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Microbiology Section

# Bacteriological Profile and Antibiogram of Aerobic Blood Culture Isolates among Suspected Blood Stream Infections: A Cross-sectional Study

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## ABSTRACT

**Introduction:** Bloodstream Infections (BSIs) are important causes of morbidity and mortality worldwide. Blood culture is the most important diagnostic tool for BSI. The epidemiology and outcome of BSI are constantly changing due to increasing antimicrobial resistance, changing patterns of antibiotic drug usage, and the increased use of transient or permanent medical devices. Thus, regular monitoring of the bacterial aetiology of BSI and their antibiograms is necessary.

**Aim:** To determine the bacteriological profile and antibiotic susceptibility patterns among suspected BSI patients.

**Materials and Methods:** A hospital-based cross-sectional study was carried out in the Department of Microbiology, Jawaharlal Nehru Institute of Medical Sciences (JNIMS), Imphal, Manipur, India, from September 2018 to August 2020. A total of 481 suspected BSI patients were included in the study. The blood culture samples were collected under aseptic conditions and cultured for seven days. The isolates were identified using conventional biochemical tests, and the antibiotic susceptibility pattern was determined by the Kirby-Bauer disk diffusion method and the epsilometer test (E-test). Methicillin resistance among the staphylococcal isolates was detected using the cefoxitin disk diffusion method. Data analysis was performed using EpiInfo™ version 7.0, and the Chi-square test was used as a statistical test.

**Results:** A total of 150 (31.2%) blood samples were culture positive out of the 481 samples processed from suspected BSI patients. The predominant isolates were gram-positive, accounting for 113/150 (75.3%), while gram-negatives accounted for 37/150 (24.7%). *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and Coagulase Negative Staphylococci (CoNS) were the primary pathogens isolated. Methicillin resistance was detected in 59 (54.6%) of the staphylococcal isolates {52 (54.7%) were Methicillin Resistant *S. aureus* (MRSA), and out of the 13 CoNS isolates, 7 (53.9%) were Methicillin Resistant CoNS (MRCoNS)}. The most susceptible drugs for gram-positives were vancomycin and linezolid, while aminoglycosides and imipenem were the most susceptible drugs for gram-negatives.

**Conclusion:** The study highlighted the prevalence and pattern of aerobic bacterial isolates in BSI cases at JNIMS Hospital, as well as, the antibiotic susceptibility patterns of the isolates. Regular epidemiological studies of BSIs, regarding the pathogens and their antibiotic susceptibility patterns, are necessary to guide clinicians in choosing appropriate empirical therapy and to update the hospital antibiotic policy from time to time. This promotes rational antibiotic use and reduces resistance among bacteria.

**Keywords:** Antibiotic policy, Antibiotic susceptibility pattern, Bacteraemia, Predominant isolates

## INTRODUCTION

Bacteraemia and other BSIs are among the most significant serious infections that cause morbidity and mortality among hospitalised patients worldwide [1]. Approximately 200,000 cases of bacteraemia occur annually with a mortality rate ranging from 20% to 50% worldwide [2,3]. They are often associated with hospitalisation, catheterisation (both central and peripheral lines), and other predisposing factors such as admission to the Intensive Care Unit (ICU), lapses in handwashing, and non-compliance with infection control practices by hospital and medical staff [2,4]. Septicaemia or sepsis occurs when there is active bacterial multiplication that releases bacterial products (toxins) into the host's bloodstream, triggering the production of cytokines. Septicaemia is characterised by fever, chills, malaise, tachycardia, hyperventilation, toxicity, and hypotension [5]. Blood cultures are the most important diagnostic tool in investigating BSIs, and it is considered the gold standard technique for the diagnosis of bacteraemia. It has a high positive predictive value, as blood is normally a sterile fluid [6-8].

A wide spectrum of microorganisms has been described as causing BSIs [9,10]. Over the past 20-30 years, there have been significant changes in the pattern of these microorganisms. *Staphylococcus aureus* and *Escherichia coli* continue to be the most common causative microorganisms. There has been an increase in the incidence of BSI caused by CoNS, other members of Enterobacteriaceae, and other non-fermentative gram-negative bacilli such as *Pseudomonas* spp. and *Acinetobacter* spp. [11,12]. Increasing antimicrobial resistance is a worldwide concern and is subject to regional variation [13,14]. Susceptible bacterial strains are now being replaced by Multidrug Resistant (MDR) strains of *Klebsiella* spp., *Pseudomonas* spp., and *Acinetobacter* spp. [12].

