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Individualized surgical management of acute intracranial infection-associated hydrocephalus

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Abstract

Objective: This study aims to discuss and summarize surgical treatments for acute intracranial infections with hydrocephalus as a supplement to antibiotic treatment. *Methods:* A total of 29 patients diagnosed with acute intracranial infection associated with hydrocephalus were divided into three groups for comparison and analysis of surgical interventions and outcomes. *Results:* In this study, 29 patients in one group underwent surgical treatment, while 28 received various forms of external cerebrospinal fluid (CSF) drainage, with a maximum of 5 drainage procedures. Additionally, 6 patients had Ommaya reservoir implantation, 6 had debridement, and 11 had a hydrocephalus shunt. Among the five patients in Group 1, all underwent shunt device extubation. The statistical analysis revealed no significant difference in surgical modes between the groups, but the outcomes did show a statistically significant difference ($\chi 2 = 6.433$, $P = 0.040$).
Conclusion: Individualized and multiple surgeries are needed for acute intracranial infection associated with hydrocephalus. In cases where the infection is secondary to a shunt, the primary surgical approach involves removing the shunt device. In situations where the infection is linked to hydrocephalus following different craniotomies, addressing scalp infection, cerebrospinal fluid leakage, and skull defects is essential. In instances of community-acquired intracranial infection associated with hydrocephalus, continuing drainage of cerebrospinal fluid is imperative.

Keywords: Intracranial infection, hydrocephalus, surgery

INTRODUCTION

Management of patients with acute intracranial infection-associated hydrocephalus (AIIAH) is complex due to the dual challenge of intracranial infection and hydrocephalus.[1] External ventricular drainage (EVD) or lumbar continuous drainage (LCD) is often required to address hydrocephalus and control infection.[1,2] However, it is crucial to limit the indwelling time of the drainage tube to reduce the risk of catheter-related infections.[3,4] Prophylactic replacement of the drainage tube through different routes may be necessary to prevent double infection and alleviate hydrocephalus.[1] AIIAH presents challenges for both patients and healthcare providers, leading to prolonged hospital stays and increased economic burden.

Ventriculoperitoneal shunt (VPS), endoscopic third ventriculostomy, and ventriculoatrial shunt (VAS) are commonly employed for the permanent treatment of hydrocephalus. However, these methods may not be effective in patients with unsterilized cerebrospinal fluid (CSF).[1] AIIAH is a rare condition[5], and there have been no definitive clinical guidelines or expert consensus on its surgical management in the past 15 years. While a few studies in English literature have briefly discussed AIIAH[6-8], they have primarily focused on antibiotic use with limited mention of surgical management strategies. This study retrospectively analyzed 29 cases to explore surgical treatment strategies for AIIAH, and the findings are presented here.

METHODS

Research objectives

Retrospective data were collected from the case sheets and discharge records of patients at Sir Run Run Show Hospital (SRRSH), Medical College

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of Zhejiang University, China, spanning from January 2013 to March 2019. A total of 7569 hospitalized cases were reviewed, with 29 cases of AIIAH ultimately included.

The flow chart in Figure 1 illustrates the process of selecting eligible cases. Acute intracranial infection encompasses meningitis, meningoencephalitis, and ventriculitis, with etiology ranging from community-acquired infections to those secondary to neurosurgery. Cases with both acute intracranial infection and hydrocephalus were identified using International Classification of Diseases codes.[10] All patients included in the study met the criteria of having concurrent acute intracranial infection and hydrocephalus for a specific duration. Cases where hydrocephalus developed after the resolution of the acute intracranial infection were excluded from the study, as this scenario is generally less complex than those complicated by ongoing intracranial infection.

