ORIGINAL ARTICLE

Bacterial Meningitis among Intracranial Surgery Patients at a University Hospital in Northern India

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Abstract

Background: Cerebrospinal infections are the cause of poor prognosis among post-neurosurgery patients owing to delay in improvement of neurological functions, leading to increased length of hospital stay, proceeding to disability or death.

Methods and materials: This retrospective observational study was performed at a tertiary care center in Northern India, where all patients with bacterial cerebrospinal infections from July 2019 to July 2022 were evaluated for post-neurosurgery cerebrospinal shunt infections, and all demographic data and risk factors were extracted from the hospital information system (HIS).

Results: The study includes 150 (150/1986, 7.55%) culture-confirmed cases of bacterial meningitis out of 1986 cases of suspected bacterial meningitis patients. Ninety-six (96/150, 64.0%) post-neurosurgery patients with cerebrospinal fluid (CSF) leaks were managed using external ventricular drain (EVD) or ventriculoperitoneal (VP) shunt. Seventy-four (74/96, 77.08%) patients were managed only on EVD, whereas 22 (22/96, 22.92%) patients were managed only on VP shunt. Eighty-two (82/96, 85.4%) multidrug-resistant microorganisms (MDROs) were isolated and 70 (70/82, 85.36%) were gram-negative bacteria, of which 56 (56/74, 75.68%) gram-negative bacteria showed extended-spectrum beta-lactamase (ESBL)-producing character in those with an EVD, 14 (14/22, 63.63%) with a VP shunt. Among gram-negative bacteria, *Acinetobacter baumannii* showed high rates of resistance: 21 (21/23, 91.30%) and 8 (8/8, 100%) were ESBL-producing *A. baumannii* in patients managed on EVD and VP shunt, respectively.

Conclusion: This study determines the risk factors, the spectrum of pathogenic microorganisms, multidrug resistance, and the nature of intracranial lesions isolated among the patients who developed bacterial cerebrospinal infections in post-neurosurgery patients.

Keywords: Bacterial meningitis, External ventricular drain, Multidrug resistance, Post-neurosurgery patients, Tertiary care center.

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Highlights

- This study denotes the incidence of bacterial cerebrospinal infections among the patients who underwent intracranial surgeries.
- We discuss the risk factors, underlying comorbidities that render susceptibility to bacterial cerebrospinal infections, and drug resistance among the pathogens isolated from cerebrospinal shunt infections.

Background

Meningitis is a dreaded complication that increases morbidity, mortality, and the length and cost of hospitalization after intracranial surgical intervention.[1] Other studies also describe it to have the highest incidence among all the patients who underwent neurosurgical interventions.[2,3] Meningitis remains the main reason for poor prognosis in postoperative intracranial surgeries in patients after neurosurgery.[4] The patients included in this study have undergone craniotomies and other endoscopic intracranial surgeries due to both benign and malignant lesions, and isolation of postoperative meningeal infections further delays the improvement in neurological functions of the patient and may progress to cause disability or death.[5]

The prevalence of intracranial bacterial infections was found to be 3% by the American National Nosocomial Infections Surveillance System, which assessed 43,135 neurosurgical cases between 1992 and 2004, and a similar incidence of 2.89–5.35% was found in bacterial meningitis patients who underwent intracranial surgeries at various hospitals in China.[5,6] Indian studies suggest a 0.7–8.9% incidence of meningitis in post-neurosurgical patients.[7] Although bacterial meningitis causes a potential threat to the life of the postoperative patients, the histopathological findings of the lesions, the stage and time of diagnosis, more importantly in malignant intracranial lesions, and the administration of appropriate antibiotics play a major role in the prognosis of the disease.[8]

Rationale for Investigation

We have come across many studies where the risk factors for developing bacterial meningitis post-intracranial surgery, the nature of lesion for which surgery was performed, history of meningitis, type of surgery, etc. were taken into account.[9,10] This study unearths the spectrum of pathogenic bacteria causing

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infection of meninges among intracranial postoperative patients and their antibiotic susceptibility pattern, along with the risk factors associated with the acquisition of bacterial meningitis in post-neurosurgery patients.

Due to selective transmission across the blood–brain barrier, only selective groups of drugs are used for the treatment of bacterial meningitis, and due to the nosocomial nature of the infection high drug resistance is observed.[11] The isolation of MDROs from the CSF samples of patients complicates the treatment procedure and amounts to higher mortality among the patients.[12] This study takes into account the spectrum of MDROs among the postoperative patients and the risk factors like the use of shunts that lead to the acquisition of drug resistance.