To study the current changes in bacterial isolates and their resistance pattern, periodic surveillance of the local pattern of BSI and their susceptibility to various antibiotics is necessary. Such studies help us understand the variations in the profile that differ according to the geographical region and timeline. Apart from being a useful guide for clinicians initiating empirical antibiotic therapy, it also alerts clinicians to emerging pathogens posing a threat to the community [3]. Therefore, the present study was undertaken to determine the bacteriological profile and antibiotic susceptibility patterns among suspected BSI patients at a tertiary care hospital in Manipur.

## MATERIALS AND METHODS

The study was a hospital-based cross-sectional study carried out in the Bacteriology section at Department of Microbiology, Jawaharlal Nehru Institute of Medical Sciences (JNIMS), Imphal, Manipur, India, from September 2018 to August 2020. A total of 481 suspected BSI patients were included in the study. Informed written consent was obtained from the participating individuals. In the case of minors, informed consent was taken from the parents/legal guardians. Privacy and confidentiality were maintained in all cases. Approval from the Institutional Ethical Committee (IEC), JNIMS, was obtained with reference number Ac/06/IEC/JNIMS/2018(PGT), dated September 21st, 2018.

**Inclusion criteria:** Clinically suspected cases of BSI, irrespective of age group and gender, attending outpatient and inpatient departments of JNIMS Hospital, were included in the study.

**Exclusion criteria:** Blood culture samples yielding fungal growth and contaminants, and patients who refused to participate, were excluded from the study.

**Sample size determination:** The required sample size was calculated using a single population proportion formula $(z^2pq)/d^2$. A prevalence (p) of 16.78% was chosen from a previous study conducted in RIMS Hospital of Manipur by Devi et al., [15]. After considering a confidence interval of 95% (z=1.96) and a marginal error of 5% (d=0.05), the minimum sample size (n) was estimated to be 215.

### Study Procedure

**Specimen collection:** Blood samples were collected under aseptic precautions before administering antibiotic therapy. In patients already receiving antibiotic therapy, the blood sample was collected just before the next dose of the antibiotic. A sterile needle and syringe were used to draw 5 mL to 10 mL of blood for adults, 2 mL to 5 mL for children, and 1 mL to 2 mL for neonates, which were then directly inoculated into blood culture bottles containing Brain Heart Infusion (BHI) broth (HiMedia Laboratories Pvt., Ltd., Mumbai, India) at a ratio of 1:5 to 1:10. Samples were transported to the laboratory and immediately incubated aerobically at 35±2°C.

All blood culture samples were processed using standard laboratory procedures. Routine inspections of the samples were conducted for a week to check for the presence of bacterial growth, such as turbidity, haemolysis, coagulation of broth, floccular deposit, surface pellicle formation, etc. After overnight incubation, subcultures were made on 5% sheep blood agar and MacConkey agar. If there was no growth on the subculture, periodic subcultures were done on day 7 and in between if any signs of bacterial growth appeared [16,17].

**Identification and antibiotic susceptibility testing of the isolates:** The isolates were identified based on conventional microbiological procedures using the following parameters: colony morphology, Gram staining, motility test, and conventional biochemical tests such as the catalase test, coagulase test, bile-esculin test, oxidase test, IMViC tests (indole production test, methyl-red test, Voges-Proskauer test, citrate utilisation test), urea hydrolysis (urease) test, Triple-Sugar Iron (TSI) test, Oxidative-Fermentative (OF) test, nitrate reduction test, and sugar fermentation test (glucose, lactose, sucrose, mannitol, and maltose) [Table/Fig-1,2] [16,17].

| GPC isolates | CAT | SC | TC | BE |
|---|---|---|---|---|
| *S. aureus* | + | + | + | NT |
| CoNS | + | ± | – | NT |
| *Enterococcus* spp. | – | NT | NT | + |

**[Table/Fig-1]:** Biochemical reactions of gram-positive isolates.
GPC: Gram-positive cocci; CAT: Catalase test; SC: Slide coagulase test; TC: Tube coagulase test; BE: Bile-esculin test; +: Positive; –: Negative; ±: positive or negative; NT: Not tested

Antibiotic susceptibility was determined using the Kirby Bauer disk diffusion method, following the Clinical and Laboratory Standards Institute (CLSI) 2018, M100 guidelines. Mueller Hinton agar and commercially available 6 mm antimicrobial disks (HiMedia Laboratories Pvt., Ltd., Mumbai, India) were used [18].