The diagnosis of acute intracranial infection involves five key aspects: clinical manifestations, imaging changes, blood examination results (such as a white blood cell count exceeding 10×10^9/L or a neutrophil proportion over 80%), abnormal pressure or characteristics of CSF, and positive microbiological examination of CSF or surgical incision secretions. Patients meeting criteria (1) to (4) are classified under clinical diagnosis, while those meeting criteria (1) to (5) are categorized under etiological diagnosis. Positive microbial culture remains the gold standard for definitive diagnosis. All 29 patients underwent examination by physicians from the Department of Infectious Medicine.

The Evans index is utilized for diagnosing hydrocephalus, with CSF tap tests not being routinely performed. The presence of low-density foci around the ventricles, particularly in the anterior and posterior corners of the lateral ventricles, indicative of hydrocephalic edema, serves as a diagnostic indicator for hydrocephalus.[9,10] Among the 29 patients included in the study (Table 1), 21 were male and 8 were female, with ages ranging from 23 to 77 years and an average age of 53.93 (±15.08) years.

Procedures

The baseline demographic characteristics of the 29 eligible cases, including medical history, clinical presentation, imaging findings, type of surgery, original disease, pathogenesis, and outcome, were documented. Based on these characteristics and original diseases, the 29 cases of AIIAH

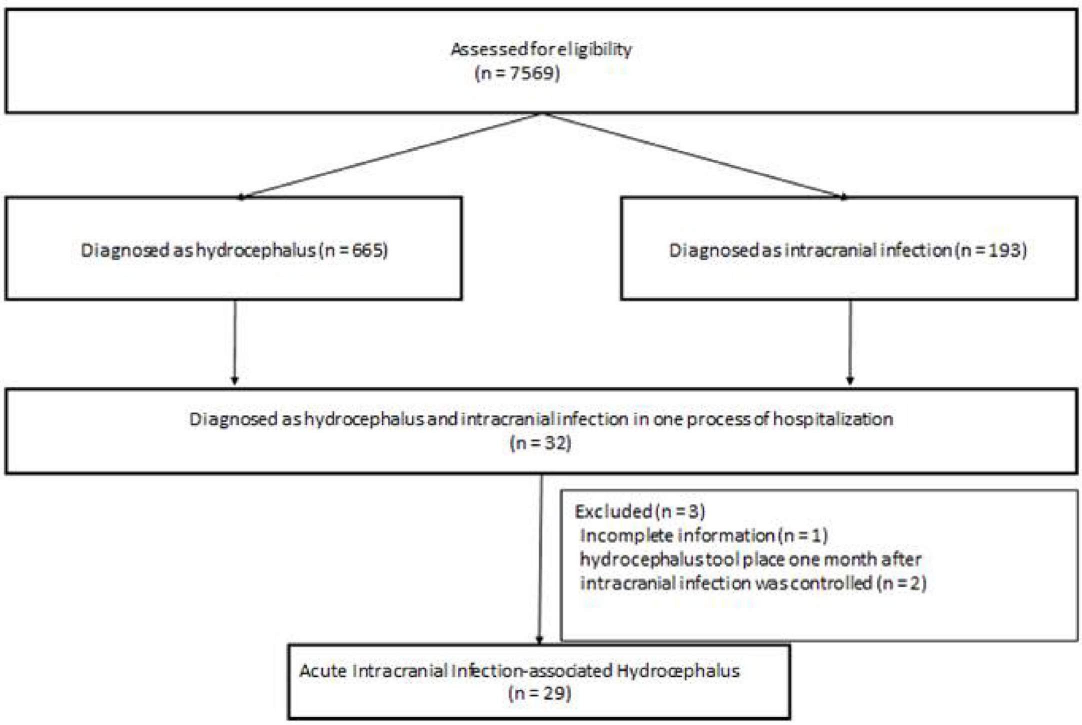

Figure 1. The flow chart depicting the process of selecting eligible cases.

