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Original Research Article

Characteristics of intracranial infection in patients after neurosurgery, and the influence of rational use of antibiotics

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Abstract

Purpose: *To investigate the characteristics of intracranial infection (ICI) in patients after neurosurgery, and the influence of rational use of antibiotics.*
Methods: *The medical records of 127 patients with neurosurgery-related ICI who were admitted into Jincheng People's Hospital, Jincheng, Shanxi, China from April 2019 to April 2022 were selected. The results of bacterial culture and drug susceptibility tests of cerebrospinal fluid were collected, and the profile of bacteria in the cerebrospinal fluid specimens of patients and the different bacterial compositions were analyzed.*
Results: *A total of 148 strains of pathogenic bacteria were cultured and isolated from the cerebrospinal fluid samples of 127 patients, out of which 91 strains of Gram-positive bacteria accounted for 61.49 %, and 57 strains of Gram-negative bacteria accounted for 38.51 %. The Gram-positive bacteria were Staphylococcus aureus, coagulase-negative Staphylococcus, and hemolytic Staphylococcus, while the Gram-negative bacteria comprised the pathogenic bacteria Acinetobacter baumannii, Klebsiella pneumoniae, and Pseudomonas aeruginosa. The Gram-positive bacteria were more sensitive to rifampicin (91.21 %), vancomycin (95.60 %), and linezolid (97.80 %), while the Gram-negative bacteria were more sensitive to imipenem (84.21 %), meropenem (75.44 %) and amikacin (77.19 %).*
Conclusion: *Gram-positive bacteria are the main pathogenic bacteria implicated in ICI after neurosurgery in patients. A further large-scale study is needed for better delineation of the disease presentation and prognosis.*

Keywords: *Neurosurgery, Intracranial infection, Antibiotics, Rational use*

INTRODUCTION

Intracranial infection (ICI) is one of the most common complications in neurosurgery. The clinical mortality rate of patients with ICI may reach 21.6 - 31.5 % [1]. Studies have shown that the occurrence of ICI not only lengthens the treatment time and cost to patients but also increases the risk of poor prognosis, disability, and death of patients [2]. The timely use of an effective antibiotic regimen after surgery is key to the prevention and treatment of ICI [3]. However, irrational use of antibacterial drugs and pathogenic bacteria resistance leads to difficulty in clinical selection of antimicrobial drugs. Previous studies [4] indicated that preventive antibiotics were used for most ICI patients before cerebrospinal fluid culture and drug susceptibility results were available. In clinical practice, it is also difficult to achieve ideal antibiotic effect with simple empirical medication. Thus, these interventions may easily lead to the emergence of drug-resistant bacteria in patients [5].

Currently, the rational use of antibiotics in patients with ICI after neurosurgery has become a global clinical research area [6]. Therefore, it is extremely important to determine the bacterial composition of ICI patients and their sensitivity to antimicrobial drugs used clinically in the treatment of ICI. Based on this, the medical records of 127 neurosurgery ICI patients admitted to Jincheng People’s Hospital were selected for use in studying the characteristics of ICI in patients after neurosurgery, as well as the impact of rational use of antibiotics.

METHODS

Clinical data

The medical records of 127 neurosurgery ICI patients (69 males and 58 females; age range: 21 to 59 yr; mean age: 38.29 ± 7.64 yr) admitted to Jincheng People’s Hospital from April 2019 to April 2022 were selected. The patients comprised. There were 65 cases of craniocerebral trauma, 37 cases of intracranial spontaneous hemorrhage, 19 cases of brain tumor, and 6 other cases. All patients received various relevant surgical treatments such as removal of intracranial hematoma and bone flap decompression surgery, intracranial mass removal surgery, ventricle drainage, or VP shunt, as appropriate. Intracranial infection was diagnosed within 3-10 days after operation, within an average time of 6.27 ± 1.62 days. This study was approved by the Ethics Committee of Jincheng People’s Hospital (approval no. of JC-003-102-09), and was conducted as per the guidelines of the Declaration of Helsinki [7]. All patients and their families were duly informed about the study, and they signed relevant consent forms.

Inclusion and exclusion criteria

Inclusion criteria: All patients who developed ICI after neurosurgery, and all patients diagnosed with ICI via clinical symptoms, signs, cerebrospinal fluid routine, biochemical examination, and other results, were included in the study. The other categories of included patients were those who had ICI symptoms such as high fever, headache, and vomiting; patients whose meningeal irritation was positive, those whose routine cerebrospinal fluid examination showed white blood cell count > 1180 × 10^6/L; patients with blood sugar content < 1.9 mmol/L and protein content > 450 mg/L; those with normal positive cerebrospinal fluid smear and bacterial culture, and patients with stable vital signs prior to enrolment in the study.

Exclusion criteria: Patients in the following categories were excluded from the study: those with brain abscess and open craniocerebral injury; patients with ICI before admission; patients with severe liver and kidney insufficiency; those who had malignant tumors, and patients who had other infectious diseases or immune diseases. Moreover, patients from whom cerebrospinal fluid samples could not be collected, and those who showed evidence of poor compliance and unwillingness to cooperate with the researchers, were excluded.

