liver cirrhosis varies in different regions of the world, mainly due to differences in socio-economic status [6]. SBP is indeed more common in low-and-middle-income countries (LMICs) compared to high-income countries [6]. Studies have shown that the rate of SBP is significantly higher in LMICs, with a relative risk of 1.31 compared to high-income countries [6-8]. This suggests that socioeconomic factors may play a role in the increasing prevalence of SBP. The likely factors responsible for high prevalence in LMICs include lower access to healthcare, poor sanitation, high incidence of hepatitis B and C infections, high rates of alcoholic liver disease, and non-alcoholic fatty liver disease [6-8]. Furthermore, it was also found that chronic hepatitis B is the most common etiology of liver cirrhosis in sub-Saharan Africa and some parts of Asia [4].

The clinical pattern, pathophysiology, and natural history of SBP among patients with liver cirrhosis are still unclear. However, some theories suggest that SBP in liver cirrhosis is likely due to translocation and overgrowth of intestinal bacteria, which is an integral step in the colonization and pathogenesis of SBP infection [3]. SBP is a severe and often fatal infection in patients with liver cirrhosis. The infection from SBP can spread to other organs, causing more severe multi-organ failure with poor prognosis [9,10]. Due to the high incidence and increased morbidity and mortality of SBP in Africa [6], it was deemed necessary to study the prevalence of SBP, microbial spectrum, and their antibiotic susceptibility pattern. The findings of this study will provide baseline data on the epidemiology, trend, microbial isolates, and their antibiotic susceptibility pattern in our environment. This will also help in early diagnosis, treatment, and overall management of SBP in cirrhotic patients. The antibiotic sensitivity pattern will help in making informed choices of antibiotics for early commencement of appropriate treatment and also prophylaxis to prevent the deadly SBP in patients with liver cirrhosis.

Methodology

Study Design

A hospital-based cross-sectional multi-center study among patients with liver cirrhosis and ascites who presented at four major tertiary healthcare institutions in Northeastern Nigeria.

Study Sites

The hospitals involved in the study were as follows: Federal University of Health Sciences Teaching Hospital, Azare (FUHSTHA), Abubakar Tafawa Balewa University Teaching Hospital (ATBUTH), Bauchi, Federal Teaching Hospital (FTH) Gombe, and Federal Medical Centre (FMC) Nguru, all in Northeastern Nigeria.

Study Population

All patients with ascites due to liver cirrhosis who presented to one of the study sites were recruited consecutively.

Inclusion Criteria:

- Patients ascites was due to liver cirrhosis, for which the diagnosis was made clinically and by abdominal ultrasound scan.
- Patients who gave informed consent to participate in the study.

Exclusion Criteria: The following patients were excluded from the study.

- Use of systemic antibiotics within the previous 7 days.

- Patients who had an ascitic tap in the preceding 7 days.

-Abdominal surgery in the preceding 4 weeks,

-patient with evidence of secondary peritonitis,

-Presence of intra-abdominal abscess, etc.

-Underlying abdominal malignancy

Study protocol

The participants who satisfied the inclusion criteria were recruited consecutively from January 2024 to December 2024.

Definition of Spontaneous Bacterial Peritonitis: for the purpose of this study, SBP was defined as primary infection of ascitic fluid demonstrated by the presence of bacteria in ascitic fluid of the liver cirrhotic patient in the absence of abdominal surgery, intra-abdominal procedure, or evidence of background intra-abdominal abscess or infection.

Ascitic fluid sample collection: All recruited patients had abdominal paracentesis performed under aseptic technique. A sterile syringe was passed at the right or left iliac fossa, 3 cm above and 3 cm medial to the anterior superior iliac spine. About 10 mL of ascites fluid was collected by a senior gastroenterologist or a senior resident doctor in internal medicine. Subsequently, the ascitic fluid was dispensed aseptically into the BACTEC bottles, which were transported at room temperature to the Department of Medical Microbiology and Immunology Laboratory of FUHSTHA.