Table 1: Data of 29 patients with acute intracranial infection-associated hydrocephalus

Case	Gender	Age	Primary Disease	Pathogens	Shunt removal/ Debridement	Drainage time(s)/ (Re)shunt	Outcome
1	Male	57	Chronic hydrocephalus	Staphylococcus epidermidis	1/0	5/1	Improved
2	Male	72	Chronic hydrocephalus	Acinetobacter baumannii	1/1		Cured
3	Female	45	Chronic hydrocephalus	Acinetobacter baumannii	1/0	1/1	Improved
4	Male	74	Chronic hydrocephalus	Acinetobacter baumannii	1/0	3/1	Improved
5	Male	47	Chronic hydrocephalus	Pseudomonas aeruginosa	1/0	4/1	Cured
6	Female	59	Cerebral hemorrhage	Acinetobacter baumannii		3/1	Cured
7	Female	39	Trauma	Unknown		3/1	Cured
8	Female	49	Trauma	Unknown		2/0	Improved
9	Male	64	Trauma	Candida tropicalis		2/0	Death
10	Female	51	Trauma	Klebsiella pneumoniae		2/0	Improved
11	Male	53	Trauma	Staphylococcus aureus		1/0	No Improvement
12	Male	23	Intracranial tumor	Acinetobacter baumannii		1/0	Death
13	Male	42	Trauma	Staphylococcus hominis		1/0	Cured
14	Male	31	Cerebral hemorrhage	Acinetobacter baumannii		5/0	Death
15	Male	63	Cerebral hemorrhage	Acinetobacter baumannii	0/1	5/0	Death
16	Male	57	Trauma	Klebsiella pneumoniae	0/1	2/0	Death
17	Male	74	Intracranial tumor	Acinetobacter baumannii	0/1	2/0	No improvement
18	Female	74	Cerebral hemorrhage	Flavobacterium indologenes		3/0	Death
19	Male	48	Intracranial tumor	Unknown	0/1	2/0	Death
20	Male	47	Trauma	Acinetobacter baumannii		2/0	Death
21	Male	58	Trauma	Unknown		1/1	Improved
22	Male	62	Trauma	Enterococcus faecalis	1/1	3/1	Improved
23	Male	62	Meningitis	Acinetobacter baumannii		2/0	Death
24	Male	77	Meningitis	Unknown		1/1	Improved
25	Male	73	Meningitis	Klebsiella pneumoniae		3/0	Death
26	Female	54	Meningoencephalitis	Unknown		1/0	Death
27	Male	55	Meningitis	Klebsiella pneumoniae		1/1	Improved
28	Female	24	Meningitis	Unknown		1/0	Improved
29	Male	30	Meningitis	Klebsiella pneumoniae		1/1	Improved

were categorized into three groups. The first group (Cases 1–5) consisted of patients who developed acute intracranial infection following a hydrocephalus shunt operation. The second group (Cases 6–22) included patients with AIIAH resulting from various craniotomy or open craniocerebral injuries. The third group (Cases 23–29) comprised patients with community-acquired AIIAH (refer to Table 2 for details).

Statistical analysis

The data was recorded and filtered using Excel software (Microsoft Office 16.0), followed by analysis with SPSS statistical analysis software (version 25, SPSS, Inc.). Mean ± standard deviation (x ± s) was used for continuous measurement data, with student's t-test employed for comparing group differences. Qualitative data were analyzed using chi-Square or Fischer's exact test as appropriate. Odds ratio and 95% confidence interval were calculated, with a p-value < 0.05 considered statistically significant.

RESULTS

In this cohort, 22 (75.86%) cases showed definite positive results for etiological examination (Table 1) and all had received antibiotic treatment. Out of the 29 patients, 13 (44.83%) either died or were discharged with no improvement. Group 2 had the highest in-hospital mortality with eight deaths (47.06%). Group 3 had three deaths (42.86%), while there were no deaths in group 1 (Table 1).

All 29 patients in the study cohort underwent surgical treatment. Among them, 28 patients had drainage one or more times, with 18 undergoing drainage more than twice. Of the 18 patients, nine died in the hospital and one was discharged without any improvement. Case 1 underwent multiple operations, including shunt removal, drainages, and a re-shunt operation, leading to improvement and discharge (Table 1). Therefore, for patients with AIIAH, various forms of drainage such as EVD, LCD, and drainage with Ommaya reservoir are commonly used surgical methods.

