Original Article

Clinical presentations and microbiological analysis of cerebrospinal fluid samples in cases of suspected bacterial meningitis patients attending a 1600 bedded teaching hospital from 2019 to 2022: A retrospective study

Mitra Kar, Ashima Jamwal, Akanksha Dubey, Chinmoy Sahu, Sangram Singh Patel, Nida Fatima

Department of Microbiology, Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow, Uttar Pradesh, India

Abstract

Background: Meningitis can be attributed to bacterial, fungal, or viral agents. In this study, we demonstrate the common bacterial agents causing meningitis along with their antibiotics susceptibility pattern in patients of all age groups. **Material and Methods:** This retrospective, observational study was carried out in the Department of Microbiology with cerebrospinal fluid (CSF) samples collected from November 2019 to May 2022. We collected 1986 nonrepeat CSF samples from clinically suspected patients of bacterial meningitis, and clinical information about the patients was extracted from the hospital information system. **Results:** Out of the 1986 CSF samples included in our study, 150 (7.55%) were found to be positive on bacterial culture. Most of our patients were in the age group of 0–20 years. Common clinical manifestations observed in our patients were: high-grade fever, 87 patients (58%); severe headache, 126 patients (84%); neck rigidity, 47 patients (31.3%); altered mental status, 76 patients (50.7%) and photophobia, 83 patients (55.3%). The most commonly isolated bacteria was *Acinetobacter species* (30%). The mean length of hospitalization (37.76 ± 25.30), the mean total cell count, high levels of protein (mg/dl) and low levels of glucose (mg/dl) of CSF were statistically significant in meningitis caused by multidrug-resistant bacteria. **Conclusion:** We recognized the spectrum of pathogens causing meningitis at our center along with the antibiotic resistance pattern to guide and facilitate early treatment by primary health care professionals and family medicine practitioners.

Keywords: Bacterial meningitis, cerebrospinal fluid (CSF), pyogenic meningitis, MALDI-TOF-MS, multidrug resistance (MDR)

Introduction

The inflammation of the three-layered sheath surrounding the spinal cord and the brain known as the meninges is called meningitis.[1] Patients present with altered consciousness, fever, and neck stiffness, but are not necessarily present in all patients; other presenting symptoms like nausea, vomiting, headache, and photophobia have also been reported.[2] The common routes of transmission are respiratory droplets or throat secretions and mother-to-child transmission through the genital tract. Meningitis can be caused by bacteria, virus, or fungus, and laboratory diagnosis of CSF directs the diagnosis and management of the illness. The epidemiology of bacterial meningitis varies according

Address for correspondence: Dr. Chinmoy Sahu, Department of Microbiology, C Block, 2nd Floor, Sanjay Gandhi Postgraduate Institute of Medical Sciences Lucknow, Uttar Pradesh – 226 014, India.
E-mail: csahu78@rediffmail.com

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to geographical region, age group, availability of healthcare services, and various other factors like Immune deficiencies.[3] Meningitis demands prolonged treatment and hospital admission, thus, making the patients vulnerable to superinfections that can be acquired from the hospital environment.[4]

Nosocomial pyogenic meningitis is defined as the meningeal inflammation presenting with clinical characteristics either after 48 h of admission or within a stipulated amount of time in case of any surgical procedures, which can be demonstrated within one month after discharge.[5] It is also seen in patients with cerebrospinal fluid (CSF) leak managed on external ventricular catheterization and ventriculo-peritoneal shunts or those undergoing intrathecal infusions of medications.[6] The increased number of neurosurgical procedures and use of broad-spectrum empiric therapy has led to an increase in nosocomial MDROs (multi-drug-resistant organisms), thereby raising the difficulties in the management of meningitis.[7]

The analysis of CSF parameters gives direction to the appropriate management of meningitis and prevents the spread of infection to other patients in the ward.[8] Considering the type of nosocomial organism susceptibility profile in meningitis patients, empiric therapy needs to be regulated by the attending physicians. We conducted this study to assess the spectrum of bacteria causing meningitis along with their antibiotic susceptibility patterns and investigated the risk factors for acquiring MDROs causing meningitis. This study highlights an important need among clinicians and family physicians to understand the susceptibility pattern and the resistance profiles of the organisms being encountered nosocomially so that the disparity between the different treatment regimes and the patient's response can be met to procure better outcomes.

