Prevalence and Antibiotic Resistance Profile of Multidrug Resistant and Extended-Spectrum β-Lactamase Producing *Escherichia coli* in a Nigerian Tertiary Hospital

Abstract

***Background****: Escherichia coli* (*E. coli*) infections pose significant challenges in healthcare settings due to increasing rates of antimicrobial resistance, especially multidrug resistance (MDR) and Extended β-lactamase (ESBL) production. Understanding the prevalence and antibacterial susceptibility profiles of *E. coli* isolates is important for guiding empirical therapy and implementing effective infection control measures.

**Aim**: This study aimed to investigate the prevalence of multidrug resistance and extended-spectrum β-lactamase-producing *E. coli* in clinical sources from Rivers State University Teaching Hospital.

**Methods**: This descriptive cross-sectional study analysed 300 clinical samples collected from patients presenting with suspected *E. coli* infections in Rivers State University Teaching Hospital. From the study sample, urine, stool, and wound swabs were collected. *E. coli* isolates were identified using standard microbiological techniques, and antibiotic susceptibility testing was performed using the disc diffusion method and confirmation of suspected ESBL-producing *E. coli* was done by using the double-disk approximation or double-disk synergy (DDS) method. The data generated from this study were represented as frequencies and percentages using chi-square with the aid of GraphPad Prism Software Version 9.

**Results**: Among the 300 clinical samples analysed, *E. coli* growth was observed in 20.3% of samples, with urine samples being the most prevalent source (62.3%). Prevalence of MDR *E. coli* strains was recorded at 45.9% of isolates exhibiting multidrug resistance. Additionally, ESBL production was detected in 42.6% of isolates. Variable susceptibility patterns were observed across different antibiotic classes, with notable sensitivity rates observed for Amikacin (80.3%) and Gentamicin (78.7%), while resistance was observed in cephalosporins, fluoroquinolones, and β-lactam antibiotics. Notably, all *E. coli* isolates remained sensitive to imipenem.

**Conclusions**: This study underscores the importance of vigilant surveillance and effective antibiotic stewardship programs to mitigate the spread of multidrug-resistant *E. coli* strains and ESBL-producing isolates. The varying susceptibility patterns observed highlight the need for tailored treatment approaches and comprehensive infection control measures to optimise patient outcomes. These findings emphasise the urgent need for collaborative efforts to address antimicrobial resistance and preserve the effectiveness of antibiotics in the management of *E. coli* infections.

***Keywords****: Multidrug Resistant, Escherichia coli, extended-spectrum β-lactamase, urinary tract infections, antibiotic susceptibility*

**Introduction**

*Escherichia coli (E. coli)* is a Gram-negative bacterium commonly found in the gastrointestinal tract of humans and animals (Rossi *et al.*, 2018). While “many strains of *E. coli* are harmless, certain pathogenic strains can cause a range of infections, including urinary tract infections (UTIs)” (Ferdosi-Shahandashti *et al.*, 2015; O. Idang et al., 2015), bloodstream infections (Vihta *et al.*, 2018), gastrointestinal infections (Fleckenstein & Kuhlmann, 2019), and respiratory tract infections (McGrath-Morrow *et al.*, 2017). The broad majority of *E. coli* strains are entirely safe to consume. Few, such as Shiga toxin-producing E. coli (STEC), can, nevertheless, cause significant foodborne illness (Jaybhaye & Deb, 2021). The prevalence of multidrug-resistant bacteria, including extended-spectrum β-lactamase (ESBL)-producing *Escherichia coli*, has emerged as a significant global health concern (Suresh *et al.*, 2016; Yehia *et al.*, 2017). These drug-resistant pathogens pose a substantial threat to public health due to their ability to withstand the effects of multiple antibiotics, leading to limited treatment options and increased morbidity and mortality rates (Reid, 2011; Nimri & Azaizeh, 2012; Navidinia *et al.*, 2017). Understanding the prevalence and characteristics of multidrug-resistant and ESBL-producing *Escherichia coli* strains is crucial for effective infection control and the development of appropriate therapeutic strategies.