Automated Culture: The culture bottles were incubated in the automated BACTEC machine with the following specifications: Bact Alert 3D machine (Serial No: 908CR6604) manufactured by bioMerieux Inc., North Carolina, USA. All samples were subcultured after 24 hours of incubation. A loop full of the broth from the culture bottle was streaked onto Blood agar, MacConkey agar, and Chocolate agar, which were incubated aerobically at a temperature of $37^{o}C$ for 18-24 hours. After which, the culture media were observed for possible microbial growth.

Bacterial Isolation and phenotypic detection: Visible growths were characterized morphologically, and a Gram stain was performed. Using a sterile wire loop, colonies were streaked on phenotypic biochemical tests, including indole, citrate, urease, oxidase, catalase, and Kligler’s Iron Agar (KIA), for Gram-negative

organisms. All were incubated aerobically at 37ºC for 24 hours and observed for color change. Negative and positive controls were used.

Antibiotic sensitivity test: The antibiotic susceptibility testing was done using the antibiotic Sensitivity Disc (Oxoid England). A bacterial suspension was made from positive culture plates by emulsifying a few colonies into a nutrient broth and standardized using a 0.5 McFarland standard. The Kirby-Bauer disc diffusion method was used. A sterile cotton swab was dipped into the bacterial suspension, elevated above the liquid, and rotated several times against the inside wall of the tube to remove excess of the inoculum. The swabs were then streaked evenly in three different directions onto the Muller-Hinton Agar (Oxoid England). Then the antibiotics disc were placed, and the choice of antibiotics was based on Clinical and Laboratory Standards Institute (CLSI). The Muller Hinton agar was then incubated aerobically at a temperature of 37ºC for 18-24 hours. The interpretation of results was made using the CLSI's guidelines (31st Edition),[11] for which sensitive, intermediate, and resistant zones were identified. The sensitivity testing was done against the common antibiotics such as ciprofloxacin (CIP), piperacillin-tazobactam (TZP), cotrimoxazole (COT), cefuroxime (CXM), amoxicillin/clavulanate-Augmentin (AUG), imipenem (IMP), gentamicin (CN), ceftriaxone (CRO), and levofloxacin (LEV).

Data analysis

Data were analyzed using Statistical Product and Service Solutions (SPSS) version 26.0 (IBM Inc., Chicago, Illinois, USA). The data was summarized and presented in text, tables, and charts. Qualitative data were documented as frequencies and percentages, while quantitative data were presented as mean and standard deviation. Chi-square test was used to determine the association between the variables. The statistical significance level was set at a P-value < 0.05.

Ethical Consideration

Ethical approval was obtained from the Health Research and Ethics Committees of the participating institutions with reference numbers: ATBUTH/REC/0068/2023, FMCA/COM/35/VOL.I, NHREC/25/10/2013, and FMCN/REC/23/037. Ethical principles and confidentiality were maintained. The study was conducted according to the Helsinki Declaration of 1964 (8th edition updated October, 2024) [12]. The results of this study will be useful for research purposes as well as for the treatment of patients with SBP.

Results

A total of 150 patients were studied. The age of the patients ranged from 22 to 86 years, with a mean of 53.9 ± 13.4 years. The peak age group was 51-70 years. The majority of the patients, 86 (57.3%), were 50 years or older. There were 97 (64.7%) males and 53 (35.3%) females, with a male-female ratio of 1.8:1. A significant number of the patients, 37 (24.7%), were civil servants, the majority were married 130 (86.7%), and most of them reside in an urban center 85 (56.7%). Table 1 shows the distribution of sociodemographic characteristics of the participants. Most common clinical features among the patients were weight loss 47 (31.3%), pedal/sacral edema 47(31.3%), abdominal pain 37(24.7%), and absent/sparse axillary hair 36(24.0%).

The prevalence of primary ascitic fluid infection among the patients was 64%. As shown in Figure 1; ninety six patients (64%) had microbial growth after ascitic fluid culture, while 54(36%) had no evidence of growth. Figure 2 shows the distribution of microbial growth based on the hospital/location. Chi-square test revealed no statistically significant difference in microbial growth on the basis of hospital/site of the patients (χ^2=3.149, df = 3, p =0.369). Similarly, there was no statistically significant difference in microbial growth based on the degree of ascites (χ^2 = 0.140, df = 2, P=0.932) among the participants (Figure 3).