Materials and Methods

This retrospective, observational study was carried out in Department of Microbiology from November 2019 to May 2022. A total of 1986 nonrepeat CSF samples from clinically suspected patients of bacterial meningitis were collected and sent within 2 h to the laboratory. This study was accepted by the Sanjay Gandhi Postgraduate Institute of Medical Sciences institutional Ethics Committee (Reference number 2020-100-EMP-EXP-16), and all measures were taken to maintain the sanctity of the human experimentation ethical standards with respect to the Helsinki Declaration of 1975, revised in 2000.

Inclusion criteria: All CSF samples from patients suspected of bacterial meningitis, irrespective of age group and sex, were admitted to the inpatient department at our hospital.

Exclusion criteria: Samples delayed in transportation, unlabeled samples, and those growing contaminants were excluded from this study.

Sample processing: All CSF samples drawn from patients showing symptoms of meningitis were sent to the bacteriology laboratory in the Department of Microbiology and subjected to routine processing compliant to the standard protocols. Each sample was subjected to Grams' stain and routine aerobic bacterial culture. The culture media used for routine bacterial culture were Mackonkey and Blood agar and Robertsons' cooked meat broth (RCM). After inoculating the samples on culture media, they were incubated for 72 h at a temperature of 37°C, and culture readings were performed once daily, if no growth was seen thereafter the sample was deemed sterile. Growth on culture was characterized by the isolation of colonies on the agar plates or a turbid RCM. The application of Grams' stained smear, routine biochemicals, and matrix-assisted-laser-desorption/ionization-time of flight (MALDI-TOF, BioMéreux, France) assay facilitated bacterial identification.[9]

Antimicrobial susceptibility testing: Respecting the CLSI 2019 guidelines,[10] antibiotic sensitivity testing was performed for all bacterial isolates using Kirby Bauer Disc Diffusion method and Epsilometeric test. A standard 0.5 McFarland inoculum was prepared for each bacterial isolate and cation-adjusted Muller–Hinton agar (MHA) plates were used for lawn culture using that inoculum. The antibiotics tested were in the form of E-test strips and antibiotic discs that were placed on lawn cultured plates and incubated overnight at 37°C. CLSI 2019 guidelines[10] were followed by us to classify the antibiotic susceptibility as sensitive, intermediate, and resistant after measuring inhibition zones for each isolate.

All data on antibiotic susceptibility patterns of pathogenic bacteria isolated from CSF samples was extracted from the laboratory registers and further analyzed in this study. Clinical characteristics of all patients were extracted from the electronic medical records, and the MDROs were assessed by observing resistance to at least one antibiotic from each of the three diverse classes of antibiotics.[11]

The statistical analysis in our study was conducted by observing the incidences. The mean and standard deviation were used in expressing the quantitative variables. While analyzing of risk factors of acquiring MDROs, χ^2 tests were used to compare the groups of categorical variables. The results were presented as 95% confidence intervals. Statistical analysis was aided by the software program IBM SPSS Statistics version 20.0 (IBM Corp., Armonk, NY, USA), with $P < 0.05$ considered statistically significant.

Results

Demographics

Out of the 1986 CSF samples from clinically suspected patients of meningitis, 150 (7.55%) samples showed growth of pathogenic bacteria on culture. Among these culture-positive patients, a majority of 55 (55/150, 36.70%) belonged to the age group of less than or equal to 20 years followed by 21–40 years

and 41–60 years which were 51 (51/150, 34.0%) and 29 (29/150, 19.33%) cases, respectively, with a 63.33% (95/150, 63.33%) predominance of male patients, which also reflected as a 61.82% male predominance in participants below the age of 20 years. A total of 46 (46/150, 30.67%) patients with bacterial meningitis in our cohort had a shunt in-situ with a mean age of 19.15 ± 17.66 years and a male predominance of 60.87% (28/46, 60.87%). The mean age of patients managed on shunts was significantly lower in comparison to those with no-shunt in-situ, as seen in Table 1.

The most common clinical manifestations in the patients were severe headache in 84% (126/150, 84%) patients, followed by high-grade fever in 58% (87/150, 58%) patients and photophobia in 55.3% (83/150, 55.3%) patients. The patients were divided into two groups, where CSF drainage was managed using a shunt in-situ (with shunt) and those with no shunt in-situ (without shunt), as demonstrated in Table 1. Among the underlying comorbidities, chronic kidney disease, Type 2 diabetes mellitus (DM), pleural effusion, and hypertension among the patients with shunts were statistically significant in comparison to those with no shunt in-situ.