Objectives

It is the need of the hour for the neurosurgeons to know the incidence, risk factors, and the spectrum of pathogenic microorganisms and appropriate antibiotic susceptibility causing bacterial meningitis among the patients who underwent intracranial surgery. The main aim of the study was to observe the incidence of bacterial cerebrospinal infections in post-neurosurgery patients.

The objectives of this study include the following:

- Identification of the risk factors and underlying comorbidities that render susceptibility to bacterial cerebrospinal infections in post-neurosurgery patients.
- Analysis of the spectrum of pathogenic bacteria and drug resistance among the pathogens isolated from cerebrospinal shunt infections.

Materials and Methods

Study Design

We performed a retrospective observational cohort study where patients with culture-confirmed bacterial cerebrospinal infections with a subset of patients who underwent neurosurgery for intracranial space-occupying lesions were investigated for post-neurosurgery cerebrospinal infections and cerebrospinal shunt infections and their risk factors.

Setting

This study was carried out at the Bacteriology section of the Department of Microbiology at a 1600-bedded tertiary care center in Northern India in the duration from July 2019 to July 2022. The clinical and demographic data of post-neurosurgery patients operated for total or near-total excision of space-occupying lesions managed with EVD and VP shunts were extracted from the HIS. The results of culture and antibiotic sensitivity pattern for all the CSF samples were recorded in the laboratory register that was extracted for the purpose of this study. The study was approved by the Institute Ethics Committee (2020-100-EMP-EXP-16).

Participants

The participants of the study include all patients with culture-confirmed cerebrospinal infection and the subset of patients who suffered from post-neurosurgery cerebrospinal infections and cerebrospinal shunt infections.

Inclusion Criteria

All CSF samples from patients who had undergone intracranial surgical procedures and developed symptoms of meningeal irritation and infection were included in this study.

Exclusion Criteria

Any CSF sample that was reported to be contaminated on culture or brought with a delay of more than 2 hours after the collection of sample.

We included patients of all age-groups managed with EVD and VP shunt after intracranial surgical procedure for drainage of CSF, showing signs of meningeal irritation due to shunt-related bacterial infection. In our study cohort, symptoms of bacterial meningitis were defined by a fever, headache, neck rigidity, altered mental status, and photophobia. We closely monitored the period of hospitalization, during which we retrieved the various CSF parameters, the Glasgow Coma Score (GCS) at admission, and derived the CSF/blood glucose ratio from the HIS.

All 150 patients with culture-confirmed cerebrospinal infections were included in the study. Out of the 150 patients, 96 (96/150, 64%) patients underwent neurosurgery for intracranial space-occupying lesions. Among the patients that underwent neurosurgery, CSF leak was managed in 74 (74/96, 77.08%) patients using an EVD shunt and in case of 22 (22/96, 22.92%) patients who were managed using VP shunt.

Variables

In all cases, the nature of the intracranial lesion was defined as either benign or malignant, and the operations commonly performed to excise the lesion were also recorded. In patients with shunts, CSF for microscopic examination and culture was obtained by first disinfecting the site of the tube where the sterile needle is inserted and then aspirating the CSF, the needle tip should also be disinfected before aspiration. For eliminating out all discrepancies, only specifically labeled samples of EVD and VP shunts were accepted in our study. All the patients included in the study were suffering from nosocomially acquired meningitis, except for some rare cases that came back after discharge to reveal the community-acquired infection.

In this study, we have observed the demographic distinctiveness, including age, gender, and comorbidities, such as hypertension, diabetes, cardiac and liver disease, epilepsy, stroke, encephalopathy, chronic respiratory disease, immunosuppression, and American Society of Anesthesiologists' physical status score.[13,14] Patients receiving treatment with immunosuppressant drugs, hematological malignancies, transplant recipients, and patients suffering from uncontrolled diabetes were deemed immunosuppressed. We also monitored the risk factors for the isolation of MDROs from the patients who were managed on shunts after intracranial procedures.

Bacterial isolates were identified by routine biochemical testing and matrix-assisted laser desorption/ionization-time of flight mass spectrometry (MALDI-TOF MS). Kirby–Bauer disk diffusion method was used to perform antibiotic sensitivity testing according to the CLSI guidelines 2019.[15] Multidrug resistant (MDR) was identified as resistance to three or more classes of antibiotics, and extensively drug resistant (XDR) was identified as resistance to drugs of last resort.