In this cohort, six cases underwent Ommaya reservoir implantation. Due to the limitations of repeated punctures for fluid extraction in fully draining the cerebrospinal fluid (CSF) and reducing intracranial pressure, the treatment approach for three cases was modified to include continuous drainage through a puncture needle connected to a drainage bag or resorting to external ventricular drainage (EVD). In another case, Ommaya reservoir implantation followed four unsuccessful attempts of EVD; subsequent to improvement in intracranial infection and inflammation control, the patient underwent ventriculoperitoneal shunt (VPS) placement and removal of the Ommaya reservoir. Overall, the therapeutic outcomes of Ommaya reservoir implantation were deemed positive.

Among the six patients, scalp infection and/or CSF leakage were observed, necessitating debridement to eliminate necrotic tissue, intracranial hematoma, or abscess. Pathogenic microorganisms were identified in five patients, with five cases experiencing secondary infections post-craniotomy and one post-resection of trigeminal neurinoma; unfortunately, three of

Table 2: Groups and operations of 29 patients with acute intracranial infection-associated hydrocephalus

Variable	Group 1	Group 2	Group 3	χ^2/F value	p value
Male	4(80.0%)	12(70.6%)	5(71.4%)	0.176	0.92
Female	1(20.0%)	5(29.4%)	2(28.6%)		
Age	59.00±13.58	52.59±13.78	53.57±20.12	0.433	0.805
Shunt Remove	5(100%)	1(100%)			
Debridement	1(20%)	5(29.4%)		0.173	0.678
Drainage patients	4(80%)	17(100%)	7(100%)	4.971	0.083
Drainage Times	2.60	2.47	1.43	0.380	0.827
Final Shunt	4(80%)	4(23.5%)	3(42.9%)	5.328	0.070
Improvement	5(100%)	7(41.2%)	4(57.1%)	6.433	0.040*

*There is significant difference between groups when p < 0.05.
Group 1 consisted of patients with acute intracranial infections secondary to hydrocephalus shunt of sterile hydrocephalus. Group 2 comprised patients who underwent open craniotomy or had open brain injuries. Group 3 is community-acquired intracranial infection and not linked to craniotomy.

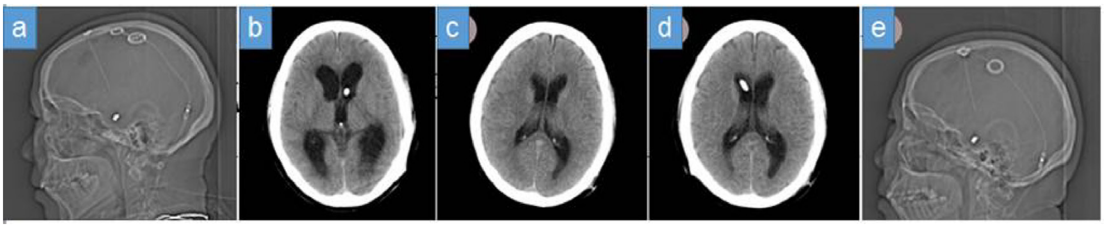

Figure 2. (Case 4) The patient developed an intracranial infection following left ventriculoperitoneal shunt (VPS) placement for hydrocephalus (**a, b**). The shunt device on the left side was removed as the initial crucial step in managing this complication (AIIAH) (**c**). Subsequently, the right VPS was reoperated on after successfully controlling the intracranial infection (**d, e**).