On antibiotic sensitivity testing of the isolates obtained from CSF culture, 121 (121/150, 80.70%) isolates in our study were multidrug-resistant. The mean age of patients with MDR meningitis was 28.42 ± 29.66 years with a male predominance of 63.64% (77/121, 63.64%). The most common comorbidities encountered among the multidrug-resistant isolates were anemia (89/102, 87.25%) followed by intracranial space-occupying lesions (77/93, 82.79%) and encephalopathy (71/85, 83.53%). Patients with anemia, history of organ transplant, and those with the mean length of hospitalization (37.76 ± 25.30), the mean total cell count, protein (mg/dl), and glucose (mg/dl) of CSF were statistically significant in patients infected with MDR microorganism in comparison to non-MDR microorganism, as described in Table 2.

Microbiological characteristics

A majority of 98% (147/150, 98%) patients suffered with culture-proven bacterial meningitis. Three (3/150, 2%) cases were diagnosed with *Cryptococcal meningitis,* and two (2/150, 1.8%) cases of *Herpes simplex virus* 1 (HSV-1) meningitis, and twelve (12/150, 8%) were diagnosed with tubercular meningitis. A total of 14 (9.3%) cases were diagnosed with mixed meningitis.

The most common Gram-negative bacilli (GNB) isolated from the patients with culture-confirmed bacterial meningitis was *Acinetobacter species* (45/150, 30%) followed by *Klebsiella pneumoniae* (27/150, 18%) and *Enterobacter cloacae* (14/150, 9.3%), while the most frequently isolated Gram-positive cocci was methicillin-resistant *coagulase-negative Staphylococcus* (MRCONS) (21/150, 14%) [Figure 1].

Table 1: Descriptive analysis of demographic characteristics and risk factors in patients suffering from bacterial meningitis with and without shunt (*n*=150)

Demographic characteristics and risk factors	With shunt (*n*=46)	Without shunt (*n*=104)	*P*
Source of infection, %			
Community-acquired (*n*=20, %)	7 (35%)	13 (65%)	0.652
Nosocomially-acquired (*n*=130, %)	39 (30%)	91 (70%)	0.652
Age, years, mean (SD)	19.15±17.66	33.92±20.70	<0.001*
Gender, male/female	28/18	67/37	0.677
Comorbidities			
Stroke (*n*=18), %	5 (27.78%)	13 (72.22%)	0.777
Epilepsy (*n*=51), %	14 (27.45%)	37 (72.54%)	0.540
Intracranial space occupying lesions (*n*=93), %	27 (29.03%)	66 (70.96%)	0.579
Encephalopathy (*n*=85), %	29 (34.11%)	56 (65.88%)	0.295
Organ transplant (*n*=2), %	0 (0.0%)	2 (100.0%)	0.344
Diabetes mellitus (*n*=33), %	3 (9.09%)	30 (90.90%)	0.002*
Chronic kidney disease (*n*=19), %	2 (10.52%)	17 (89.47%)	0.042*
Heart disease (*n*=5), %	0 (0.0%)	5 (100.0%)	0.130
Hypertension (*n*=42), %	6 (14.28%)	36 (85.71%)	0.007*
Pleural effusion (*n*=15), %	10 (66.67%)	5 (33.33%)	0.001*
COPD (*n*=3), %	2 (66.67%)	1 (33.33%)	0.172
Anemia (*n*=102), %	27 (26.47%)	75 (73.52%)	0.104
Other parameters			
Length of hospital stay, mean (SD)	35.85±22.043	36.94±25.199	0.798
CSF total cell count (per cubic mm), mean (SD)	1692.78±8765.259	1456.09±4741.038	0.830
CSF glucose (mg/dl), mean (SD)	41.23±24.63	46.51±34.99	0.355
CSF protein (mg/dl), mean (SD)	125.48±47.15	125.70±54.09	0.981
Death (*n*=36), %	7 (19.44%)	29 (80.56%)	0.094

*P<0.05 is significant

Table 2: Demographic characteristics of patients and risk factors for isolation multidrug-resistant microorganisms in patients with bacterial meningitis (*n*=121)