Regarding the microbial spectrum, most commonly isolated microbial agents were *Escherichia coli* 42(43.8%)*, Staphylococcus aureus* 25(26.0%), *and Klebsiella spp.* 13(13.5%). Other isolated organisms are shown in Table 2. Antimicrobial sensitivity pattern of the pathogens was also tested (Table 3) against the common antibiotics such as ciprofloxacin (CIP), piperacillin-tazobactam (TZP), cotrimoxazole (COT), cefuroxime (CXM), amoxicillin/clavulanate-Augmentin (AUG), imipenem (IMP), gentamicin (CN), ceftriaxone (CRO), and levofloxacin (LEV). *Escherichia coli* was more sensitive to LEV (95.2%), CN (92.9%), IMP (85.7%), CXM (76.2%), TZP (76.2%), and CIP (69.0%). *Staphylococcus aureus* was more sensitive to LEV (92.0%), CN (92.0%), TZP (92.0%), IMP (80.0%), and CIP (72.0%). *Klebsiella spp.* was more sensitive to LEV (76.9%), CN (76.9%), TZP (76.9%), IMP (76.9%), and CIP (76.9%). *Pseudomonas spp.* was more sensitive to LEV (100.0%), TZP (100.0%), CN (83.3%), IMP (83.3%), and CIP (83.3%). *Streptococcus spp.* was more sensitive to LEV (100.0%), CN (100.0%), IMP (100.0%), CIP (100.0%), and TZP (75.0%). Finally, *Enterobacter spp.* was more sensitive to LEV (100.0%), CN (100.0%), IMP (100.0%), and CIP (100.0%). Generally, LEV, CN, IMP, CIP, and TZP were sensitive against most of the pathogens, except TZP, which was not sensitive against *Enterobacter spp.* Furthermore, most of the pathogens were resistant to COT (80-100%), CRO (50-78.6%), AUG (50-100%), and CXM (23.8-100%). On the other hand, *Escherichia coli, Klebsiella spp., Pseudomonas aeruginosa, Streptococcus spp., and Enterobacter spp.* were found to be 100% resistant to COT. More specifically, *Enterobacter spp.* was found to be multidrug-resistant (MDR); it was found to be 100% resistant to AUG, TZP, and CXM.

Table 1: Sociodemographic characteristics of the participants

Age(years)	**Frequency**	**Percentage**
≤30	5	3.3
31-50	59	39.3
51-70	70	46.7
71-90	16	10.7
Total	**150**	**100**
Gender		
Male	97	64.7
Female	53	35.3
Total	**150**	**100**
Education		
Non Formal	51	34.0
Primary	34	22.7
Secondary	40	26.7
Tertiary	25	16.7
Total	**150**	**100**
Residence		
Rural	65	43.3
Urban	85	56.7
Total	**150**	**100**
Marital Status		
Single	6	4.0
Married	130	86.7
Divorcee	6	4.0
Widow	8	5.3
Total	**150**	**100**
Occupation		

Civil Servant	37	24.7
House wives	26	17.3
Farming	33	22.0
Butcher	13	8.7
Tailoring	17	11.3
Trading	20	13.3
Business	4	2.7
Total	**150**	**100**