**For gram-positive isolates, the following antibiotics were used:** penicillin (P-10 units), erythromycin (E-15 µg), trimethoprim-sulfamethoxazole (COT-1.25/23.75 µg), ciprofloxacin (CIP-5 µg), linezolid (LZ-30 µg), tetracycline (TE-30 µg), ampicillin (AMP-10 µg), vancomycin (VA-30 µg), teicoplanin (TEI-30 µg), High-Level Gentamicin (HLG-120 µg), and High-Level Streptomycin (HLS-300 µg).

**For gram-negative isolates, the following antibiotic disks were used:** Amoxicillin-clavulanate (AMC-20/10 µg), Cefotaxime (CTX-30 µg), Ceftriaxone (CTR-30 µg), Levofloxacin (LE-5 µg), Imipenem (IMP-10 µg), Gentamicin (GEN-10 µg), Amikacin (AK-30 µg), Piperacillin-tazobactam (PIT-100/10 µg), and Cefepime (CPM-30 µg).

Vancomycin susceptibility testing for staphylococcal isolates was performed using the Epsilometer test (E-test) with Vancomycin Ezy MIC™ Strip (VAN) having concentrations ranging from 0.016 to 256 µg/mL (HiMedia Laboratories Pvt., Ltd., Mumbai, India), following the manufacturer's guidelines. Methicillin resistance among staphylococcal isolates was detected using the cefoxitin disk (CX-30 µg) diffusion method. Extended spectrum β-lactamase production in *K. pneumoniae* and *E. coli* isolates was determined by the double disk diffusion method using Ceftazidime (CAZ-30 µg), Ceftazidime-clavulanate (CAC-30/10 µg), Cefotaxime (CTX-30 µg), and Cefotaxime-clavulanate (CEC-30/10 µg) disks [18].

**Quality control:** Quality control measures included checking the sterility of every batch of prepared media for 24 hours [16]. American Type Culture Collection (ATCC) strains were used as reference

| GNB isolates | Motility test | Catalase test | Oxidase test | IMViC | | | | Urease test | TSI test | Nitrate test | OF test | Sugar fermentation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Indole | MR | VP | Citrate | | | | | Glucose | Lactose | Sucrose | Mannitol | Maltose |
| *E. coli* | + | + | – | + | + | – | – | – | A/A gas + | + | F | f gas + | f | v | f | f |
| *K. pneumoniae* | – | + | – | – | – | + | + | + | A/A gas + | + | F | f gas + | f | f | f | f |
| S. Paratyphi A | + | + | – | – | + | – | – | – | K/A gas + | + | F | f gas + | nf | nf | f | f |
| *P. aeruginosa* | + | + | + | – | – | – | + | – | K/K | + | O | nf | nf | nf | nf | nf |
| *Acinetobacter* spp. | – | + | – | – | – | – | v | v | K/K | – | O or N | nf | nf | nf | nf | nf |

**[Table/Fig-2]:** Biochemical reactions of gram-negative isolates.
GNB: Gram-negative bacilli; Indole: Indole production test; MR: Methyl-Red test; VP: Voges-Proskauer test; Urease test: Urea hydrolysis test; TSI test: Triple sugar iron test; Nitrate test: Nitrate reduction test; OF test: Oxidative-Fermentative test; +: Positive; –: Negative; v: Variable; A/A: Acid/Acid; K/A: Alkaline/Acid; K/K: Alkaline/Alkaline; gas +: Gas production; F: Fermentative; O: Oxidative; N: Nonsaccharolytic; f: Fermented; nf: Not fermented

(standard) for quality control related to culture and antibiotic susceptibility tests. The reference strains used were *S. aureus* (ATCC 25923), *E. coli* (ATCC 25922), *K. pneumoniae* (ATCC 27736), *E. faecalis* (ATCC 29212), and *P. aeruginosa* (ATCC 27853).

## STATISTICAL ANALYSIS

Descriptive statistics, such as percentages and proportions, were used to present the data. The analysis was performed using EpiInfo™ version 7.0.