Multidrug resistance is a leading concern in public health (Catalano et al., 2022). “Antimicrobial resistance is the capability of a microorganism to resist the action of different antimicrobials. In this type of resistance, microbes can resist the medication that could once be successful against them. When this resistance occurs to multiple drugs, it is known as multidrug resistance (MDR)” (Parmanik et al., 2022). Multidrug-resistant *Escherichia coli* is a growing problem worldwide, particularly in healthcare settings (Koirala *et al.*, 2021; Olowo-Okere *et al.*, 2020; Odoyo *et al.*, 2023; Nfongeh *et al.*, 2023). These strains have acquired resistance to multiple classes of antibiotics, rendering traditional treatment approaches ineffective (Walker *et al.*, 2022). Infections caused by multidrug-resistant *Escherichia coli* are associated with prolonged hospital stays, increased healthcare costs, treatment failures, and adverse patient outcomes (Ning *et al.*, 2019; López-Montesinos *et al.*, 2020). The prevalence of these drug-resistant strains varies across different regions and healthcare facilities, highlighting the importance of local surveillance to inform infection control measures and therapeutic interventions.

ESBL-producing *Escherichia coli* strains, characterised by the production of enzymes called extended-spectrum β-lactamases, pose additional challenges in the management of infections (Alipourfard & Nili, 2011; Kadaei & Rashki, 2014; Hayati *et al.*, 2021). “These enzymes confer resistance to a broad range of β-lactam antibiotics, including penicillins and cephalosporins, further limiting treatment options” (Mora-Ochomogo & Lohans, 2021). ESBL-producing *Escherichia coli* strains can disseminate rapidly within healthcare settings, leading to outbreaks and increased healthcare-associated infections (Puvača & de Llanos Frutos, 2021; Hayward *et al.*, 2022).

Infections associated with ESBL-producing *Escherichia coli* represent a significant clinical challenge due to their multidrug resistance and limited treatment options (Pandit *et al.*, 2020; Zhu *et al.*, 2023). These drug-resistant strains are commonly implicated in various healthcare-associated and community-acquired infections, leading to increased morbidity and mortality rates.

Urinary tract infections (UTIs) are among the most frequently reported infections caused by ESBL-producing *Escherichia coli* (Fan *et al.*, 2014; Esteve-Palau *et al.*, 2015). “UTIs are the most common bacterial infections and affect one million people globally each year” (Zhou et al., 2023). These infections primarily affect the lower urinary tract but can progress to the kidneys, resulting in pyelonephritis. ESBL-producing strains complicate UTI treatment by rendering many commonly used antibiotics ineffective, limiting therapeutic options to a few last-line antibiotics. Wound and surgical site infections caused by ESBL-producing *Escherichia coli* are also a concern. These infections can occur after surgical procedures, particularly those involving the gastrointestinal or genitourinary tracts (Golzarri *et al.*, 2019). The presence of ESBLs in these strains increases the risk of treatment failure, prolonged hospital stays, and postoperative complications (Golzarri *et al.*, 2019; Egyir *et al.*, 2020).

Infections associated with ESBL-producing *Escherichia coli* are not limited to the healthcare setting. Community-acquired infections, such as bloodstream infections, respiratory tract infections and urinary tract infections, have also been reported (Vanstone *et al.*, 2013; Phipps *et al.*, 2019; Oroboghae *et al.*, 2018). ESBL-producing strains are known to cause severe bloodstream infections (Ha *et al.*, 2013), posing a significant threat to individuals with weakened immune systems or underlying medical conditions. Treatment options for such infections are often limited to a few antibiotics, leading to challenges in managing these life-threatening conditions.

Furthermore, ESBL-producing *Escherichia coli* strains have been implicated in infections in vulnerable populations, including neonates and the elderly. Neonatal sepsis caused by ESBL-producing strains can result in high mortality rates, as these bacteria exhibit resistance to commonly used antibiotics in neonatal care units (Kadaei & Rashki, 2014). In the elderly, ESBL-producing *Escherichia coli* infections contribute to increased hospitalisation rates, complications, and poorer health outcomes (Quan *et al.*, 2016).

The ability of ESBL-producing *Escherichia coli* strains to spread rapidly within healthcare facilities poses an additional concern. Outbreaks of ESBL-producing *Escherichia coli* infections have been reported in hospitals and long-term care facilities (Machado *et al.*, 2022), highlighting the importance of effective infection control measures and surveillance to prevent the dissemination of these drug-resistant strains.