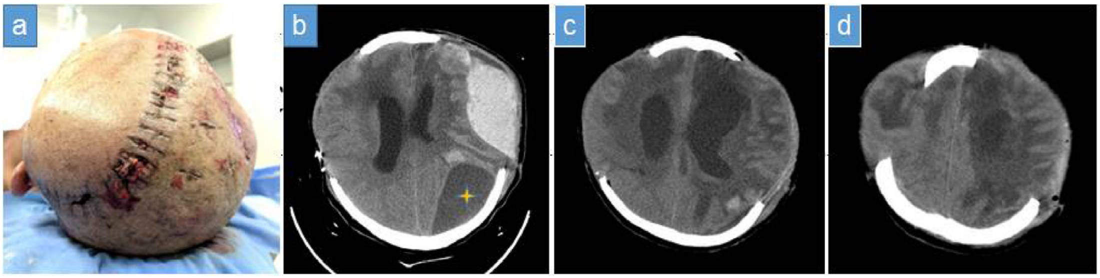

Figure 3. (Case 16) The patient presented with acute intracranial infection post-craniotomy following trauma. **a**) The left scalp incision revealed necrotic brain tissue protruding from it; **b**) A hematoma was observed under the flap, alongside a rounded and obtuse lateral ventricle, with a low-density focus later identified as pus during debridement; **c**) Following debridement and LCD, removal of the hematoma and abscess led to dilation of the lateral ventricles; **d**) Extensive necrosis in the brain tissue indicated a very poor prognosis, ultimately resulting in the patient's demise

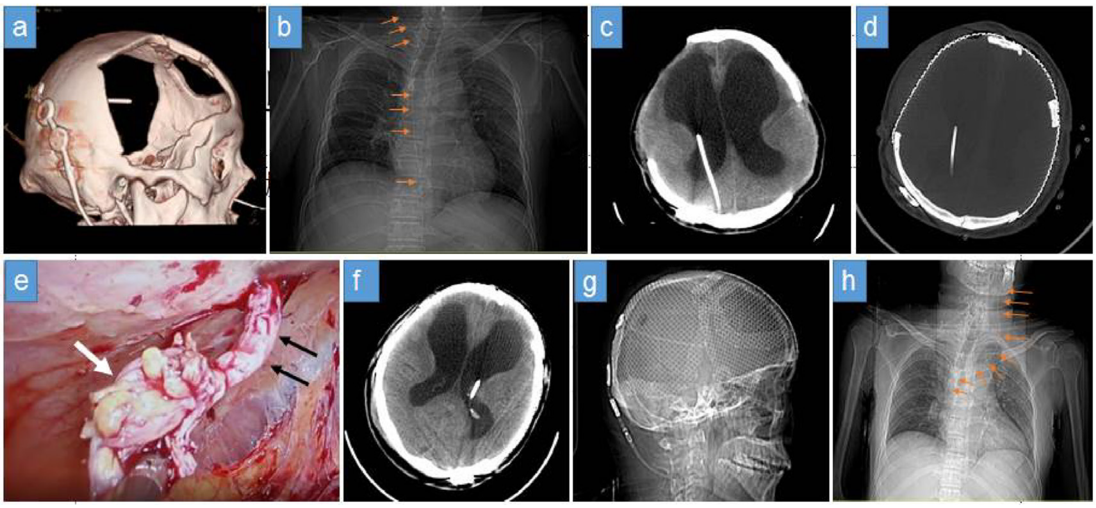

Figure 4. (Case 22) The patient underwent bilateral hematoma removal and decompressive craniectomy at a local hospital following a craniocerebral injury. Subsequent ventriculoperitoneal shunt (VPS) placement was performed due to hydrocephalus, but resulted in a secondary intracranial infection. Upon transfer to our hospital after receiving sensitive antibiotic treatment. CT images (**a, b**, and **c**) revealed the need for skull defect repair while the original shunt remained in place. The two sides of skull defect were repaired and the original shunt was still in place (**d**). After 18 days, the original shunt device was removed. Subsequently, the abdominal end of the shunt tube, heavily surrounded by inflammatory tissues (**e**), was extracted with the assistance of a laparoscope operation, and a left ventriculoatrial shunt (VAS) was performed simultaneously. The shunt was then observed running from the left ventricle to the right atrium (**f, g**, and **h**).

these cases resulted in mortality.