## RESULTS

**Demographic characteristics:** A total of 481 blood culture samples were collected from clinically suspected patients with BSI during the study period. Among these, 281 (58.4%) were from males and 200 (41.6%) were from females. The highest number of samples were from the 0-10 years age group. The mean age was 24.5 (SD±25.35) years. Out of the total samples received, 244 (50.7%) were from the paediatric department, followed by 193 (40.1%) from the medicine department [Table/Fig-3].

| Variables | Category | n (%) |
|---|---|---|
| Gender | Male | 281 (58.4) |
| | Female | 200 (41.6) |
| Age group (in years) | 0-10 | 235 (48.9) |
| | 11-20 | 21 (4.4) |
| | 21-30 | 31 (6.4) |
| | 31-40 | 47 (9.8) |
| | 41-50 | 53 (11) |
| | 51-60 | 41 (8.5) |
| | 61-70 | 32 (6.7) |
| | >70 | 21 (4.4) |
| Department | Medicine | 193 (40.1) |
| | Paediatrics | 244 (50.7) |
| | Surgery | 25 (5.2) |
| | OBG | 15 (3.1) |
| | ENT | 4 (0.8) |

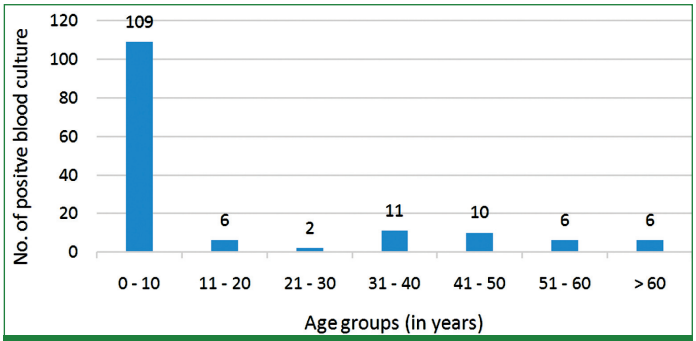
**[Table/Fig-3]:** Demographic characteristics of the suspected BSI patients.
OBG: Obstetrics and gynaecology; ENT: Ear, nose and throat

A single blood culture specimen was obtained from outpatient services, while the rest were from inpatient services of JNIMS Hospital. Out of the total 480 inpatient samples, 183 (38.1%) were collected from patients admitted to ICUs, and 297 (61.9%) were collected from various wards of the hospital. Among the 183 samples from the ICUs, the highest number of samples was from the Neonatal ICU (NICU) with 72 (39.3%) samples [Table/Fig-4].

| Type of ICU | Number of samples collected (N=183) n (%) |
|---|---|
| NICU | 72 (39.3) |
| MICU | 38 (20.8) |
| PICU | 32 (17.5) |
| SICU | 26 (14.2) |
| ATC-ICU | 13 (7.1) |
| ICCU | 2 (1.1) |

**[Table/Fig-4]:** Sample collection from Intensive Care Units (ICU).

**Prevalence of BSIs:** Out of the total 481 blood culture samples processed, 150 (31.2%) samples were culture-positive, while there was no growth in the remaining 331 (68.8%) samples. Among the culture-positive cases (n=150), 78 (52%) were males and 72 (48%) were females. The age group of 0-10 years had the highest number of positive cases, with 109 (72.7%), followed by 11 (7.3%) in the age group of 31-40 years [Table/Fig-5].




**[Table/Fig-5]:** Age-wise distribution of positive blood culture.

In the present study, the maximum number of culture-positive cases were observed among patients attending the paediatric department with 111/150 (74%), followed by medicine with 29/150 (19.3%), surgery with 5/150 (3.3%), Obstetrics and Gynaecology (OBG) with 3/150 (2%), and otorhinolaryngology (ENT) with 2/150 (1.3%).

Out of the 183 blood culture samples sent from various ICUs of JNIMS Hospital, 63 (34.4%) were culture-positive. The maximum number of culture-positive cases were from NICU with 33/63 (52.4%), followed by PICU with 19/63 (30.2%), SICU with 7/63 (11.1%), MICU with 3/63 (4.8%), and ATC-ICU with 1/63 (1.6%). Blood culture samples from ICCU did not yield any growth.