Demographics and risk factors	MDR microorganisms (*n*=121/150, 80.70%)	*P*	95% CI
Demographics			
Age, years, mean (SD)	28.42±29.66	<0.001*	24.70–32.14
Gender, male/female	77/44	0.875	1.28–1.44
Comorbidities			
Stroke (*n*=18), %	17 (94.44%)	0.115	1.80–1.92
Epilepsy (*n*=51), %	42 (82.35%)	0.707	1.57–1.74
Intracranial space occupying lesions (*n*=93), %	77 (82.79%)	0.399	1.28–1.45
Encephalopathy (*n*=85), %	71 (83.52%)	0.310	1.32–1.50
Organ transplant (*n*=2), %	0 (0.0%)	0.004*	1.83–2.03
Diabetes mellitus (*n*=33), %	26 (78.78%)	0.757	1.71–1.86
Chronic kidney disease (*n*=19), %	13 (63.42%)	0.148	1.84–1.95
Heart disease (*n*=5), %	4 (80.0%)	0.969	1.93–2.00
Hypertension (*n*=42), %	35 (83.33%)	0.606	1.63–1.79
Pleural effusion (*n*=15), %	13 (86.67%)	0.535	1.84–1.95
COPD (*n*=3), %	2 (66.67%)	0.535	1.96–2.01
Anemia (*n*=102), %	89 (87.25%)	0.003*	1.18–1.34
Other parameters			
Length of hospital stay, mean (SD)	37.76±25.30	<0.001*	33.21–42.32
CSF total cell count (per cubic mm), mean (SD)	1752.36±6860.51	0.0058*	517.51–2987.21
CSF glucose (mg/dl), mean (SD)	43.83±32.60	<0.001*	37.96–49.69
CSF protein (mg/dl), mean (SD)	128.055±50.511	<0.001*	118.96 137.14
Death (*n*=36), %	32 (88.89%)	0.152	1.18–1.34
Source of infection, %			
Shunts (*n*=46, %)	42 (91.30%)	0.028*	1.57–1.74
Community – acquired (*n*=20, %)	12 (60%)	0.012*	1.16–1.64
Nosocomially – acquired (*n*=130, %)	109 (83.94%)	0.012*	1.10–1.23

*P<0.05 is significant

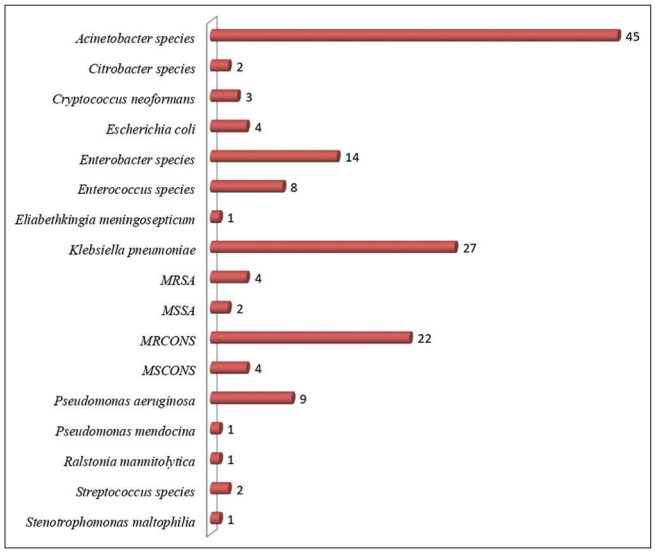

Figure 1: Microorganisms isolated from the cerebrospinal fluid cultures performed in the laboratory (*N*=150)

Forty-two (42/46, 91.30%) MDR microorganisms were isolated from the patients with shunt in-situ, while 79 (79/104, 75.96%) MDR microorganisms were isolated from patients with no shunt in-situ. The most common microorganism isolated from patients with shunt was *Acinetobacter species* (12/46, 26.08%) followed by *Klebsiella pneumoniae* (11/46, 23.91%) and *Enterobacter cloacae* (7/46, 15.22%), showing 100%, 100%, and 85.71% multidrug resistance, respectively. The most common Gram-positive cocci isolated from patients with a shunt was *Enterococcus spp* (2/46, 4.38%) isolates.

Multidrug resistance

We identified 121 (121/150, 80.70%) MDR isolates from culture-positive CSF samples. Among the GNB, *Klebsiella pneumoniae* was the most resistant to ciprofloxacin, ceftazidime, and ceftriaxone, and cefoperazone–sulbactam, showing fluoroquinolone resistance, extended-spectrum beta-lactamase (ESBL) character and complete carbapenem resistance to meropenem and ertapenem, and only 7.4% of GNB were sensitive to imipenem, but all isolates were sensitive to colistin [Table 3].

The *Acinetobacter spp* isolates obtained in our study were most 100% (45/45, 100%) susceptible to colistin followed by only 6.67% microorganisms which are susceptible to amikacin, ceftriaxzone, imipenem, and meropenem each. The microorganism was most resistant to ceftazidime, ceftriaxone, and cefoperazone sulbactam as only 4.44% of isolates were sensitive to them.