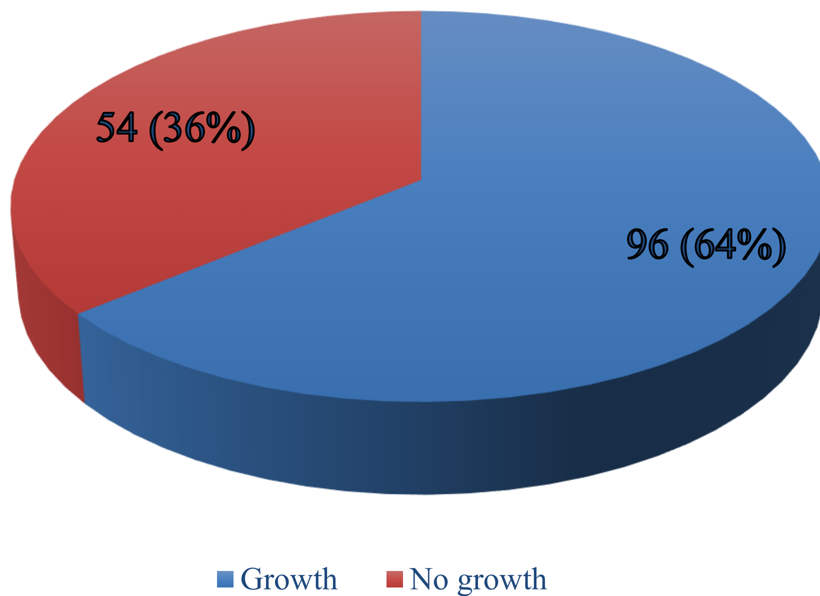

Figure1: Prevalence of Ascitic fluid infection among the participants

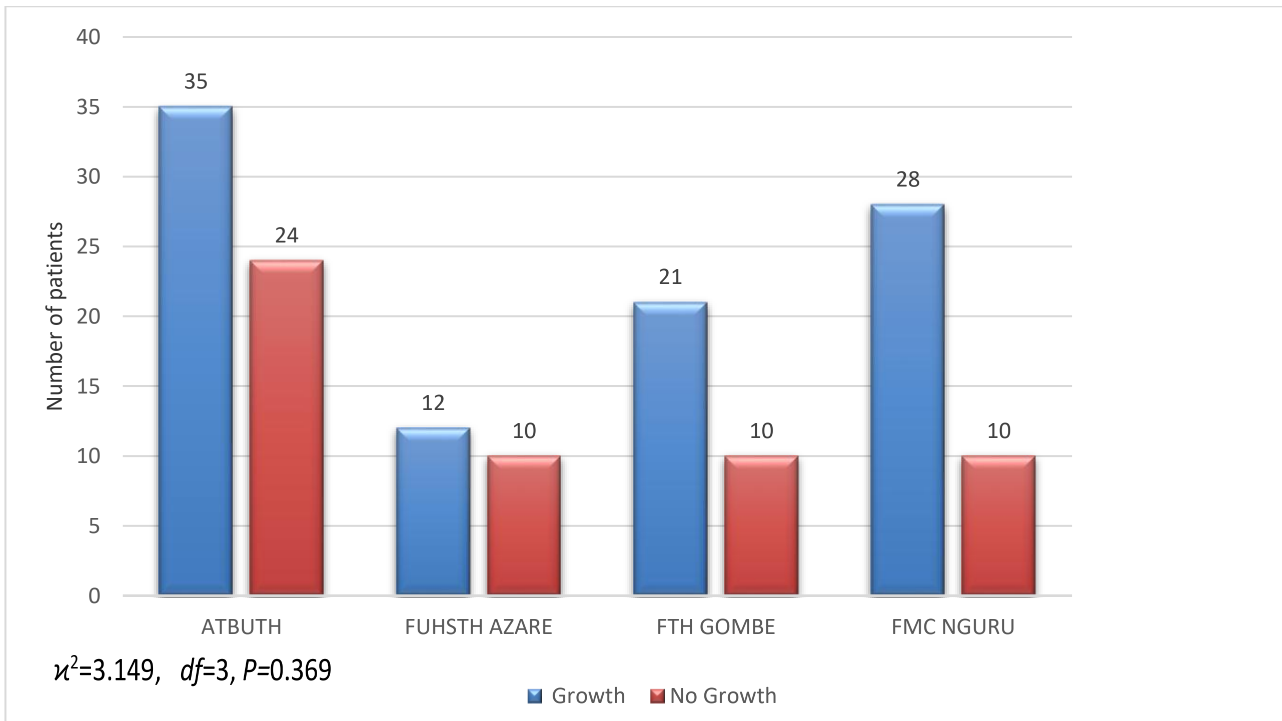

Figure 2: Distribution of Microbial Growth based on the study sites.