Table 1: Demographic characteristics of patients and risk factors for bacterial meningitis in patients who underwent intracranial operations and those who did not undergo intracranial operations ($N = 150$)

Patient characteristics and risk factors	*Underwent intracranial operations (n = 96, 64%)*	*Did not undergo intracranial operations (n = 54, 36%)*	*p-value*
Demographics			
Age, years, mean (SD)	30.31 ± 16.85	27.89 ± 26.32	0.49
Gender, male/female	57:39	38:16	0.507
Comorbidities			
Stroke ($n = 18$), %	10 (10.41%)	8 (14.81%)	0.018*
Epilepsy ($n = 51$), %	32 (33.33%)	19 (35.18%)	0.556
Encephalopathy ($n = 85$), %	52 (54.17%)	33 (61.11%)	0.131
Organ transplant ($n = 2$), %	0 (0.0%)	3 (5.56%)	0.02*
Diabetes mellitus ($n = 33$), %	17 (17.70%)	16 (29.63%)	0.036*
Chronic kidney disease ($n = 19$), %	6 (6.25%)	13 (24.07%)	<0.001*
Heart disease ($n = 5$), %	2 (2.08%)	3 (5.56%)	0.255
Hypertension ($n = 42$), %	22 (22.92%)	20 (37.04%)	0.064
Pleural effusion ($n = 15$), %	10 (10.41%)	5 (9.25%)	0.821
COPD ($n = 3$), %	1 (1.04%)	2 (3.70%)	0.923
Anemia ($n = 102$), %	72 (75.0%)	30 (55.56%)	0.085
Other parameters			
Length of hospital stay, mean (SD)	36.99 ± 20.42	33.75 ± 29.10	0.426
CSF total cell count (per cubic mm), mean (SD)	1486.58 ± 4964.65	2060.05 ± 8470.47	0.601
CSF glucose (mg/dL), mean (SD)	46.89 ± 34.71	41.06 ± 26.44	0.286
CSF protein (mg/dL), mean (SD)	127.47 ± 51.74	126.44 ± 52.71	0.908
Death ($n = 36$), %	23 (23.95%)	15 (27.78%)	0.603

*p-value <0.05 is significant

Bias

As this is a retrospective cohort study where most of the data were obtained from the HIS and laboratory register, so there is a possibility of information bias due to lack of any information that was maintained in records.

Study Size

The study size was arrived by retrospectively analyzing culture results of CSF for the past 3 years from the laboratory registers and HIS.

Quantitative Variables

Most of the quantitative data like age of the patients and clinical parameters like the CSF glucose, protein, and total leukocyte count were obtained from the HIS. The GCS of the patients was obtained at admission which was again mentioned in the electronic data system. The duration of hospital stay among our patients was calculated from the day of patient admission to the day of next outpatient department (OPD) visit, which was obtained from the electronic records.

Statistical Methods

The statistical analysis for our study was performed by observing frequencies. Quantitative variables were expressed as mean and standard deviation (SD). In the analysis of risk factors for MDR, the comparison between groups for categorical variables was estimated by using χ^2 tests. The results were presented as 95% CIs. Statistical analysis was performed using the software program IBM SPSS Statistics version 20.0 (SPSS Inc.), with $p < 0.05$ considered statistically significant.

Results

Participants

The study includes 150 (150/1986, 7.55%) culture-confirmed cases of bacterial meningitis out of 1986 cases of suspected bacterial meningitis patients admitted to a tertiary care center over the course of 3 years. Of the 150 bacterial meningitis patients, 96 (64.0%) patients underwent intracranial surgery. Seventy-four (74/96, 77.08%) patients were managed on EVD and 22 (22/96, 22.92%) patients were managed on VP shunt, post neurosurgery. Eighty-two (82/96, 85.4%) MDR microorganisms were isolated among the causative pathogens responsible for cerebrospinal shunt infections.

Descriptive Data

The mean age of post-neurosurgery patients suffering from cerebrospinal infections was 30.90 ± 17.78 years. A male predominance of 59.4% (57/96) was eminent among our study cohort. Sixty-one (61/96, 63.54%) cases of benign intracranial lesions and 35 (35/96, 36.46%) cases of malignant intracranial lesions were observed in the patients who underwent neurosurgery. The most common causes of intracranial space-occupying lesions experienced by the individuals in our study cohort were pituitary macroadenoma (16/61, 26.23%) among benign intracranial lesions and oligodendroglioma (11/35, 31.43%) among malignant intracranial lesions. Underlying comorbidities like stroke, organ transplant, diabetes mellitus, and chronic kidney disease were identified as significant risk factors for bacterial meningitis in patients who underwent intracranial operative procedures in comparison with those who did not undergo any intracranial operative procedure described in Table 1. Headache (94, 97.91%)

was the most common initial symptom followed by altered mental status (51, 53.125%) and photophobia (50, 52.08%) among the patients who were admitted before surgery, as described in Table 2. The symptoms were either attributable to the pressure and extent of spread of the intracranial lesion.