The *Pseudomonas spp* isolates obtained from our study were most susceptible to second-line drugs like colistin, with

Table 3: Percentage sensitivity pattern for first and second-line drugs in most commonly isolated Gram-negative bacilli

Antibiotics	Enterobacter species % sensitivity	Acinetobacter species % sensitivity	K. pneumoniae % sensitivity	Pseudomonas species % sensitivity
Amikacin	7.14%	6.67%	0.00%	10.00%
Ceftazidime	0.00%	4.44%	0.00%	20.00%
Ceftriaxzone	0.00%	6.67%	0.00%	NA
Ciprofloxacin	0.00%	4.44%	0.00%	NA
Levofloxacin	NA	NA	NA	10.00%
Cefoperazone – Sulbactam	7.14%	4.44%	0.00%	20.00%
Imipenem	7.14%	6.67%	7.40%	30.00%
Meropenem	7.14%	6.67%	0.00%	30.00%
Ertapenem	7.14%	NA	0.00%	NA
Colistin	100.00%	100.00%	100.00%	90.00%
Aztreonam	NA	NA	NA	30.00%
Piperacillin – Tazobactam	NA	NA	NA	20.00%

90% susceptibility, followed by imipenem, meropenem, and azetreonam, to each of which the microorganism was 30% sensitive. The microorganism was most resistant to amikacin and levofloxacin to which only 10% isolates were susceptible, followed by ceftazidime, cefoperazone sulbactam, and piperacillin tazobactam with susceptibility of 20% each [Table 3].

Of all the gram-positive microorganisms, *Coagulase positive* (6/6, 100%) and *Coagulase-negative Staphylococcus* (24/25, 96%) and *Enterococcus* isolates (1/2, 50%) were most sensitive to vancomycin and teicoplanin followed by amikacin among *Coagulase positive* and *Coagulase-negative Staphylococcus*, with susceptibility of 33.33 and 44%, respectively, All the *Coagulase positive* and 96% (24/25, 96%) of *Coagulase-negative Staphylococcus* were susceptible to vancomycin and teicoplanin. All isolates of *Enterococcus spp* were susceptible to linezolid and minocycline [Table 4].

Prolonged hospital stay, presence of a shunt; the increased total leukocyte count, high proteins, and decreased levels of glucose in the CSF; and patient comorbidities like organ transplant recipient status and anemia impose a statistically significant risk of acquiring multidrug-resistant microorganisms causing bacterial meningitis in the study [Table 2].

Discussion

This single-center retrospective study describes the clinico–epidemiological profile of bacterial meningitis at our center from November 2019 to May 2022. We intended to determine the frequency of pyogenic meningitis at our center along the spectrum of pathogen bacteria and their appropriate antibiotic sensitivity patterns, guiding the general physician in administering appropriate empirical treatment keeping in mind the drug-resistant nature of the causative pathogen. We also established risk factors allied with bacterial meningitis in the patients with and without shunts and the ability to acquire multidrug resistance infections among the patients based on these risk factors.

The clinical manifestation most commonly encountered in this cohort of patients was headache in 84% (126/150, 84%) patients, which disagrees with a study by Lee *et al.*[12] which proposes fever as the predominant finding. The reason for headache being the predominant finding among our study group could be attributed to a cohort of patients mainly suffering from space-occupying lesions in the brain.

In India, the outbreak of bacterial meningitis predominantly affects young male, although there could be a shift in the age group during epidemics that could lead to increased chances of infections in adults.[12] The most commonly affected group in our study were of male patients below 20 years of age which corroborates with the findings of research by Duggal *et al.*[13] and Bhat *et al.*[14] The low number of female patients seeking treatments and utilization of hospital services in India could be a reason for the low proportion of female patients in our study.[15]

Type 2 DM, chronic kidney disease, and hypertension are statistically significant risk factors among the patients without a shunt in-situ, as these patients mainly present the patients > 20 years of age, while pleural effusion was a significant risk factor among patients with shunt in-situ with a higher incidence of patients below the age of 20 years. In concordance with research by Frasca *et al.*,[16] Niemelä *et al.*,[17] and Garner-Spitzer *et al.*,[18] comorbidities, e.g., hypertension and DM were notably related to bacterial meningitis as observed in our study.