The prevalence of these drug-resistant pathogens in clinical settings is a growing concern (Machado *et al.*, 2022), as it limits treatment options, increases healthcare costs, and contributes to high morbidity and mortality rates. The prevalence of multidrug-resistant and ESBL-producing *E. coli* in clinical settings in Nigeria has been reported to be as high as 71% and 69% respectively (Makanjuola *et al.*, 2018; Mofolorunsho *et al.*, 2021). These figures highlight an alarming trend that threatens effective clinical management of bacterial infections. Therefore, this study aimed to investigate the prevalence of multidrug resistance and extended-spectrum β-lactamase-producing *Escherichia coli* from clinical sources in Rivers State University Teaching Hospital.

**Materials and Methods**

**Study Population**

The study population comprised patients admitted to Rivers State University Teaching Hospital during the specified study period. The study population consisted of individuals with clinical samples collected for routine microbiological analysis. These samples included urine, stool, wound swabs, or other relevant specimens collected as part of standard clinical care. The inclusion of various specimen types allowed for the assessment of different infection sites and sources. Patients presenting with a range of clinical conditions and diagnoses were part of the study population. Patients with comorbidities, previous hospitalisations, and recent healthcare-associated infections were also included in the study population to capture a comprehensive picture of the prevalence and characteristics of multidrug-resistant and ESBL-producing strains.

**Sample Size Determination**

The prevalence of ESBL-producing *Escherichia coli* in Port Harcourt, as reported by Onanuga *et al.* (2019), which found a prevalence of 24%, was utilised to compute the minimal sample size of the participants enrolled in the research as follows.

Using the formula:

$N= \frac{z^{2}pq}{d^{2}}$ (Naing *et al.* 2006)

Where N = Minimum sample size

Z = Standard normal deviation corresponding to 95% confidence level set at 1.96

p =24% = 0.24

q = 1-p = 0.76

d = desired precision, 5% (0.05)

So, N = $\frac{1.96^{2} × 0.24 × 0.76}{0.05^{2}}$ = 281

Thus, approximately 281 subjects were ideal as the minimum sample size for this study. However, to avoid missing data and improve the power of the study, a total of 300 subjects were recruited.

**Eligibility of Subjects**

Inclusion Criteria involved patients admitted to Rivers State University Teaching Hospital during the study period, Patients with clinical samples collected for routine microbiological analysis and patients of all age groups and both genders. There was no exclusion criterion.

**Specimen Collection and Processing**

Urine, stool and swab samples were aseptically collected using respective sterile sample containers and swab sticks. Standard laboratory methods were used to process the samples. The samples were inoculated onto MacConkey agar plates and incubated at 37°C for 24 hours. The plates were then observed for the growth of the bacteria. Gram staining was carried out on each bacterial isolate and thereafter, identified by conventional biochemical tests.

**Identification of *Escherichia coli* Isolates**

**Colony Morphology and Gram Stain**

All isolates were identified primarily according to general cultural characteristics (colour, shape, texture and size) of the colony in addition to lactose fermentation on MacConkey agar after incubating overnight at 37ºC. All the bacterial isolates were examined after being stained with Gram stain to examine the cells’ shape, grouping, and Gram reaction microscopically.

**Biochemical Tests**

**Indole production test**

Peptone broth was inoculated with fresh cultures of bacteria and incubated at 37ºC for 24 hrs, then 10 drops of Kovac's reagent were added to each test tube. The appearance of a red ring at the top of the broth within 10 minutes was considered a positive result.

**Citrate utilisation test**

Simmon citrate agar slants were inoculated with fresh bacterial isolates and incubated at 37ºC for 24-48 hrs. Changing the colour from green to blue was considered a positive result.

**Urease test**

Urease activity of the isolates was detected by inoculating the surface of urea agar slants with the bacterial growth and incubating at 37ºC for 24 hrs. Changing the colour of the medium to purple-pink indicates a positive result, while keeping the media at its yellow-orange colour was considered a positive result.

**Oxidase test**

This test was done by using filter paper moistened with a few drops of a freshly prepared solution of Oxidase reagent (tetramethyl-p-phenylene diamine dihydrochloride). Aseptically, a clump of cells cultured was picked up from the growth and smeared on the filter paper. The development of a violet or purple colour within 2-10 seconds was considered a positive result.

**Catalase test**

A single colony was placed onto a clean glass microscope slide with a sterile applicator, and then a drop of hydrogen peroxide (3%) was placed onto the colony. The production of gaseous bubbles indicates the presence of catalase that hydrolyses hydrogen peroxide to water and oxygen.

**Triple Sugar Iron Test**

Isolates were inoculated into TSI slants with a straight inoculation needle by first stabbing through the centre of the medium to the bottom of the tube and then streaking the surface of the agar slant and subsequently incubating at 37ºC for 24-48 hours.