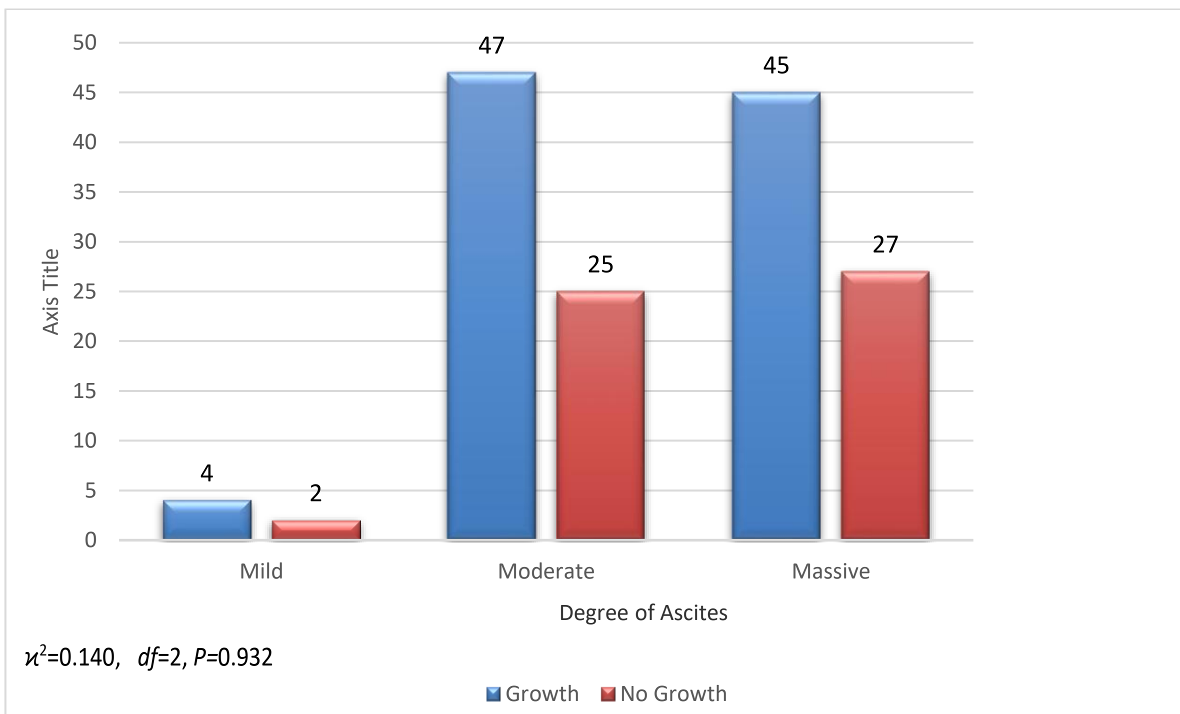

Figure 3: Distribution of Microbial Growth Based on the Degree of Ascites.

Table 2: Microbial spectrum isolated from the ascetic fluid of the participants

Isolated pathogens	Frequency	Percentage
Escherichia coli	42	43.8
Staphylococcus aureus	25	26.0
Klebsiella spp.	13	13.5
Pseudomonas aeruginosa	6	6.3
Candida spp.	4	4.2
Streptococcus spp.	4	4.2
Enterobacter spp.	2	2.0
Total	**96**	**100**

Table 3: Antimicrobial Sensitivity Pattern of the Isolated Pathogens from Ascitic Fluid

Isolated pathogen	Total	Ciprofloxacin		Piperacillin-Tazobactam		Cotrimoxazole	
		S	R	S	R	S	R
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Escherichia coli	42(100.0)	29(69.0)	13(31.0)	32(76.2)	10(23.8)	0(0.0)	42(100.0)
Staphylococcus aureus	25(100.0)	18(72.0)	7(28.0)	23(92.0)	2(8.0)	5(20.0)	20(80.0)
Klebsiella spp.	13(100.0)	10(76.9)	3(23.1)	10(76.9)	3(23.1)	0(0.0)	13(100.0)
Pseudomonas spp.	6(100.0)	5(83.3)	1(16.7)	6(100.0)	0(0.0)	0(0.0)	6(100.0)
Streptococcus spp.	4(100.0)	4(100.0)	0(0.0)	3(75.0)	1(25.0)	0(0.0)	4(100.0)
Enterobacter spp.	2(100.0)	2(100.0)	0(0.0)	0(0.0)	2(100.0)	0(0.0)	2(100.0)
Isolated pathogen	Total	Cefuroxime		Amoxicillin-Clavulanate		Imipenem	
		S	R	S	R	S	R
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)