Acinetobacter species (45/150, 30%) was the most frequently isolated GNB with laboratory-confirmed bacterial meningitis, while the most frequently isolated GPC was MRCONS (21/150, 14%) [Figure 1], in contrast with studies by Van de Beek *et al.*,[19] Wall E *et al.*,[20] Amaya-Villar *et al.*,[21] and Mook-Kanamori *et al.*,[22] suggested *Streptococcus pneumoniae* as the most common pathogen causing meningitis in patients. The difference in the spectrum of pathogenic microorganisms may be because most patients (93/150, 62%) in our study underwent intracranial operations and had prolonged hospitalization, which was supported by Sharma *et al.*[23]

The microorganism commonly isolated from patients with shunt in-situ was *Acinetobacter species* (12, 26.08%) followed by *Klebsiella*

Table 4: Percentage sensitivity pattern for first and second-line drugs in most commonly isolated Gram-positive cocci

Antibiotics	Coagulase positive Staphylococcus % sensitivity	Coagulase-negative Staphylococcus % sensitivity	Enterococcus % sensitivity
Ampicillin	NA	NA	37.5%
Ampicillin – Sulbactam	33.33%	12.00%	50.00%
Amikacin	33.33%	44.00%	NA
Clindamycin	33.33%	24.00%	0.00%
Cefoxitin	19.35%	80.64%	NA
Doxycycline	16.67%	40.00%	0.00%
Erythromycin	33.33%	24.00%	NA
Gentamicin	0.00%	4.00%	NA
Levofloxacin	0.00%	0.00%	0.00%
Vancomycin	100.00%	96.00%	50.00%
Teicoplanin	100.00%	96.00%	50.00%
Linezolid	NA	NA	100.00%
Minocycline	NA	NA	100.00%

pneumoniae (11, 23.91%) and *Enterobacter cloacae* (7, 15.21%), of the above-mentioned microorganisms 100%, 100% and 85.71% of the respective microorganisms were MDR. The findings of our study were contrasting with the findings of studies conducted by Bisno *et al.*[24] and Crnich *et al.*,[25] where the most common pathogenic microorganisms isolated from indwelling shunts were coagulase-negative staphylococci followed by *S. aureus*. Findings from our study corroborate with the studies conducted by Sacar *et al.*[26] and Celik *et al.*,[27] where nosocomial bacterial meningitis and shunt infections were commonly caused by GNB.

Among GNB, *Klebsiella pneumoniae* was resistant to most first-line drugs; in contrast to studies conducted by Mostafavi *et al.*[28] where gram positive cocci (GPC) were predominant and in agreement with studies by Sarguna *et al.*[29] where shunt infections with *Klebsiella pneumoniae and Escherichia coli* were common. *Klebsiella pneumoniae*, *Acinetobacter spp*, and *Enterobacter cloacae* show increasing ESBL character and Carbapenem resistance by high to complete resistance to imipenem and meropenem, while all isolates were susceptible to colistin which is in agreement with a study conducted by Nau *et al.*[30]

We observed that *Coagulase positive* and *negative Staphylococcus* and *Enterococcus spp* isolates were most sensitive to vancomycin and teicoplanin with 100%, 96%, and 50%, each respectively, in agreement with a research by Mostafavi *et al.*,[28] where GPC were most susceptible to glycopeptides, while in contrast to it the isolates from our study show complete resistance to fluoroquinolones. Aminoglycosides do not effectively cross the blood–brain barrier and are not recommended for treating bacterial meningitis, while fluoroquinolones easily cross the blood–brain barrier.[30] Unfortunately, high fluoroquinolone resistance among our isolates was observed and glycopeptides were the drugs of last resort concordant with a study by Jackson *et al.*,[31] although 50% glycopeptides resistance was observed in *Enterococcus spp* isolates.

Among the other parameters described for risk factors for isolating multidrug-resistant microorganisms from patients suffering from bacterial meningitis, CSF-leukocytes, higher protein levels, and low levels of glucose were statistically significant, as described in a study by Fouad *et al.*[32] The prolonged duration of hospitalization and the presence of a shunt are also statistically significant risk factors in acquiring multidrug resistance in our study.

The key points of this study include the transition of the spectrum of pathogenic bacteria, which in older studies mainly comprised of Gram-positive pathogens to a recent increase in meningitis by Gram-negative bacterium. The frequent isolation of MDR isolates demands knowledge of the trends in antibiotic susceptibility patterns for the clinicians to administer appropriate antibiotics in critically ill patients with meningitis. The true novelty of this study exists in its utilization as a cornerstone in the administration of empirical therapy in critical cases like meningitis to prevent morbidity and mortality. This study also emphasizes adherence to infection control practices that includes hand hygiene and maintenance of care bundles, which prevents shunt or catheter-associated infections.