**Antibiotic Susceptibility Testing**

Antibiotic susceptibility testing was performed by the disc diffusion technique as described in the guidelines of the Clinical and Laboratory Standards Institute (2014). “The following antibiotics were used: Cefpodoxime (30 𝜇g), Tetracycline (30 𝜇g), Ceftazidime (30 𝜇g), Amoxicillin+Clauvulanic Acid (30 𝜇g), Imipenem (10 𝜇g), Cefepime (30 𝜇g), Amikacin, Gentamicin (120 𝜇g), Cefotaxime (30 𝜇g) Cefuroxime (30 𝜇g), Ofloxacin (5 𝜇g), and Ciprofloxacin (5 µg). Five millilitres (5ml) of sterile peptone water was inoculated with a fresh culture of each *E. coli* isolate and the turbidity of the suspension was adjusted to a 0.5 McFarland’s standard. A sterile cotton swab was dipped into the inoculum and swabbed evenly across the surface of the Muller-Hinton agar plate. The inoculated plates were placed at room temperature for 10 minutes to allow absorption of excess moisture, then the antibiotic discs were placed firmly on the inoculated plates with forceps to ensure contact with the agar and then incubated at 37ºC for 24 hours. After incubation, the diameters of the inhibition zones were measured in millimeters and compared with those of standards of the Clinical and Laboratory Standards Institute” (CLSI, 2014).

**Phenotypic Screening for Extended-Spectrum Beta-Lactamase (ESBL) Production.**

“The ESBL screening test was performed by the standard disc diffusion method by using ceftazidime (30 μg), cefotaxime (30 μg), and ceftriaxone (30 μg) (Oxoid, UK). More than one antibiotic disc was used for screening to improve the sensitivity of ESBL detection, as recommended by CLSI guidelines 2014. Freshly grown colonies were suspended in peptone water, and the turbidity of the suspension was adjusted to 0.5 McFarland’s standard. This suspension was inoculated onto Mueller–Hinton agar (Oxoid, UK) with a sterile cotton swab, and then all the above three antibiotic discs were placed at a gap of 20 mm and incubated at 35 ± 2°C for 16–18 hours. The isolates with reduced susceptibility to ceftazidime (zone diameter of ≤ 22 mm), ceftriaxone (zone diameter of ≤ 25 mm) and cefotaxime (zone diameter of ≤ 27 mm) around the discs were suspected as ESBL producers” (CLSI, 2014).

**Phenotypic Confirmation of ESBL Producers**

Confirmation of suspected ESBL producers was done by using the double-disk approximation or double-disk synergy (DDS) method on Mueller–Hinton agar, as recommended by CLSI guidelines 2014 (CLSI, 2014). A disc of amoxicillin + clavulanic acid (20/10 μg) was placed in the centre of the Mueller–Hinton Agar plate, and then cefotaxime (30 μg) and ceftazidime (30μg) were placed at a distance of 20mm (centre to centre) from the amoxicillin+clavulanic acid disc on the same plate. The plate was incubated at 37ºC for 24 hours and examined for an enhancement or expansion of the inhibition zone of the oxyimino-β-lactam caused by the synergy of the clavulanate in the amoxicillin-clavulanate disk, which was interpreted as positive for ESBL production.

**Data Analysis**

Descriptive statistics were used to determine the prevalence rates of multidrug-resistant and ESBL-producing *E. coli* using GraphPad Prism Software Version 9, San Diego, CA.

**RESULTS**

**Sociodemographic Characteristics of the Subjects**

A total of 300 subjects participated in the study. The age distribution of the subjects was as follows: 48 subjects (16%) were aged 18 to 20 years, 96 subjects (32%) were aged 21 to 40 years, 132 subjects (44%) were aged 41 to 60 years, and 24 subjects (8%) were aged 61 years and above. The mean age of the subjects was 45.61 years.

In terms of gender distribution, 114 subjects (38%) were male, while 186 subjects (62%) were female (Table 1).