**Bacteriological profiles of culture isolates:** The majority of the isolates responsible for BSI were gram-positive, accounting for 113/150 (75.3%), whereas gram-negatives accounted for 37/150 (24.7%). A total of eight bacterial species were isolated. *S. aureus* with 95 (63.3%) isolates was the most common, while *E. coli* with 1 (0.7%) and Salmonella serotype Paratyphi A with 1 (0.7%) were the least common isolates [Table/Fig-6].

| Microorganisms | Species isolated | n (%) |
|---|---|---|
| Gram-positive | *Staphylococcus aureus* | 95 (63.3) |
| | CoNS | 13 (8.7) |
| | *Enterococcus* spp. | 5 (3.3) |
| Gram-negative | *Pseudomonas aeruginosa* | 17 (11.3) |
| | *Acinetobacter* spp. | 9 (6) |
| | *Klebsiella pneumoniae* | 9 (6) |
| | *Escherichia coli* | 1 (0.7) |
| | Salmonella Paratyphi A | 1 (0.7) |

**[Table/Fig-6]:** Pattern of the isolated microorganisms.

### Antibiotic Susceptibility Patterns of Culture Isolates

**Gram-positive isolates:** The susceptibility patterns of the gram-positive bacteria (n=113) isolated from the blood cultures of suspected BSI are presented in [Table/Fig-7]. Gram-positive isolates exhibited wider variations in their resistance patterns, with maximum resistance observed against penicillin and least resistance observed against linezolid and vancomycin.

**Gram-negative isolates:** The antibiotic susceptibility pattern of the gram-negative microorganisms is shown in [Table/Fig-8]. These microorganisms demonstrated high resistance against amoxicillin-clavulanate, cefotaxime, and ceftriaxone. However, a lower resistance pattern was observed against imipenem, amikacin, levofloxacin, and gentamicin.

**Methicillin resistance:** Out of the 95 *S. aureus* isolates, 52 (54.7%) were MRSA, and out of the 13 CoNS isolates, 7 (53.9%) were MRCoNS.

**Extended Spectrum β-Lactamase (ESBL) production:** The prevalence of ESBL producers amongst *K. pneumoniae* and *E. coli* isolates was 7/10 (70%). Six out of nine (66.7%) *K. pneumoniae* isolates were ESBL producers.

| Gram-positive isolates | | Antibiotics | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | P n (%) | E n (%) | COT n (%) | CIP n (%) | TE n (%) | LZ n (%) | VA n (%) | AMP n (%) | TEI n (%) | HLG n (%) | HLS n (%) |
| *S. aureus* (n=95) | S (%) | 21 (22.1) | 32 (33.7) | 50 (52.6) | 66 (69.5) | 55 (57.9) | 94 (98.9) | 84 (88.4) | NT | NT | NT | NT |
| | I (%) | 0 | 3 (3.2) | 1 (1.1) | 4 (4.2) | 1 (1.1) | 0 | 1 (1.1) | NT | NT | NT | NT |
| | R (%) | 74 (77.9) | 60 (63.2) | 44 (46.3) | 25 (26.3) | 39 (41.1) | 1 (1.1) | 10 (10.5) | NT | NT | NT | NT |
| CoNS (n=13) | S (%) | 2 (15.4) | 4 (30.8) | 7 (53.8) | 11 (84.6) | 8 (61.5) | 13 (100) | 12 (92.3) | NT | NT | NT | NT |
| | I (%) | 0 | 1 (7.7) | 1 (7.7) | 1 (7.7) | 0 | 0 | 1 (7.7) | NT | NT | NT | NT |
| | R (%) | 11 (84.6) | 8 (61.5) | 5 (38.5) | 1 (7.7) | 5 (38.5) | 0 | 0 | NT | NT | NT | NT |
| *Enterococcus* spp. (n=5) | S (%) | NT | NT | NT | NT | NT | 5 (100) | 4 (80) | 2 (40) | 5 (100) | 3 (60) | 4 (80) |
| | I (%) | NT | NT | NT | NT | NT | 0 | 0 | 0 | 0 | 0 | 0 |
| | R (%) | NT | NT | NT | NT | NT | 0 | 1 (20) | 3 (60) | 0 | 2 (40) | 1 (20) |