There were also several limitations in our study; first, we did not use molecular methods for the detection of antibiotic resistance for every isolate obtained, although MALDI-TOF-MS assay was used for identifying each isolate. Second, we did not monitor the susceptibility to all antibiotics that could be effective against each microorganism but stuck to the panel of antibiotics used for GPC and GNB isolates used routinely for antibiotic susceptibility testing in our laboratory. Third, our study is a retrospective, observational, and single-center study that determines the spectrum of causative microorganisms for bacterial meningitis along with the antibiotic susceptibility pattern of the isolates determining the antimicrobial resistance at our hospital, which may differ among centers.

Conclusion

This study determines the pathogenic bacteria causing meningitis across all age groups along with the antibiotic resistance pattern aiding the clinicians in starting appropriate empirical antibiotics and preventing the acquisition of multidrug resistance. We also highlight the emergence of hospital-acquired infections which require the need to maintain aseptic precautions by the clinicians and the hospital staff.

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Author contribution

Protocol development: Mitra Kar, Ashima Jamwal, Chinmoy Sahu.

Data collection: Akanksha Dubey, Nida Fatima. Data analysis: Chinmoy Sahu, Sangram Singh. Patel. Supervision: Chinmoy Sahu, Sangram Singh Patel.

Writing – original draft: Mitra Kar, Ashima Jamwal. Writing – review & editing: Mitra Kar, Ashima Jamwal, Akanksha Dubey, Chinmoy Sahu, Sangram Singh Patel, Nida Fatima.

All authors read and approved the final version of the manuscript.

Consent for publication

All individuals have given consent to participate in the study.

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Conflicts of interest

There are no conflicts of interest.

References

1. Assegu Fenta D, Lemma K, Tadele H, Tadesse BT, Derese B. Antimicrobial sensitivity profile and bacterial isolates among suspected pyogenic meningitis patients attending at Hawassa University Hospital: Cross-sectional study. BMC Microbiol 2020;20:125.
2. Alnomasy SF, Alotaibi BS, Mujamammi AH, Hassan EA, Ali ME. Microbial aspects and potential markers for differentiation between bacterial and viral meningitis among adult patients. PLoS One 2021;16:e0251518.
3. Baranwal RK, Kumar M, Sharma AK, Prasad A, Seema K, Priyadarshini V. Microbiological profile of cerebrospinal fluid (CSF) in pyogenic meningitis patients at tertiary care hospital. Int J Med Res Prof 2018;4;113-8.
4. Tang LM, Chen ST, Hsu WC, Lyu RK. Acute bacterial meningitis in adults: A hospital-based epidemiological study. Qjm 1999;92:719-25.
5. Huang CR, Chen SF, Lu CH, Chuang YC, Tsai NW, Chang CC, *et al.* Clinical characteristics and therapeutic outcomes of nosocomial super-infection in adult bacterial meningitis. BMC Infect Dis 2011;11:1-8.
6. Pelegrín I, Lora-Tamayo J, Gómez-Junyent J, Sabé N, García-Somoza D, Gabarrós A, *et al.* Management of ventriculoperitoneal shunt infections in adults: Analysis of risk factors associated with treatment failure. Clin Infect Dis 2017;64:989-97.
7. Zheng G, Shi Y, Cao Y, Qian L, Lv H, Zhang L, *et al.* Clinical feature, therapy, antimicrobial resistance gene distribution, and outcome of nosocomial meningitis induced by multidrug-resistant enterobacteriaceae—A longitudinal cohort study from two neurosurgical centers in northern China. Front Cell Infect Microbiol 2022;12:839257.
8. Hrishi AP, Sethuraman M. Cerebrospinal fluid (CSF) analysis and interpretation in neurocritical care for acute neurological conditions. Indian J Crit Care Med 2019;23(Suppl 2):S115.
9. Singhal N, Kumar M, Kanaujia PK, Virdi JS. MALDI-TOF mass spectrometry: An emerging technology for microbial identification and diagnosis. Front Microbiol 2015;6:791.
10. Clinical and Laboratory Standards Institute. Performance Standards for Antimicrobial Susceptibility Testing: Twenty-Third Informational Supplement. Wayne, PA, USA: Clinical and Laboratory Standards Institute. CLSI document M100-S29; 2019.
11. Iredell J, Brown J, Tagg K. Antibiotic resistance in Enterobacteriaceae: Mechanisms and clinical implications. BMJ 2016;352:h6420.
12. Lee JK, Seok JY, Lee JH, Choi EH, Phi JH, Kim SK, *et al.* Incidence and risk factors of ventriculoperitoneal shunt infections in children: A study of 333 consecutive shunts in 6 years. J Korean Med Sc 2012;27:1563-8.
13. Duggal S, Duggal N, Charoo H, Mahajan RK. Recent outbreak of meningococcal meningitis--A microbiological study with brief review of literature. J Commun Dis 2007;39:209-16.
14. Bhat BV, Verma IC, Puri RK, Srinivasan S, Nalini P. A profile of pyogenic meningitis in children. J Indian Med Assoc 1991;89:224-7.
15. Malhotra C, Do YK. Socio-economic disparities in health system responsiveness in India. Health Policy Plan 2013;28:197-205.
16. Frasca D, McElhaney J. Influence of obesity on pneumococcus infection risk in the elderly. Front Endocrinol 2019;10:71.
17. Niemelä S, Lempinen L, Löyttyniemi E, Oksi J, Jero J. Bacterial meningitis in adults: A retrospective study among 148 patients in an 8-year period in a university hospital, Finland. BMC Infect Dis 2023;23:45.
18. Garner-Spitzer E, Poellabauer EM, Wagner A, Guzek A, Zwazl I, Seidl-Friedrich C, *et al.* Obesity and sex affect the immune responses to tick-borne encephalitis booster vaccination. Front Immunol 2020;11:860.
19. Van de Beek D, De Gans J, Spanjaard L, Weisfelt M, Reitsma JB, Vermeulen M. Clinical features and prognostic factors in adults with bacterial meningitis. N Engl J Med 2004;351:1849-59.
20. Wall EC, Everett DB, Mukaka M, Bar-Zeev N, Feasey N, Jahn A, *et al.* Bacterial meningitis in Malawian adults, adolescents, and children during the era of antiretroviral scale-up and Haemophilus influenzae type B vaccination, 2000–2012. Clin Infect Dis 2014;58:e137-45.
21. Amaya-Villar R, García-Cabrera E, Sulleiro-Igual E, Fernández-Viladrich P, Fontanals-Aymerich D, Catalán-Alonso P, *et al.* Three-year multicenter surveillance of community-acquired Listeria monocytogenes meningitis in adults. BMC Infect Dis 2010;10:324.
22. Mook-Kanamori BB, Fritz D, Brouwer MC, Van Der Ende A, Van De Beek D. Intracerebral hemorrhages in adults with community associated bacterial meningitis in adults: Should we reconsider anticoagulant therapy? PLoS One 2012;7:e45271.
23. Sharma R, Goda R, Borkar SA, Katiyar V, Agarwal S, Kumar A, *et al.* Outcome following postneurosurgical Acinetobacter meningitis: An institutional experience of 72 cases. Neurosurg Focus 2019;47:E8.
24. Bisno AL, Sternau L. Infections of central nervous system shunts. In: Bisno AL, Waldvogel FA, editors. Infections Associated with Indwelling Medical Devices. Washington: American Society for Microbiology; 1994. p. 91-109.
25. Crnich CJ, Safdar N, Maki DG: Infections associated withimplanted medical devices, in Finch RG, Greenwood D, Norrby SR, Whitley RJ (ed): Antiobiotics and Chemotherapy:Anti-Infective Agents and Their Uses in Therapy, ed 8. New York: Churchill Livingston, 2003, pp 575–618.