**Table 1: Sociodemographic Characteristics of the Subjects**

|  |  |  |
| --- | --- | --- |
| **Variable** | **Frequency (N)** | **Percentage (%)** |
| **Age** |  |  |
| 18 - 20 | 48 | 16 |
| 21 - 40 | 96 | 32 |
| 41 - 60 | 132 | 44 |
| ≥ 61 | 24 | 8 |
| Total | 300 | 100 |
| *Mean* | *45.61* | - |
| **Sex** |  |  |
| Male | 114 | 38 |
| Female | 186 | 62 |
| Total | 300 | 100 |

**Prevalence and Distribution of *Escherichia coli* from Various Clinical Samples**

The prevalence of *Escherichia coli* in clinical samples is presented in Table 2 Out of the 300 clinical samples analysed, *E. coli* growth was observed in 61 samples, accounting for 20.3% of the total isolates. Conversely, no *E. coli* growth was noted in 239 samples, representing 79.7% of the total isolates.

Table 3 presents the distribution of *Escherichia coli* isolates from various clinical samples. Among the 61 *E. coli* isolates identified, the majority were obtained from urine samples, accounting for 38 isolates (62.3%). High vaginal swabs contributed 15 isolates (24.6%), followed by sputum samples with 5 isolates (8.2%). A smaller proportion of *E. coli* isolates were obtained from blood samples, comprising 3 isolates (4.9%).

**Table 2: Prevalence of *E. coli* in Clinical Samples**

|  |  |  |
| --- | --- | --- |
| ***E. coli*** | **Frequency (N)** | **Percentage (%)** |
| *E. coli* growth | 61 | 20.3 |
| No *E. coli* growth | 239 | 79.7 |
| Total | 300 | 100 |

**Table 3: Distribution of *E. coli* isolates from various Clinical Samples**

|  |  |  |
| --- | --- | --- |
| **Clinical Sample** | **Number of Isolates** | **Percentage (%)** |
| Blood | 3 | 4.9 |
| Sputum | 5 | 8.2 |
| Urine | 38 | 62.3 |
| High vaginal swab | 15 | 24.6 |
| Total | 61 | 100 |

**Antibiotic Susceptibility Pattern of *E. coli* Isolates from the Clinical Samples**

The antibiotic susceptibility pattern of *E. coli* isolates from the clinical samples is presented in Table 4.

Among the 61 *E. coli* isolates tested, 49 (80.3%) were sensitive to amikacin, while 12 isolates (19.6%) were resistant to this antibiotic. Similarly, 48 isolates (78.7%) were sensitive to gentamicin, with 13 isolates (21.3%) showing resistance. In terms of cephalosporins, 28 isolates (45.9%) were sensitive to cefepime, while 33 isolates (54.1%) were resistant. For cefuroxime sodium, 27 isolates (44.3%) were sensitive, while 34 isolates (55.7%) were resistant. For fluoroquinolones, 26 isolates (42.6%) were sensitive to ofloxacin, while 35 isolates (57.4%) were resistant. Similarly, 27 isolates (44.3%) were sensitive to ciprofloxacin, with 34 isolates (55.7%) being resistant. Cefpodoxime showed lower sensitivity, with only 15 isolates (24.6%) being sensitive and 46 isolates (75.4%) being resistant. Ceftazidime exhibited a sensitivity rate of 36.1%, with 22 isolates being sensitive and 39 isolates (63.9%) being resistant. Only 4 isolates (6.6%) were sensitive to amoxicillin + clavulanic acid, while 57 isolates (93.4%) were resistant. Cefotaxime showed a sensitivity rate of 22.9%, with 14 isolates being sensitive and 47 isolates (77.1%) being resistant.

Remarkably, all 61 *E. coli* isolates were sensitive to imipenem, representing 100% sensitivity to this carbapenem antibiotic. However, 12 isolates (19.7%) were sensitive to tetracycline, while 49 isolates (80.3%) were resistant.