Procedures

Cerebrospinal fluid was obtained from 127 patients with ICI after neurosurgery. The cerebrospinal fluid samples from lumbar puncture, lateral ventricle drainage tube, and lumbar cistern drainage tube were collected using the test tube in a disposable lumbar puncture bag, and the samples were sent to the laboratory for analysis within 30 min after collection. The isolated pathogenic bacteria were cultured aerobically at 37 °C for 24 h in a culture medium provided by Hangzhou Tianhe Reagent Co. Ltd. The analysis and identification of bacterial species were carried out with an automatic microbial analyzer (VITEK-2 Compact, BioMérieux, France). Drug sensitivity test was carried out with agar diffusion method using drug sensitivity test paper provided by Wenzhou Kangtai Biotechnology Co. Ltd.

Assessment of parameters

The indices determined comprised the following: bacterial composition of cerebrospinal fluid samples of ICI patients after neurosurgery, sensitivity characteristics of Gram-positive bacteria and Gram-negative bacteria in cerebrospinal fluid samples of ICI patients after neurosurgery, as well as clinical use of antimicrobials in post-ICI patients following neurosurgery.

Statistical analysis

The SPSS 26.0 statistical software was used for data analysis in this study. Data are expressed in terms of numbers and percentages (n (%)) or mean ± standard deviation (SD).

RESULTS

Composition of bacteria in cerebrospinal fluid samples of patients

A total of 148 strains of pathogenic bacteria were cultured and isolated from the cerebrospinal fluid samples of 127 patients, out of which 91 strains of Gram-positive bacteria accounted for 61.49 %. These bacteria were *Staphylococcus aureus*, coagulase-negative *Staphylococcus*, and hemolytic *Staphylococcus*, while the Gram-negative bacteria comprised the pathogenic bacteria: *Acinetobacter baumannii, Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* (Table 1).

Table 1: Composition of bacteria in cerebrospinal fluid samples of patients

Pathogenic bacteria	Number of bacteria	Constituent ratio (%)
Gram-positive bacteria	***91***	***61.49***
Staphylococcus aureus	31	20.95
Coagulase-negative Staphylococcus	26	17.57
Staphylococcus haemolyticus	15	10.13
Staphylococcus epidermidis	10	6.76
Enterococcus	4	2.70
Others	5	3.38
Gram-negative bacteria	***57***	***38.51***
Acinetobacter baumannii	18	12.16
Klebsiella pneumoniae	13	8.78
Pseudomonas aeruginosa	10	6.76
Escherichia coli	5	3.38
Enterobacter cloacae	4	2.70
Serratia marcescens	3	2.03
Others	4	2.70
Total	**148**	**100.00**

Sensitivity characteristics of different bacteria to commonly used antibiotics

The Gram-positive bacteria were more sensitive to rifampicin (91.21 %), vancomycin (95.60 %), and linezolid (97.80 %), while the Gram-negative bacteria were more sensitive to imipenem (84.21 %), meropenem (75.44 %) and amikacin (77.19 %, Table 2).

Table 2: Sensitivity characteristics of 91 strains of Gram-positive bacteria to antibacterial drugs commonly used in clinical practice

Antibacterial drug	Number of bacteria	Sensitivity (%)
Oxazoline	38	41.76
Rifampicin	83	91.21
Sulfamethoxazole/ trimethoprim	53	58.24
Cefazolin	17	18.68
Penicillin	9	9.89
Tetracycline	55	60.44
Azithromycin	47	51.65
Ciprofloxacin	46	50.55
Vancomycin	87	95.60
Gentamicin	28	30.77
Clindamycin	43	47.25
Linezolid	89	97.80
Cefazolin	15	26.32
Sulfamethoxazole/ trimethoprim	23	40.35
Piperacillin	17	29.82
Cefoperazone	40	70.18
Imipenem	48	84.21
Meropenem	43	75.44
Ceftriaxone	13	22.81
Ceftazidime	28	49.12
Cefepime	24	42.11
Ciprofloxacin	26	45.61
Gentamicin	28	49.12
Amikacin	44	77.19
Aztreonam	13	22.81

Clinical usage of antibacterial drugs in patients with ICI after neurosurgery

A total of 55 patients received preventive medication, while 43 patients received empirical medication, and 61 patients received targeted medication. With respect to antibacterial drug use, penicillin accounted for the highest proportion of preventive medication (14.19 %), while glycopeptides accounted for the highest proportion of empiric antimicrobial therapy (12.16 %). The major targeted drugs used were cephalosporins and glycopeptides, with each accounting for 12.16 % (Table 4).