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Escherichia coli	42(100.0)	32(76.2)	10(23.8)	15(35.7)	27(64.3)	36(85.7)	6(14.3)
Staphylococcus aureus	25(100.0)	9(36.0)	16(64.0)	10(40.0)	15(60.0)	20(80.0)	5(20.0)
Klebsiella spp.	13(100.0)	2(15.4)	11(84.6)	4(30.8)	9(69.2)	10(76.9)	3(23.1)
Pseudomonas spp.	6(100.0)	1(16.7)	5(83.3)	2(33.3)	4(66.7)	5(83.3)	1(16.7)
Streptococcus spp.	4(100.0)	1(25.0)	3(75.0)	2(50.0)	2(50.0)	4(100.0)	0(0.0)
Enterobacter spp.	2(100.0)	0(0.0)	2(100.0)	0(0.0)	2(100.0)	2(100.0)	0(0.0)

Isolated pathogen	Total	Gentamicin		Ceftriaxone		Levofloxacin	
		S	R	S	R	S	R
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Escherichia coli	42(100.0)	39(92.9)	3(7.1)	9(21.4)	33(78.6)	40(95.2)	2(4.8)
Staphylococcus aureus	25(100.0)	23(92.0)	2(8.0)	9(36.0)	16(64.0)	23(92.0)	2(8.0)
Klebsiella spp.	13(100.0)	10(76.9)	3(23.1)	5(38.5)	8(61.5)	10(76.9)	3(23.1)
Pseudomonas spp.	6(100.0)	5(83.3)	1(16.7)	2(33.3)	4(66.7)	6(100.0)	0(0.0)
Streptococcus spp.	4(100.0)	4(100.0)	0(0.0)	1(25.0)	3(75.0)	4(100.0)	0(0.0)
Enterobacter spp.	2(100.0)	2(100.0)	0(0.0)	1(50.0)	1(50.0)	2(100.0)	0(0.0)

Discussions

Spontaneous bacterial peritonitis (SBP) is a bacterial infection of ascitic fluid and a common complication in patients with liver cirrhosis [1-3]. It is a recognized cause of acute decompensation and death in liver cirrhotic patients [13]. It is well established that 30% to 50% of cirrhotic patients either have preexisting bacterial infections when they are hospitalized or acquire them during this period. Such infections were responsible for up to 25% of deaths in these patients [14,15]. In this study, the prevalence of ascitic fluid infection among the cirrhotic patients was 64%. This is similar to the findings of a study conducted in Nigeria, where they reported a prevalence of 66.7% among patients with liver cirrhosis [16]. Additionally, Tay et al.[6] in an epidemiological meta-analysis on worldwide prevalence of SBP, reported that the pooled prevalence of SBP was highest in Africa (68.2%), much higher than the global average of 17.12%, and lowest in North America (10.81%). The same study also reported that among the individual countries

worldwide, Nigeria was observed to have the highest prevalence of SBP (93.55%). However, the prevalence was lowest in Singapore (5.12%) [6]. The high prevalence of SBP in Africa and particularly Nigeria might not be unrelated to the high rate of both community-acquired and hospital-acquired infections [17,18].