The common intracranial lesions that required neurosurgery are described in Table 3. Benign intracranial lesions (61/96, 63.54%) are the most common intracranial lesions that led to neurosurgery. The most common benign lesion was pituitary macroadenoma (16/61, 26.23%), followed by meningioma (14/61, 22.95%) and vestibular Schwannoma (10/61, 16.39%) (Table 3). Among the malignant lesions, the one that was most commonly identified was oligodendroglioma (11/35, 31.43%), followed by astrocytoma (9/35, 25.71%) and medulloblastoma (6/35, 17.14%).

Main Results

Acinetobacter spp. (45/1986, 2.26%) accounts for the most common causative microorganism causing cerebrospinal infections among neurosurgery ward patients according to the data maintained for 3 years at our tertiary care center. The most common pathogenic microorganisms responsible for causing cerebrospinal shunt infections were *Acinetobacter spp.* (33/96, 34.375%) followed by *Klebsiella pneumoniae* (18/96, 18.75%). In patients managed on EVD, the microorganism most frequently isolated was *Acinetobacter spp.* (34%), followed by *K. pneumoniae* (23.0%) and *Enterobacter cloacae* (11.0%) (Fig. 1). Out of the *Acinetobacter spp.* isolated among the EVD patients, *A. baumannii* was identified in 23/25, 92%, while *Acinetobacter lwoffii* was identified in 2/25, 8% by MALDI-TOF-MS assay. For those patients managed on VP shunt,

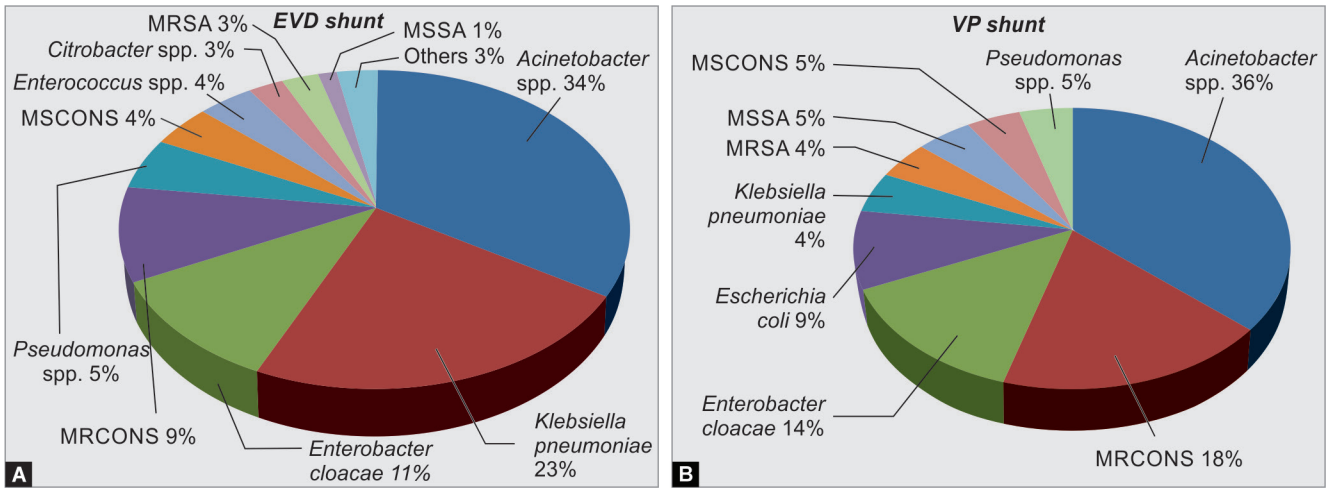
Table 2: The clinical and the histopathological comparison among the patients who underwent surgeries for intracranial lesions, followed by extraventricular drainage (EVD) shunts or ventriculo-peritonial shunts (VP shunt) postoperatively and developed bacterial meningitis (*N* = 96)