**Table 4:** **Antibiotic Susceptibility Pattern of *E.coli* isolates from the Clinical Samples**

|  |  |  |
| --- | --- | --- |
| **Antibiotics****(Zone of Inhibition Range in mm)** | **Antibiotic Class** | ***E. coli* Isolates (N = 61)** |
| **Sensitive (%)** | **Resistant (%)** |
| Amikacin 30 µg (AK) (< 18 = R; ≥ 18 = S) | Aminoglycoside | 49 (80.3) | 12 (19.6) |
| Gentamicin 120 µg (CN) (< 17 = R; ≥ 17 = S) | Aminoglycoside | 48 (78.7) | 13 (21.3) |
| Cefepime 30 µg (FEP) (< 19 = R; ≥ 19 = S) | Cephalosporin | 28 (45.9) | 33 (54.1) |
| Cefuroxime Sodium (CXM) (< 19 = R; ≥ 19 = S) | Cephalosporin | 27 (44.3) | 34 (55.7) |
| Ofloxacin 5 µg (OFX) (< 22 = R; ≥ 24 = S) | Floroquinolone | 26 (42.6) | 35 (57.4) |
| Ciprofloxacin 5 µg (CIP) (< 22 = R; ≥ 25 = S) | Floroquinolone | 27 (44.3) | 34 (55.7) |
| Cefpodoxime 10 µg (CPD) (< 21 = R; ≥ 21 = S) | Cephalosporin | 15 (24.6) | 46 (75.4) |
| Ceftazidime 30 µg (CAZ) (< 19 = R; ≥ 22 = S) | Cephalosporin | 22 (36.1) | 39 (63.9) |
| Amoxicillin + Clavulanic Acid 30 µg (AMC) (< 19 = R; ≥ 19 = S) | β-lactam and β-lactamase inhibitor | 4 (6.6) | 57 (93.4) |
| Cefotaxime 30 µg (CTX) (< 17 = R; ≥ 20 = S) | β-lactam | 14 (22.9) | 47 (77.1) |
| Imipenem 10 µg (IPM) (< 19 = R; ≥ 22 = S) | Carbapenem | 61 (100) | 0 (0) |
| Tetracycline 30 µg (TE) (< 19 = R;≥ 19 = S) | Tetracycline | 12 (19.7) | 49 (80.3) |

**Prevalence of Multidrug-Resistant and Extended β-lactamase (ESBL) Producing *E.coli* Isolates**

The prevalence of multidrug-resistant (MDR) and Extended β-lactamase (ESBL) producing *Escherichia coli* isolates is presented in Table 5.

Out of the 61 *E. coli* isolates tested, 28 isolates (45.9%) were identified as multidrug-resistant (MDR), while 33 isolates (54.1%) were non-MDR. Regarding ESBL production, 26 isolates (42.6%) were identified as ESBL producers, while 35 isolates (57.4%) were non-ESBL producers.

**Table 5: Prevalence of Multidrug-resistant and Extended β-lactamase (ESBL) producing *E.******coli* isolates**

|  |  |
| --- | --- |
| **Variable** | ***E. coli* Isolates (N = 61)** |
| Multidrug Resistance (MDR) | Non-MDR (%) | MDR (%) |
|  | 28 (45.9) | 33 (54.1) |
| Extended β-lactamase (ESBL) Production | Non-ESBL (%) | ESBL (%) |
|  | 35 (57.4) | 26 (42.6) |

**Discussion**

Among the 300 clinical samples analysed, *E. coli* growth was detected in 61 samples, representing 20.3% of the total isolates. Conversely, the absence of *E. coli* growth was observed in 239 samples, accounting for 79.7% of the total isolates. This prevalence of *E. coli* in clinical samples underscores the significance of this bacterial species as a potential pathogen in the studied healthcare setting. The observed prevalence of *E. coli* in the clinical samples aligns with existing literature documenting the ubiquitous nature of this bacterium in healthcare settings (Tajbakhsh *et al.*, 2016; Iliyasu *et al.*, 2018; Dadashi *et al.*, 2019). Factors such as poor hygiene practices, inadequate sanitation, and compromised host immunity can contribute to the transmission and proliferation of *E. coli* in healthcare environments. Additionally, the ability of *E. coli* to survive and persist in diverse environmental conditions further enhances its potential as a nosocomial pathogen (Gonzales‐Siles & Sjöling, 2016), capable of causing both community-acquired and healthcare-associated infections.

 Among the 61 *E. coli* isolates identified, urine samples emerged as the predominant source, accounting for the majority of isolates at 62.3%. This observation is consistent with the well-documented association between *E. coli* and urinary tract infections (UTIs) (Ejrnæs *et al.*, 2011; Mao *et al.*, 2012; Lin *et al.*, 2022), as *E. coli* is one of the most common pathogens implicated in both community-acquired and healthcare-associated UTIs (Medina-Polo *et al.*, 2021; Kumar Shrestha *et al.*, 2022). The high prevalence of *E. coli* in urine samples underscores the importance of vigilant screening and management strategies to address UTIs effectively, considering the potential for complications such as pyelonephritis and septicemia.