In this study, the microbial agents commonly isolated were *Escherichia coli* (43.8%)*, Staphylococcus aureus* (26.0%), *and Klebsiella spp.* (13.5%). This is similar to a study conducted in Nigeria where *Escherichia coli, Klebsiella spp.*, *Streptococcus spp.,* and *Staphylococcus aureus* were reported to be the predominant organisms isolated [16]. However, *Streptococcus spp.* was not a common organism in our study; it was only isolated in 4.2% of our patients. Additionally, a study conducted in Ghana reported that the leading organisms isolated in the ascitic fluid of patients with SBP were *Escherichia coli* (41.7%)*, Klebsiella spp.* (16.67%), and *Staphylococcus aureus* (8.33%) [19]. They also isolated *Corynebacterium spp*. (16.67%), an anaerobic organism. The percentage of *Staphylococcus aureus* isolated in this study (26.0%) was higher than that of a similar study in Ghana, which isolated 8.33% *Staphylococcus aureus.* The high percentage of *Staphylococcus aureus* may be due to bacterial contamination of the sample we took. This is not likely because adequate measures were taken to prevent sample contamination. However, generally, *Staphylococcus aureus* is a common organism in SBP, particularly in nosocomial (hospital-acquired) infections, due to factors such as a high prevalence of nasal colonization with *Staphylococcus aureus* in cirrhotic patients or translocation from other staphylococcal infections [20]. Cirrhotic patients are at higher risk of bacterial translocation due to immune system dysfunction. Liver disease impairs the immune system, making patients more susceptible to infections. This, combined with a high bacterial load in the gut, can lead to bacterial translocation and subsequent infection in the ascitic fluid [21]. Additionally, *Staphylococcus aureus* is often associated with indwelling medical devices used in hospitalized patients. This is linked to the use of indwelling medical devices such as central venous lines, urethral catheters, or nasogatric tube, which can serve as a source of bacteremia that leads to peritonitis. So, nosocomial SBP is increasingly associated with Gram-positive bacteria, with *Staphylococcus aureus* being a major cause [20-22].

Generally, Gram-negative bacteria were the main causative agents of spontaneous bacterial peritonitis reported in the literature, with *Escherichia coli* and *Klebsiella spp.* being the most frequently isolated organisms. However, other gram-positive bacteria, including *Streptococcus viridans, Staphylococcus aureus,* and *Enterococcus spp.,* were also reported [8,23]. A study in China reported a slightly different pattern and percentage of microbial agents isolated in SBP patients, with *Escherichia coli* (25.5%)*, Staphylococcus epidermidis* (14.6%), and *Enterococcus faecium.* (11.1%) being the most common [24]. This difference in pattern and percentage of microbial agents isolated between this study and that of Zhang et al. might be attributed to differences in socioeconomic status, cultural practices, climate, and environmental conditions.

In this study, the isolates were most susceptible to levofloxacin (92 -100%), gentamicin (76.9 – 100%), imipenem (76.9 – 100%), piperacillin-tazobactam (75.0 – 100%), and ciprofloxacin (69.0 – 100%). However, in China, their isolates were most susceptible to amikacin (91.5%), meropenem (89.8%), and piperacillin-tazobactam (87.6%) [24]. The variation in the susceptibility pattern may be due to the differences in the availability and management of antimicrobial agents. The clinical significance of this result in our environment is that any of these sensitive antibiotics can be used as either initial treatment in patients with SBP or as prophylaxis to prevent SBP in patients with ascites and liver cirrhosis. This, in turn, will reduce the morbidity and mortality associated with SBP in patients with liver cirrhosis.

Narrowing down to common organisms, *Escherichia coli* was found to be 85.7% sensitive to imipenem, and 95.2% sensitive to levofloxacin, while *Klebsiella spp.* were 76.9% susceptible to gentamicin, imipenem, and levofloxacin, respectively. A similar antibiotic sensitivity pattern was reported in Ethiopia among patients with ascitic fluid infection and liver cirrhosis, where they reported that *Escherichia coli*

was 100% sensitive to both meropenem and levofloxacin. *Klebsiella pneumoniae* was also found to be 100% sensitive to gentamicin, meropenem, and Levofloxacin respectively [25].