Patient characteristics	*Total (N = 96)*	*EVD shunt (N = 74)*	*VP shunt (N = 22)*	*p-value*
Age, years, mean (SD)	30.90 ± 17.77	33.14 ± 16.20	23.36 ± 20.98	0.022*
Gender: male/female	57:39	41:33	16:6	0.146
ASA score, %				
ASA I–II	34 (35.42%)	28 (82.35%)	6 (17.65%)	0.363
ASA III–IV	62 (64.58%)	46 (74.19%)	16 (25.80%)	0.363
Comorbidities				
Hypertension, %	22 (22.91%)	19 (86.36%)	3 (13.64%)	0.238
Diabetes mellitus, %	17 (17.70%)	14 (82.35%)	3 (17.65%)	0.569
Chronic kidney disease, %	6 (6.25%)	5 (83.33%)	1 (16.67%)	0.707
Heart disease, %	2 (2.08%)	1 (50%)	1 (50%)	0.357
Epilepsy, %	32 (33.33%)	25 (78.125%)	7 (21.875%)	0.864
Stroke, %	10 (10.41%)	9 (90%)	1 (10%)	0.305
Encephalopathy, %	52 (54.167%)	34 (65.38%)	18 (34.61%)	0.003*
Anemia, %	72 (75%)	57 (79.17%)	15 (20.83%)	0.400
Chronic obstructive pulmonary disease, %	1 (1.04%)	1 (100%)	0 (0.0%)	0.584
Initial symptoms				
Fever, %	40 (41.67%)	33 (82.5%)	7 (17.5%)	0.286
Headache, %	94 (97.91%)	73 (77.65%)	21 (22.34%)	0.357
Neck stiffness, %	28 (29.17%)	20 (71.43%)	8 (28.57%)	0.398
Altered mental status, %	51 (53.125%)	38 (74.51%)	13 (25.49%)	0.523
Photophobia, %	50 (52.08%)	40 (80%)	10 (20%)	0.478
CSF parameters				
CSF total cell count (cells/cubic mm) (mean, SD)	1486.58 ± 4964.65	1041.86 ± 3398.034	2982.45 ± 8265.7	0.107
CSF protein (mg/dL) (mean, SD)	127.47 ± 51.74	127.71 ± 51.87	126.63 ± 52.50	0.932
CSF glucose (mg/dL) (mean, SD)	46.89 ± 34.71	46.74 ± 31.19	47.36 ± 45.47	0.942
Nature of intracranial lesions				
Benign intracranial lesion, %	61 (63.5%)	51 (83.60%)	10 (16.39%)	0.045*
Malignant intracranial lesion, %	35 (36.5%)	23 (65.71%)	12 (34.29%)	0.045*
Source of infection, %				
Community acquired	3 (3.125%)	3 (100%)	0 (0.0%)	0.337
Nosocomially acquired	93 (96.87%)	71 (76.34%)	22 (23.65%)	0.337
Death, %	23 (23.95%)	16 (69.56%)	7 (30.44%)	0.325
Other parameters				
Duration of hospital stay (mean, SD)	36.99 ± 20.42	36.91 ± 20.10	37.27 ± 21.92	0.943
GCS score (mean, SD)	12.20 ± 3.025	12.23 ± 3.037	12.09 ± 3.054	0.85
CSF/blood glucose ratio (mean, SD)	0.39 ± 0.388	0.41 ± 0.39	0.33 ± 0.377	0.397

*p-value <0.05 is significant

Table 3: The common intracranial lesions among the post-intracranial operation patients managed on EVD shunts and VP shunts included in our study (*N* = 96)

Intracranial lesions	*Operation performed*	*EVD shunts (N = 74)*	*VP shunts (N = 22)*
Benign intracranial lesions			
Arachnoid cyst (*N* = 3), %	Endonasal rhinoseptal microscopic sellar arachnoid cyst excision	2 (66.67%)	1 (33.33%)
Cavernous hemangioma (*N* = 2), %	Craniotomy with lax duraplasty and complete excision of cavernous hemangioma	2 (100%)	0 (0.0%)
Cerebrovascular malformations (*N* = 7), %	Craniotomy and clipping of aneurysm	6 (85.71%)	1 (14.29%)
Choroid plexus papilloma (*N* = 1), %	Keyhole craniotomy and endoscopic-assisted subtotal/total excision of tumor	1 (100%)	0 (0.0%)
CNS epidermoid cyst (*N* = 2), %	Retromastoid craniotomy with total excision of tumor	2 (100%)	0 (0.0%)
CNS inflammatory demyelination disease (*N* = 1), %	Meningomyelocele excision and repair	0 (0.0%)	1 (100%)
Craniopharyngioma (*N* = 5), %	Endoscopic endonasal transsphenoidal excision of tumor	3 (60%)	2 (40%)
Meningioma (*N* = 14), %	Craniotomy with complete resection of the tumor	11 (78.57%)	3 (21.42%)
Pituitary macroadenoma (*N* = 16), %	Endoscopic endonasal transsphenoidal excision of tumor	15 (93.75%)	1 (6.25%)
Schwannoma (*N* = 10), %	Endoscopic endonasal transsphenoidal excision of tumor	9 (90%)	1 (10%)
Malignant intracranial lesions			
Astrocytoma (*N* = 9), %	Craniotomy with total excision of tumor	6 (66.67%)	3 (33.33%)
Clival chordoma (*N* = 2), %	Endoscopic endonasal transsphenoidal excision of tumor	2 (100%)	0 (0.0%)
Hemangioblastoma (*N* = 2), %	Endoscopic endonasal transsphenoidal excision of tumor	2 (100%)	0 (0.0%)
Malignant ependymoma (*N* = 3), %	Craniotomy with total/near-total excision of tumor	3 (100%)	0 (0.0%)
Medulloblastoma (*N* = 6), %	Craniotomy with total/near-total excision of tumor	0 (0.0%)	6 (100%)
Oligodendroglioma (*N* = 11), %	Endoscopic third ventriculostomy	10 (90.90%)	1 (9.09%)
Pinealoblastoma (*N* = 2), %	Medium pressure ventriculo-peritoneal (MPVP) shunt with chamber	0 (0.0%)	2 (100%)