DISCUSSION

Neurosurgery is used for treating patients with traumatic brain injury, intracranial space-occupying lesions, and other diseases. These patients need more invasive operations in the course of clinical treatment, and most patients are in critical condition when they are admitted to the hospital. Neurosurgery may damage the blood-brain barrier of patients to a certain extent, resulting in high risk of ICI in such patients [8]. Studies have shown that ICI is a relatively common postoperative complication in neurosurgery patients [9]. The risk factors for

Table 3: Clinical usage of antimicrobials in patients with ICI after neurosurgery

Antibacterial drug	Preventive medication		Empirical medication		Targeted drug use	
	No. of cases	***Utilization rate (%)***	***Number of cases***	***Utilization rate (%)***	***Number of cases***	***Utilization rate (%)***
Cephalosporins	17	11.49	3	2.03	18	12.16
Glycopeptides	3	2.03	18	12.16	18	12.16
Penicillin	21	14.19	4	2.70	3	2.03
Quinolones	2	1.35	2	1.35	2	1.35
Carbapenems	5	3.38	11	7.43	14	9.46
Aminoglycosides	3	2.03	3	2.03	3	2.03
β-Lactams	4	2.70	2	1.35	3	2.03

postoperative ICI in patients include otorrhea, postoperative incision drainage, and artificial dura mater [10]. A previous study [11] reported 8.42 % incidence of ICI after neurosurgery, which is relatively high. Compared with patients without infection, the disability and mortality rates of ICI patients are significantly higher. The occurrence of complications has serious impacts on the prognosis and rehabilitation of patients. Therefore, clinical attention should be paid to ICI after neurosurgery.

The clinical treatment of ICI patients after neurosurgery involves the use of antimicrobial drugs. However, due to the difficulties encountered in ICI treatment, the therapeutic effect of commonly used clinical anti-infective regimens is usually not satisfactory [12]. High drug resistance rates and diverse drug resistance mechanisms are closely related to irrational clinical drug use [13]. Research has demonstrated that the etiological diagnosis of ICI after neurosurgery usually shows the presence of Gram-positive bacteria, and the main pathogenic bacteria are *Staphylococcus aureus* and *Pseudomonas aeruginosa.* In this study, 148 strains of pathogenic bacteria were cultured and isolated from the cerebrospinal fluid samples of 127 patients, out of which 91 strains of Gram-positive bacteria accounted for 61.49 %, and 57 strains of Gram-negative bacteria accounted for 38.51 %. The Gram-positive bacteria were *Staphylococcus aureus*, coagulase-negative *Staphylococcus*, and hemolytic *Staphylococcus*, while the Gram-negative bacteria were the pathogenic bacteria *Acinetobacter baumannii*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa*. The results of this study showed that the pathogenic organisms in cerebrospinal fluid culture from ICI patients after neurosurgery were mainly Gram-positive bacteria, which is consistent with the results of previous studies [15,16]. The results of drug susceptibility analysis in this study showed that Gram-positive bacteria were more sensitive to rifampicin (91.21 %), vancomycin (95.60 %), and linezolid (97.80 %), while Gram-negative bacteria were more sensitive to imipenem (84.21 %), meropenem (75.44 %) and amikacin (77.19 %).

At present, early prevention and treatment are used mainly for postoperative ICI, and the corresponding antibacterial drug treatment is given to patients based on the results of bacterial culture or drug susceptibility tests [17]. In a study, it was found that ICI symptoms generally appeared 7 days after the operation, and switching to targeted antibiotic therapy after empirical anti-infection therapy effectively reduced the probability of ICI in patients [18]. However, due to the late results of bacterial culture or drug susceptibility tests, there is a delay in the implementation of empirical drug intervention in clinical practice, resulting in negative impact on the targeted treatment of infection [19]. Previous studies showed that the accuracy of empirical antibiotics in surgical infection and ventilator-associated pneumonia was only 38.7 % [20,21]. Analysis of the use of antibacterial drugs in this study showed that 55 patients received preventive medication, 43 patients received empirical medication, and 61 patients received targeted medication. Penicillin was the most-used preventive medication (14.19 %), while glycopeptides were the most-used empirical antibacterial drug therapy (12.16 %). The most-used targeted drugs were cephalosporins and glycopeptides, each accounting for 12.16 %. These results show that glycopeptide antibacterial drugs have high application value in empiric and targeted drug therapy. Appropriate antibacterial drugs or a drug combination regimen should be selected for treatment, based on the results of drug sensitivity test. This will make for rapid inhibition or killing of pathogenic bacteria, thereby enhancing therapeutic effect and safety of life of the patient.

Limitations of this study

Due to pre-existing neurosurgical super-infection, prognosis of super-infection remains poor. The interpretation of clinical data shown in this study should be explained with caution due to the small sample size used and the retrospective characteristics of a single hospital-based study.

CONCLUSION

Gram-positive organisms are the main pathogenic bacteria that cause ICI in patients after neurosurgery. Therefore, before treatment of ICI patients after neurosurgery, pathogenic bacteria analysis and drug sensitivity test should be conducted first. A further large-scale study is needed for better delineation of the disease presentation and prognosis.

DECLARATIONS

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Ethical approval

This study was approved by the Ethics Committee of Jincheng People's Hospital, China (approval no. of JC-003-102-09).

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

No conflict of interest associated with this work.

Contribution of Authors

The authors declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by them.

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