Regarding antibiotic resistance, most of the pathogens in this study were resistant to cotrimoxazole (80-100%), ceftriaxone (50-78.6%), amoxicillin/clavulanate (50-100%), and cefuroxime (23.8-100%). On the other hand, *Escherichia coli, Klebsiella spp., Pseudomonas aeruginosa, Streptococcus spp., and Enterobacter spp.* were found to be 100% resistant to Cotrimoxazole. More specifically, we found *Enterobacter spp.* to be multidrug-resistant (MDR), being 100% resistant to amoxicillin/clavulanate, piperacillin-tazobactam, and cefuroxime. The MDR characteristics of *Enterobacter spp.* have been reported in the literature; the organisms belong to the SPICE group (*Serratia spp.*, Providencia spp., Indole-positive spp., e.g., *Proteus vulgaris*, *Citrobacter freundii* complex, and *Enterobacter spp.*) [26-28]. They produce an inducible chromosomal gene that encodes AmpC beta-lactamase enzyme, which often leads to the rapid development of MDR during treatment with common antibiotics, making infections difficult to treat. The mechanisms of resistance of *Enterobacter spp.* arise from inducible AmpC Beta-Lactamase: The AmpC gene is typically suppressed or expressed at low levels. However, exposure to certain antibiotics, especially broad-spectrum ones, acts as an inducer. This exposure can activate the gene, leading to high-level, sustained production of the AmpC enzyme. The hyperproduced AmpC enzyme can rapidly hydrolyze and inactivate many beta-lactam antibiotics, including penicillins, most cephalosporins (first, second, and third generations), and some beta-lactamase inhibitor combinations (like piperacillin/tazobactam), leading to MDR [26-28]. It is therefore not surprising to find that *Enterobacter spp.* in this study were resistant to amoxicillin/clavulanate, piperacillin-tazobactam, and cefuroxime. In summary, the key discussion point for *Enterobacter spp.* is their inherent ability to "escape" the effects of standard beta-lactam antibiotics via inducible AmpC production. Therefore, this phenomenon makes appropriate and timely antibiotic selection challenging, emphasizing the need for robust infection control and careful antimicrobial stewardship.

Furthermore, *Escherichia coli* and *Klebsiella spp.* were 64.3% and 69.2% resistant to amoxicillin/clavulanate, respectively. However, Ethiopian researchers observed that *Escherichia coli* and *Klebsiella spp.* were 100% resistant to amoxicillin/clavulanate [25]. The high resistance to amoxicillin/clavulanate may be due to the bacterial-specific characteristics, such as overproduction of β-lactamases and AmpC β-lactamase hyperproduction. Additionally, the organism may have originated from a specific, high-risk environment (e.g., a hospital ward with high antibiotic usage) [29-31], as was the case in this study; samples were collected from a hospitalized patient. Prior antibiotic exposure may also be a reason; the patient population from which the samples were collected may have had a history of extensive antibiotic exposure, which led to resistant strains. This is applicable to our environment, where the use of antibiotics is not restricted, and there is widespread abuse and misuse of antibiotics [29-31].

The clinical implication of these findings is that the resistant antibiotics might not be useful in the treatment or prophylaxis against SBP in our environment. Therefore, it is recommended that clinicians use the susceptible antibiotics in the initial treatment of these patients. It is also recommended that all patients with ascites and liver cirrhosis should have abdominal paracentesis performed for ascitic fluid culture and sensitivity tests, because the prevalence of SBP is high (64%) in our environment. This will help in the early commencement of appropriate treatment, thereby reducing disease progression to sepsis, multi-organ failure, and death. This, in turn, will improve the outcome of treatment in these patients. The high resistance rates to common antibiotics in this study, conducted in four tertiary healthcare institutions in Northeast Nigeria, call for a general enlightenment among healthcare personnel for the strict implementation of antimicrobial stewardship. There has to be concerted efforts by the government and other stakeholders towards controlling access to antimicrobial agents to curb the rising rates of antimicrobial resistance in our communities. Continuous surveillance is also recommended to follow-up the trend across other geopolitical zones of Nigeria.

Conclusion

The prevalence of primary ascitic fluid infection among the cirrhotic patients was high (64.0%). The most commonly isolated pathogens were gram-negative bacilli (*Escherichia coli* and *Klebsiella spp.*) and a gram-positive coccus (*Staphylococcus aureus*). It is, therefore, important to use the most sensitive antibiotics such as levofloxacin, ciprofloxacin, gentamycin, or imipenem in a patient with ascites and cirrhosis to prevent fatal complications of SBP.

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