**[Table/Fig-7]:** Antibiotic susceptibility patterns of gram-positive isolates.
S: Susceptible; I: Intermediate; R: Resistant; NT: Not tested; P: Penicillin; E: Erythromycin; COT: Trimethoprim-sulfamethoxazole; CIP: Ciprofloxacin; TE: Tetracycline; LZ: Linezolid; VA: Vancomycin; AMP: Ampillicin; TEI: Teicoplanin; HLG: High-level gentamicin; HLS: High-level streptomycin

| Gram-negative isolates | | Antibiotics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | AK n (%) | AMC n (%) | PIT n (%) | GEN n (%) | CTX n (%) | CTR n (%) | CPM n (%) | IMP n (%) | LE n (%) |
| *P. aeruginosa* (n=17) | S (%) | 14 (82.4) | NT | 4 (23.5) | 10 (58.8) | NT | NT | 2 (11.8) | 16 (94.1) | 15 (88.2) |
| | I (%) | 0 | NT | 0 | 0 | NT | NT | 0 | 0 | 0 |
| | R (%) | 3 (17.6) | NT | 13 (76.5) | 7 (41.2) | NT | NT | 15 (88.2) | 1 (5.9) | 2 (11.8) |
| *K. pneumoniae* (n=9) | S (%) | 5 (55.6) | 0 | 7 (77.8) | 7 (77.8) | 2 (22.2) | 2 (22.2) | 7 (77.8) | 8 (88.9) | 4 (44.4) |
| | I (%) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 (11.1) |
| | R (%) | 4 (44.4) | 9 (100) | 2 (22.2) | 2 (22.2) | 7 (77.8) | 7 (77.8) | 2 (22.2) | 1 (11.1) | 4 (44.4) |
| *Acinetobacter* spp. (n=9) | S (%) | 7 (77.8) | NT | 5 (55.6) | 6 (66.7) | 2 (22.2) | 2 (22.2) | 3 (33.3) | 8 (88.9) | 5 (55.6) |
| | I (%) | 0 | NT | 0 | 0 | 2 (22.2) | 2 (22.2) | 1 (11.1) | 0 | 1 (11.1) |
| | R (%) | 2 (22.2) | NT | 4 (44.4) | 3 (33.3) | 5 (55.6) | 5 (55.6) | 5 (55.6) | 1 (11.1) | 3 (33.3) |
| *E. coli* (n=1) | S (%) | 1 (100) | 0 | 1 (100) | 1 (100) | 0 | 0 | 1 (100) | 1 (100) | 0 |
| | I (%) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | R (%) | 0 | 1 (100) | 0 | 0 | 1 (100) | 1 (100) | 0 | 0 | 1 (100) |
| *S. Paratyphi* A (n=1) | S (%) | NT | 0 | 1 (100) | NT | 0 | 0 | 1 (100) | 1 (100) | 1 (100) |
| | I (%) | NT | 0 | 0 | NT | 0 | 0 | 0 | 0 | 0 |
| | R (%) | NT | 1 (100) | 0 | NT | 1 (100) | 1 (100) | 0 | 0 | 0 |

**[Table/Fig-8]:** Antibiotic susceptibility patterns of gram-negative isolates.
S: Susceptible; I: Intermediate; R: Resistant; NT: Not tested; AK: Amikacin; AMC: Amoxicillin-clavulanate; PIT: Piperacillin-tazobactam; GEN: Gentamicin; CTX: Cefotaxime; CTR: Ceftriaxone; CPM: Cefepime; IMP: Imipenem; LE: Levofloxacin

## DISCUSSION

Despite modern advances in diagnosis and treatment, BSI remains a challenging and often life-threatening problem. Therefore, timely detection, identification, and antimicrobial susceptibility testing of blood-borne pathogens are crucial functions of diagnostic microbiology laboratories, especially in tertiary care centres [19]. There is a strong association between delays in initiating effective therapy and in-hospital mortality in cases of septic shock. Each hour of delay in therapy initiation is associated with an average decrease in survival of 8% [20]. The epidemiology and outcomes of BSIs may be influenced by changing patterns of blood culture isolates, increasing rates of antimicrobial resistance, and the widespread use of new medical technologies, such as indwelling devices [2].

In the present study, out of the total 481 blood culture samples processed, 150 samples were positive for aerobic bacterial growth. The culture positivity rate in the present study was 31.2%, which is comparable to the study conducted by Vasudeva N et al., (31.2%) [21]. In contrast, various studies have reported lower positivity rates, including 5.6% in Mehdinejad M et al., 14.24% in Banik A et al., 9.2% in Gohel K et al., 9.94% in Mehta M et al., 11.8% in Chaudhury A et al., 20.02% in Arora U et al., and Sharma M et al., (22.9%) [3,20-26]. Higher positivity rates, compared to the present study, can be seen in studies conducted by Sawargaonkar M et al., (40.01%) and Kumar N et al., (52%) [27,28]. The variation in positivity rates among different studies may be attributed to differences in the methodology used for blood culture, the volume or number of blood culture samples taken, study design, geographical differences, nature of the patient population, differences in the epidemiological agents, and variations in infection control policies [27].