Furthermore, the distribution of *E. coli* isolates across different clinical samples highlights the diverse sites of infection associated with this bacterium. High vaginal swabs contributed a significant proportion of isolates at 24.6%, indicating the potential involvement of *E. coli* in genital tract infections. While *E. coli* is not typically considered a primary pathogen in the vaginal environment (Villegas *et al.*, 2021), its presence in high vaginal swabs suggests a possible role in ascending infections or opportunistic colonisation, particularly in the context of gynaecological and obstetric conditions (Kovachev, 2014). Additionally, the isolation of *E. coli* from sputum samples (8.2%) and blood samples (4.9%) underscores its capacity to cause respiratory tract infections and bloodstream infections, respectively. These findings emphasise the importance of comprehensive diagnostic approaches and tailored treatment strategies to address *E. coli* infections affecting different anatomical sites.

Aminoglycosides, represented by amikacin and gentamicin, demonstrated notable efficacy against *E. coli* isolates, with 80.3% and 78.7% sensitivity rates, respectively, aligning with the findings of Bari *et al.* (2017) as well as the study by Rizwan *et al.* (2018). This effectiveness can be attributed to the mechanism of action of aminoglycosides, which involves irreversible binding to the bacterial ribosome, inhibiting protein synthesis (Upmanyu & Malviya, 2020). Resistance to aminoglycosides typically arises from enzymatic modification of the antibiotic molecule or alterations in membrane permeability (Garneau-Tsodikova & Labby, 2016). The implications of high sensitivity to aminoglycosides are significant, as they serve as valuable options for treating severe *E. coli* infections, especially when β-lactam antibiotics are contraindicated.

Cephalosporins, including cefepime and cefuroxime sodium, exhibited varying degrees of efficacy against *E. coli* isolates, with sensitivity rates ranging from 44.3% to 45.9%; these observations contradicted the findings of Rizwan *et al.* (2018) but were similar to the findings of Biswas *et al.* (2014). The resistance observed may be attributed to the production of extended-spectrum β-lactamase (ESBL) enzymes, which hydrolyze the β-lactam ring of cephalosporins, rendering them ineffective (Ali *et al.*, 2018). ESBL-producing *E. coli* strains pose a significant challenge in clinical settings, as they are resistant to multiple β-lactam antibiotics, including cephalosporins and penicillins (Anima *et al.*, 2017). This underscores the importance of judicious antibiotic use and the need for alternative treatment strategies when dealing with ESBL-producing pathogens.

Fluoroquinolones, represented by ofloxacin and ciprofloxacin, demonstrated reduced efficacy against *E. coli* isolates, with sensitivity rates of 42.6% and 44.3%, respectively, deviating from the findings of Rizwan *et al.* 2018 but comparable with the report of Biswas *et al.* (2014). Resistance to fluoroquinolones typically arises from mutations in bacterial DNA gyrase and topoisomerase IV, which reduce drug binding affinity and lead to decreased susceptibility (Redgrave *et al.*, 2014). The widespread resistance observed highlights the challenge of managing fluoroquinolone-resistant *E. coli* infections, necessitating the exploration of alternative treatment options, such as carbapenems or combination therapies.

β-lactam antibiotics, including cefpodoxime, ceftazidime, and amoxicillin+clavulanic acid, exhibited variable efficacy against *E. coli* isolates, with sensitivity rates ranging from 6.6% to 36.1%. These trends are comparable to the findings of previous studies (Biswas *et al.*, 2014; Niranjan & Malini, 2014; Bari *et al.*, 2017; Rizwan *et al.*, 2018). The prevalence of resistance underscores the presence of ESBL-producing strains, which can hydrolyze the β-lactam ring of these antibiotics, rendering them ineffective (Ali *et al.*, 2018). The emergence of ESBL-producing *E. coli* strains poses a significant public health concern, as they are associated with treatment failure, prolonged hospital stays, and increased healthcare costs (McDonald *et al.*, 2021). This highlights the urgent need for comprehensive antimicrobial stewardship programs, infection control measures, and the development of novel antibiotics to combat ESBL-mediated resistance.

Carbapenems, represented by imipenem, demonstrated universal efficacy against *E. coli* isolates, with 100% sensitivity observed and consistent with existing literature (Biswas *et al.*, 2014; Niranjan & Malini, 2014; Bari *et al.*, 2017; Rizwan *et al.*, 2018). This highlights the continued importance of carbapenems as last-line treatment options for severe *E. coli* infections, especially in cases of multidrug-resistant strains (Chin *et al.*, 2018; Nørgaard *et al.*, 2019). However, the emergence of carbapenem-resistant *E. coli* strains is a growing concern (Ghasemian *et al.*, 2018; Harting, 2019; Tilahun *et al.*, 2021), necessitating vigilant surveillance and judicious use of these antibiotics to preserve their effectiveness.