Figs 1A and B: Microorganisms isolated from post-intracranial operation meningitis patients with EVD (*N* = 74) and VP shunt (*N* = 22) among the patients included in this study (*N* = 96), MRCONS, Methicillin-resistant coagulase negative *Staphylococcus*; MSCONS, Methicillin-sensitive coagulase negative *Staphylococcus*; MRSA, Methicillin-resistant *Staphylococcus aureus*; MSSA, Methicillin-sensitive *Staphylococcus aureus*

the most frequently isolated microorganism was *Acinetobacter spp.* (36%), followed by MRCONS (18%) and *E. cloacae* (14%) (Fig. 1). All the *Acinetobacter spp.* isolated from the VP shunt samples were subjected to MALDI-TOF-MS and were identified as *A. baumannii* (8/8, 100%). The postoperative patients managed on EVD and VP shunt developed infection with *Pseudomonas*

spp., and *Pseudomonas aeruginosa* in 5% of patients each in both cases (Fig. 1). The most commonly isolated *Pseudomonas spp.* was *P. aeruginosa* (3/4, 75.0%) and one rare isolate of *Pseudomonas mendocina* was identified by MALDI-TOF-MS.

The most common microorganism isolated from CSF of post-neurosurgery patients who underwent neurosurgery for benign intracranial lesions includes *A. baumannii* (21/61, 34.43%) followed by *K. pneumoniae* (11/61, 18.03%) and *E. cloacae* (8/61, 13.11%). Among patients who underwent neurosurgery for malignant intracranial lesions, the most common microorganism isolated was *A. baumannii* (10/35, 28.57%) followed by MRCONS (8/35, 22.86%) and *K. pneumoniae* (7/35, 20.0%).

Eighty-two (82/96, 85.4%) MDROs were isolated in this study out of them 70 (70/82, 85.36%) were gram-negative bacteria, of which 56 (56/70, 80%) gram-negative bacteria showed resistance to ESBL-producing character in those with an EVD, 14 (14/70, 20%) with a VP shunt. Among gram-negative bacteria, *A. baumannii* showed higher rates of resistance: 21 (21/23, 91.30%) were ESBL-producing *A. baumannii* in patients with EVD, 8 (8/8, 100%) with a VP shunt. All *E. cloacae* and *K. pneumoniae* isolated from patients with EVD and VP shunt were ESBL-producing microorganisms. Carbapenem-resistant organisms isolated from the study are 66 (66/82, 80.49%) (carbapenem-resistant organisms isolated from EVD are 53 and those isolated from VP shunt are 13), all *P. aeruginosa* isolated from EVD are resistant to carbapenem, and those isolated from the VP shunt were sensitive to carbapenems. We observed that all *P. aeruginosa* were resistant to piperacillin–tazobactam in patients on EVD and all isolates from patients with VP shunt were sensitive to it. Complete resistance to quinolones was observed, in patients with isolation of *A. baumannii* from EVD and VP shunts. Up to 80% resistance rate to aminoglycosides was observed among *P. aeruginosa* isolates from the samples included in our study, while complete resistance was observed in the case of *Acinetobacter spp.*, *Escherichia coli*, and *K. pneumoniae*. Colistin was used as a drug of last resort in 30 (30/96, 31.25%) patients, which was given by intrathecal route with successful outcomes. Out of all the *Enterococcus spp.* isolated from the CSF samples from postoperative patients, only 1 (1/3, 33.33%) isolate was vancomycin-resistant but linezolid-sensitive.