The male preponderance observed in the present study has also been documented in other studies [29,30]. Men are often involved in more physical activities for their livelihood, which may predispose them to BSI. Additionally, they may have better access to healthcare facilities for treatment, which could explain the higher culture positivity rate among males in most studies [20]. The biological makeup of women, where estrogen suppresses the expression of virulence factors in some microorganisms, may also contribute to gender differences in culture positivity rates [31].

The age group of 0-10 years had the highest number of positive cases, accounting for 109 (72.7%), followed by 11 cases (7.3%) in the age group of 31-40 years. Similar findings have also been reported by studies conducted in India and abroad [31,32]. The high number of BSI cases among paediatric patients may be due to their susceptibility to infection owing to their developing innate and adaptive immune systems [28]. In the present study, the maximum number of BSI cases was observed in patients attending the paediatrics department (74%, 111/150), and among the various ICUs of the hospital, the NICU recorded the highest number of BSI cases (52.4%, 33/63), followed by the PICU (30.2%, 19/63). These findings are compatible with the studies conducted by Arora U et al., and Bhabhor H et al., [25,33].

| Author | Place of study | Year of publication | Positivity rate | Gram-positive isolates | Gram-negative isolates |
|---|---|---|---|---|---|
| Chaudhury A et al., [24] | Tirupati | 1999 | 11.8% | 51.7% | 48.3% |
| Kohli R et al., [29] | Nairobi | 2010 | 5.8% | 64% | 33% |
| Moyo S et al., [11] | Tanzania | 2010 | 13.4% | 82.1% | 17.9% |
| Pandey S et al., [35] | Kathmandu | 2013 | 12.6% | 16% | 84% |
| Singh AK et al., [1] | Lucknow | 2014 | 10.2% | 46.6% | 51.8% |
| Gohel K et al., [22] | Gujarat | 2014 | 9.2% | 58.3% | 40.2% |
| Devi A et al., [15] | Imphal | 2015 | 16.8% | 48.9% | 51.1% |
| Pal N et al., [34] | Kanpur | 2016 | 22.3% | 29.6% | 59.3% |
| Banik A et al., [20] | Port Blair | 2018 | 14.2% | 60.4% | 36.3% |
| Nazir A et al., [32] | Srinagar | 2018 | 25.3% | 54.2% | 24.9% |
| Sawargaonkar M et al., [27] | Aurangabad | 2019 | 40% | 61.9% | 38.1% |
| Sharma AK et al., [37] | Ranchi | 2019 | 28% | 65.9% | 34.2% |
| Kumar N et al., [28] | West Bengal | 2020 | 52.1% | 53.4% | 35.6% |
| Birru M et al., [38] | Ethiopia | 2021 | 9.8% | 59.1% | 41.1% |
| Worku M et al., [39] | Ethiopia | 2022 | 27% | 61.1% | 31.5% |
| Trivedi MS et al., [36] | Jabalpur | 2023 | 28% | 38.1% | 61.9% |
| Present study | Imphal | 2023 | 31.2% | 75.3% | 24.7% |

**[Table/Fig-9]:** Comparison of culture positivity rate and isolates among various studies.

In the present study, gram-positive isolates outnumbered gram-negative isolates, accounting for 113/150 (75.3%), while gram-negative isolates accounted for 37/150 (24.7%). The preponderance of gram-positive microorganisms has also been reported in other studies [Table/Fig-9] [1,11,15,20,22,24,27-29,32,34-39]. However, gram-negative predominance was found in a few other studies [1,34-36].

Among the gram-positive microorganisms, the predominant isolate was *S. aureus* (95, 63.3%), followed by CoNS (13, 8.7%) and *Enterococcus* spp. (5, 3.3%). Other studies have also reported *S. aureus* as the predominant bloodstream pathogen [21,22,28]. However, in some studies, CoNS was found to be the most predominant causative agent of bacteremia, followed by *S. aureus*. Since CoNS are part of the normal skin flora, the clinical significance can be determined by repeated positive blood cultures or a single positive blood culture with significant evidence of infection and the presence of long-standing indwelling devices, such as central venous catheters, intravascular catheters, etc., [31,32].