26. Sacar S, Turgut H, Toprak S, Cirak B, Coskun E, Yilmaz O, *et al*. A retrospective study of central nervous system shunt infections diagnosed in a university hospital during a 4-year period. BMC Infect Dis 2006;6:43.
27. Celik I, Erol FS, Cihangiroglu M, Akdemir I, Tiftikci M. Evaluation of the cases with VP shunt infections. Turkish J Antibiotic Chemother 2003;7:60-4.
28. Mostafavi SN, Khedmati M, Kelishadi R. Microbiology and antimicrobial sensitivity of ventriculo-peritoneal shunt infections in a referral paediatric neurosurgery ward during a period of 7 years. J Global Antimicrob Resist 2022;29:63-7.
29. Sarguna P, Lakshmi V. Ventriculoperitoneal shunt infections. Indian J Med Microbiol 2006;24:52-4.
30. Nau R, Sörgel F, Eiffert H. Penetration of drugs through the blood-cerebrospinal fluid/blood-brain barrier for treatment of central nervous system infections. Clin Microbiol Rev 2010;23:858-83.
31. Jackson MA, Schutze GE, Byington CL, Maldonado YA, Barnett ED, Campbell JD, *et al*. The use of systemic and topical fluoroquinolones. Pediatrics 2016;138:e20162706.
32. Fouad R, Khairy M, Fathalah W, Gad T, El-Kholy B, Yosry A. Role of clinical presentations and routine CSF analysis in the rapid diagnosis of acute bacterial meningitis in cases of negative gram stained smears. J Trop Med 2014;2014:213762.