Multidrug resistance, characterised by resistance to three or more classes of antibiotics, was observed in 45.9% of the *E. coli* isolates tested, aligning with the findings of Alqasim *et al.* (2018) as well as the report by Shilpakar *et al.* (2021). This phenomenon can be attributed to various factors, including the overuse and misuse of antibiotics (Kasanga *et al.*, 2023), horizontal gene transfer of resistance genes (Doi *et al.*, 2012; Juhas, 2015), and the selective pressure exerted by antibiotic exposure (Bessa *et al.*, 2018). The presence of MDR *E. coli* strains poses significant challenges in clinical settings, as they limit treatment options and increase the risk of treatment failure and adverse patient outcomes (Cerceo *et al.*, 2016; Alkofide *et al.*, 2020). Furthermore, the emergence and dissemination of MDR *E. coli* strains contribute to the global burden of antibiotic resistance (Galindo-Méndez, 2020), highlighting the urgent need for comprehensive antimicrobial stewardship programs, infection control measures, and the development of novel antibiotics to combat multidrug resistance.

Extended β-lactamase (ESBL) production, characterised by the production of enzymes that hydrolyze β-lactam antibiotics, was identified in 42.6% of the *E. coli* isolates tested. This finding is corroborated by the study in China (Quan *et al.*, 2016), the study by Sing *et al.* (2016), as well as the findings of Alqasim *et al.* (2018). ESBL-producing *E. coli* strains pose a significant clinical challenge, as they are resistant to a broad range of β-lactam antibiotics, including penicillins, cephalosporins, and monobactams (Rodríguez-Baño *et al.*, 2006; Padmini *et al.*, 2017; Husna *et al.*, 2023). The presence of ESBL-producing strains is often associated with healthcare-associated infections and is linked to increased morbidity, mortality, and healthcare costs (Esteve-Palau *et al.*, 2015; Scheuerman *et al.*, 2018; Zaha *et al.*, 2019). Moreover, ESBL-producing *E. coli* strains have the potential to spread within healthcare facilities and communities (Kim *et al.*, 2017; Davidova-Gerzova *et al.*, 2023), further exacerbating the problem of antibiotic resistance. Effective management of ESBL-producing *E. coli* infections requires a multifaceted approach, including antimicrobial stewardship initiatives, infection control measures, and the use of alternative treatment options, such as carbapenems or combination therapies (Viale *et al.*, 2015; Karam *et al.*, 2016; Giurazza *et al.*, 2021). Additionally, surveillance of ESBL-producing strains is essential for monitoring trends in resistance patterns and guiding antibiotic prescribing practices to optimise patient outcomes and mitigate the spread of resistant strains (Gulumbe *et al.*, 2022; Kasanga *et al.*, 2023; Djordjevic *et al.*, 2024).

**Conclusion**

This study provides important insights into *Escherichia coli* prevalence and antibiotic susceptibility profiles in Rivers State University Teaching Hospital. Notably, *E. coli* growth was observed in 61 (20.3%) of the 300 clinical samples analysed, with urine samples being the most prevalent source. The presence of *E. coli* in clinical samples raises concerns regarding the potential for infection and underscores the importance of effective surveillance, diagnosis, and treatment strategies. Also, results from this study unveils concerning rates of multidrug resistance (45.9%) and Extended β-lactamase (ESBL) production (42.6%) among the isolates tested and highlights varying susceptibility patterns across different antibiotic classes, with notable sensitivity rates observed for imipenem (100%), amikacin (80.3%) and gentamicin (78.7%), contrasting with higher resistance rates seen for cephalosporins, fluoroquinolones, and β-lactam antibiotics. These results underscore the urgent need for effective antimicrobial stewardship programs and infection control measures to mitigate the spread of antibiotic resistance and optimise patient outcomes in the face of increasingly resistant *E. coli* infections.

Ethical Approval

Ethical approval was obtained from the Rivers State University Teaching Hospital research and ethics committee.

Consent

The study was explained to all willing subjects who passed the minimum inclusion criteria. Thereafter, subjects were required to agree to at least an oral consent.

Disclaimer (Artificial intelligence)

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Details of the AI usage are given below:

1.

2.

3.

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