In the present study, among the gram-negative microorganisms, non-fermenters as a group were responsible for the maximum number of BSI cases, followed by members of the Enterobacteriaceae family. *P. aeruginosa* (17, 11.3%) was the predominant isolate, followed by *Acinetobacter* spp. (9, 6%), *K. pneumoniae* (9, 6%), *E. coli* (1, 0.7%), and S. Paratyphi A (1, 0.7%). Various studies have also documented similar results, with *P. aeruginosa* being the most common gram-negative isolate, followed by *Acinetobacter* spp. [19,28]. However, in a few studies, *Acinetobacter* spp. [20,32], *E. coli* [21], *K. pneumoniae* [37], and S. serotype Typhi [15] were reported as the most common gram-negative isolates.

The in-vitro susceptibility pattern of the isolates was assessed. *S. aureus* showed maximum susceptibility to linezolid (98.9%), vancomycin (88.4%), ciprofloxacin (69.5%), and tetracycline (57.9%). However, the isolates were resistant to penicillin (77.9%), erythromycin (63.2%), and co-trimoxazole (46.3%). Similar patterns were also observed in CoNS isolates. Other studies have reported 100% susceptibility to linezolid and vancomycin by the staphylococcal isolates [15,28,32,37].

In the present study, the prevalence of MRSA was found to be 54.7%, which was higher compared to the study done by Pal N et al., where the prevalence was 33.3% [34]. However, Gohel K et al., reported that 70.6% of the *S. aureus* isolates were MRSA [22]. On the other hand, the methicillin-resistant rate among the CoNS isolates in the present study was 53.9%, which is in accordance with the study conducted by Pal N et al., [34].

*Enterococcus* species showed maximum susceptibility (100%) towards linezolid and teicoplanin, followed by vancomycin (80%), which was similar to the findings of Yangzom T et al., [40]. Resistance to ampicillin (60%) noted in the present study is in accordance with Arora U and Devi P, [25]. One (20%) enterococcal isolate exhibited HLSR, and two (40%) isolates exhibited HLGR.

The *P. aeruginosa* isolates were resistant to cefepime (88.2%) and piperacillin-tazobactam (76.5%), but they were susceptible to imipenem (94.1%), levofloxacin (88.2%), amikacin (82.4%), and gentamicin (58.8%). Similarly, isolates of *Acinetobacter* spp. showed resistance to cephalosporins (55.6%), but they were susceptible to imipenem (88.9%), amikacin (77.8%), and gentamicin (66.7%). Similar resistance patterns of the non-fermenters were also observed in other studies conducted in India [40,41]. Kumar N et al., also reported a high degree of resistance towards cefepime by the non-fermenters, which is in concordance with the present study [28].

All the *K. pneumoniae* isolates were resistant to amoxicillin-clavulanate, followed by ceftriaxone (77.8%) and cefotaxime (77.8%). However, they showed less resistance towards imipenem (11.1%), cefepime (22.2%), gentamicin (22.2%), amikacin (44.4%), and levofloxacin (44.4%). The high frequency of resistance to β-lactam antibiotics can also be attributed to their indiscriminate usage as first-line medications [42]. A high prevalence rate of ESBL producers (70%) was observed in the present study, which was comparatively higher than that reported by Gohel K et al., (39.6%) and Arora U et al., (34.4%) [22, 25]. About 66.7% of *K. pneumoniae* isolates were ESBL producers, which is similar to the findings of Pal N et al., [34].

### Limitation(s)

Modern automated blood culture systems such as BacT/ALERT 3D, BD BACTEC, etc., and the Vitek system, MALDI-TOF for bacterial identification, were not used due to limited resources and infrastructure. The resistance pattern for each isolate could not be studied in detail, and the MIC for the drugs, except for vancomycin, could not be established.

## CONCLUSION(S)

The study highlighted the pattern of aerobic bacterial isolates from BSI cases in JNIMS Hospital, as well as the antibiotic susceptibility patterns of the isolates. The epidemiology and outcome of BSI are

ever-evolving due to the increased rate of antimicrobial resistance and changing patterns of antimicrobial usage worldwide. Regular epidemiological studies of BSIs, focusing on the pathogens and their antibiotic susceptibility patterns, are thus necessary to guide clinicians in choosing appropriate empirical therapy and to update the hospital's antibiotic policy from time to time.

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