Other Analysis

Multidrug-resistant microorganisms were isolated from CSF culture in 86.48% (64/74, 86.48%) patients with EVD and 81.81% (18/22, 81.81%) in VP shunt. Table 4 demonstrates that there is a statistical significance between the presence of underlying comorbidities like hypertension, fever as the initial symptom of bacterial meningitis, the increased value of CSF cell counts and CSF proteins, and decreased value of CSF glucose, length of hospital stay, GCS values at admission and the CSF glucose to blood glucose ratio to diagnose the cause of isolation of MDR microorganisms from the EVD and VP shunt. Out of 96 patients who underwent neurosurgery due to intracranial space-occupying lesions, 23 (23/96, 23.95%) patients succumbed to their illness due to nosocomially acquired cerebrospinal infections post neurosurgery.

Discussion

This study demonstrates the clinical and microbiological profiles of the patients who developed cerebrospinal infections following neurosurgical procedures at a tertiary care center in Northern India. We studied the cases of 96 nosocomially acquired cerebrospinal infection post neurosurgery and evaluated their demographics, underlying comorbidities, risk factors, spectrum of pathogenic microorganisms, and their drug-resistance patterns. The incidence of postsurgical cerebrospinal infections at our center was 4.83% (96/1986, 4.83%), which is in agreement with the studies conducted by Reichert et al.,[1] Blomstedt,[16] Patir et al.,[17] and Korinek et al.[3] A male predominance (57/96, 59.4%) was observed in our study cohort, which could be attributed to more male patients visiting the OPD or emergency department of the hospital, seeking treatment which correlates with studies by Zhou et al.[4]

The incidence of cerebrospinal infection at our center was 7.55% (150/1986, 7.55%), which is estimated to be lower in comparison to the incidence of cerebrospinal infection that was noted to be in the range of 32–94% in an analysis performed by McClelland et al.,[18] Kourbeti et al.,[10] Korinek et al.,[3] and Dashti et al.[19] This difference in incidence could be attributed to the regular use of preoperative prophylactic administration of antibiotics before every surgery performed at our tertiary care center. Although prophylactically all the intraoperative CSF samples were sent for culture at our institute, it is highly recommended that samples from highly symptomatic patients are sent for microscopic examination and culture.

Post-intracranial surgery, all patients were managed on either EVD or VP shunt. The presence of any shunts increases the risk of cerebrospinal infections. The patients were managed on the shunts for at least 10–15 days in most cases, and most of the patients showed positive CSF cultures within the same timeframe, which correlates with the study conducted by Scheithauer et al.[20] According to early studies, the rate of cerebrospinal shunt infections was reported to be 1.5–39%, however, the rate seems to have dropped to 2–9%,[21] which corresponds with the rate of CSF shunt infections, which was reported to be 4.83% (96/1986, 4.83%) in our study.

In literature, post-neurosurgery cerebrospinal infections were commonly reported to be caused by *Staphylococcus aureus*, *Propionibacterium acnes*, and coagulase-negative *Staphylococcus*.[22] In contrast to early reports, our study observed the major pathogenic bacteria causing infection among post-neurosurgery patients to be *Acinetobacter spp.* (33/96, 34.375%) followed by *K. pneumoniae* (18/96, 18.75%). The shunts used in neurosurgery are premedicated with antibiotics such as minocycline, clindamycin, and rifampin, and silver coating is active mainly against gram-positive bacteria and significantly reduces the chances of shunt infections by them.[23] Notably, some recent studies have reported the emergence of gram-negative bacilli as a major pathogen in many neurosurgical units, especially *A. baumannii*,[24] which mirrors the results of our observations.

Our study dealt mainly with nosocomial infections and hospital-acquired microorganisms causing bacterial meningitis. *Acinetobacter spp*. (33/96, 34.375%) was the most commonly isolated bacteria followed by *Staphylococcus* species (20/96, 20.83%), which is in agreement with the study conducted by Khan et al.[25] Gram-negative bacilli, mostly belonging to the Enterobacteriaceae group, were observed in our study as *K. pneumoniae* was isolated in 18.75% (18/96, 18.75%) cases,

Table 4: Risk factors for isolation of MDR microorganisms in patients with intracranial lesions who underwent surgery (*N* = 82/96, 85.4%)

Patient characteristics	*Total (N = 82/96, 85.4%)*	*p-value*	*95% CI*
Age, years, mean (SD)	30.89 ± 17.85	<0.001*	26.97–34.81
Gender: male/female	46:36	0.114	1.33–1.55
ASA score, %			
ASA I–II	29 (35.36%)	0.980	1.54–1.75
ASA III–IV	53 (64.64%)	0.980	1.54–1.75
Comorbidities			
Hypertension, %	22 (26.83%)	0.027*	1.17–1.37
Diabetes mellitus, %	16 (19.51%)	0.262	1.11–1.28
Chronic kidney disease, %	6 (7.31%)	0.296	1.02–1.13
Heart disease, %	2 (2.44%)	0.555	0.99–1.06
Epilepsy, %	28 (34.14%)	0.683	1.24–1.45
Stroke, %	10 (12.19%)	0.167	1.05–1.19
Encephalopathy, %	46 (56.09%)	0.358	1.45–1.67
Anemia, %	65 (79.27%)	0.019*	1.70–1.88
Chronic obstructive pulmonary disease, %	1 (1.22%)	0.678	0.99–1.04
Initial symptoms			
Fever, %	40 (48.78%)	0.001*	1.38–1.60
Headache, %	80 (97.56%)	0.555	1.94–2.01
Neck stiffness, %	22 (26.83%)	0.223	1.17–1.37
Altered mental status, %	45 (54.88%)	0.405	1.44–1.66
Photophobia, %	43 (52.44%)	0.866	1.41–1.63
CSF parameters			
CSF total cell count (cells/cubic mm) (mean, SD)	1603.05 ± 5270.96	0.0073*	444.89–2761.21
CSF protein (mg/dL) (mean, SD)	128.14 ± 49.99	<0.001*	117.15–139.12
CSF glucose (mg/dL) (mean, SD)	46.98 ± 35.75	<0.001*	39.12–54.83
Nature of infection			
Benign intracranial lesion, %	52 (63.41%)	0.950	1.51–1.73
Malignant intracranial lesion, %	30 (36.58%)	0.950	1.27–1.49
Nature of intracranial surgery performed			
Craniotomy with drainage, %	52 (63.41%)	0.015*	1.53–1.74
Endoscopic surgery, %	30 (36.59%)	0.015*	1.44–1.98
Origin of infection			
Community acquired	3 (3.65%)	0.467	1.00–1.08
Nosocomially acquired	79 (96.35%)	0.467	1.92–2.00
Death%	20 (24.39%)	0.810	1.66–1.85
Other parameters			
Duration of hospital stay (mean, SD)	37.63 ± 21.17	<0.001*	32.98–42.29
GCS score (mean, SD)	12.04 ± 2.98	<0.001*	11.38–12.69
CSF/blood glucose ratio (mean, SD)	0.39 ± 0.40	<0.001*	0.30–0.49

*p-value <0.05 is significant

E. cloacae was isolated in 11.4% (11/96, 11.4%), and *E. coli* was isolated in 2.1% (2/96, 2.1%) cases as observed in studies conducted in 1992 by Federico et al.[2] and Erdem et al.[26]

The rate of isolation of MDROs was high among the patients who had undergone craniotomy with shunt placement in our study. The risk of isolating MDROs in patients who had undergone craniotomy with shunt placement in our study is statistically significant, as described in Table 4. The ESBL and carbapenem resistance in the intensive care unit was in concordance with a study conducted at our center by Sahu et al.[27] Owing to the high drug resistance among gram-negative isolates, intrathecal colistin administration was observed in 31.25% (30/96) of patients with neurosurgical bacterial meningitis with favorable outcomes due to poor CSF penetration of intravenous colistin which is similar to a study conducted by Rao et al.[28]

The mean length of hospitalization in patients who underwent intracranial surgery and developed bacterial meningitis was 36.99 ± 20.42 days, and the length of hospital stay among the patients suffering from intracranial malignant lesions was 36.25 ± 18.50 days, which corroborates our findings with the study by Zhou et al.[4] that the patients had a length of hospital stay more than 15 days in case of malignant lesions due to prolonged treatment. The increased

total cell count of CSF, low CSF glucose, high CSF protein, increased length of hospital stay, the GCS, and low CSF/blood glucose ratio as a risk for isolation of MDROs are statistically significant in our study, as described in Table 4.

The factors that limit the information conveyed by our study are that it is a retrospective, single-center study, so firstly we had to depend upon the HIS for the clinical data and charting, thus representing a selection bias. The drawback of it being a single-center study is that it does not represent the rate of isolation of postsurgical bacterial meningitis in the population of Northern India. There were factors that we did not take into consideration, including the prophylactic antibiotics administered and catheter insertion and removal of shunts.

Conclusion

This study determines gram-negative bacteria as the budding cause of post-neurosurgery infection and the emergence of *Acinetobacter spp*. as the most common organism causing cerebrospinal shunt infections. Presence of shunts predisposes the postoperative patients to many MDR microorganisms. There is a high incidence of MDR organisms reported from our study as prophylactic antibiotics are already administered before a surgical procedure.

Authors' Contributions

MK and CS: Protocol development. AD and AJ: Data collection. CS and SSP: Data analysis and Supervision. MK: Writing—original draft. MK, AJ, AD, CS, and SSP all authors read and approved the final version of the manuscript.

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