When compared with Groups 2 and 3, Group 1 showed the most favorable prognosis, with a statistically significant difference ($p = 0.040$) (Table 2). In group 1, five patients initially underwent VPS due to hydrocephalus, and later when they developed secondary acute intracranial infection. Upon transfer to our hospital from elsewhere, these patients underwent shunt device removal as soon as acute intracranial infection was diagnosed. Following removal, one patient recovered early with antibiotic treatment alone, while four patients underwent drainage and also showed improvement. Among these four patients, one received VAS after infection control and was eventually discharged from the hospital, while the other three patients underwent VPS once more and were successfully treated.

Ultimately, eleven patients underwent shunt operations to address hydrocephalus after multiple surgeries and control of acute intracranial infection (Table 2). Four of these patients were from Group 1, as previously mentioned. All patients were discharged upon improvement or recovery.

DISCUSSION

The incidence of AIIAH is rare[5], with only 29 cases selected out of 7,569 in this study. The research was motivated by the complexity and high mortality rate associated with this condition.[11] Treatment in previous literature involved a combination of surgical and antibiotic therapies (Table 3).[1,12-14] All 29 patients received systemic antibiotics; however, as the focus of the study was on surgical strategies, no statistical analysis regarding antibiotics was conducted. The cohort of 29 cases was divided into three groups, each with different disease characteristics and surgical approaches. The first group involved removing the shunt device and addressing the source of infection. Five patients from this group had previously undergone ventriculoperitoneal shunt (VPS) procedures in other hospitals and were transferred to SRRSH due to postoperative acute meningitis. After shunt removal, surgical drainage, and antibiotic treatment, four patients underwent permanent shunting again and eventually recovered.

The first group consisted of patients with acute intracranial infections secondary to hydrocephalus shunt. Although these patients should have received prolonged antibiotic therapy, the approach proved to be ineffective. The study findings emphasized the importance of removing the shunt device once intracranial infection is confirmed. Continuous drainage of the CSF should be carried out until its sterility is ensured. Once the condition is deemed appropriate, a hydrocephalus shunt procedure can be performed (either VPS or VAS) to cure the patient.[15] The second group comprised patients who underwent open craniotomy or had open brain injuries. This group often presented with additional challenges such as scalp infections, CSF leakage, or skull defects. In severe cases, scalp infections were not merely superficial and were accompanied by CSF leakage, meningeal encephalitis, and ventriculitis. Subsequent hydrocephalus indicated the further spread of intracranial inflammation, which impacted the circulation and absorption of CSF and led to a poor prognosis for the patients.[16] Despite attempts at scalp debridement and/or CSF drainage, the inflammation of the soft tissue and brain remained uncontrollable in some patients, ultimately resulting in death. Nonetheless, there were instances of successful treatment.

In cases of intracranial infection, some patients may have both hydrocephalus and a skull defect. The recommended surgical approach involves draining the CSF one or more times. It

Table 3: Surgical treatments of acute intracranial infection-associated hydrocephalus in the literature

Author	Patients	Pathogenic Microorganism	Operations	Cured
George T, *et al.*[1] (2019)	15	Klebsiella Staphylococcus	External ventricular drainage	11
Sacar S, *et al.*[12] (2006)	22	Staphylococcus	Ventriculoperitoneal shunt removal External ventricular drainage	19
Telles JPM, *et al.*[13] (2022)	57	Staphylococcus	Debridement	19
Popa F, *et al.*[14] (2009)	17	Staphylococcus Enterococci	Laparoscopic treatment	16

is advised to perform cranioplasty either before or simultaneously with hydrocephalus shunting to ensure optimal outcomes. This is particularly important in cases of large skull defects where the skin flap may be too soft to maintain intracranial pressure effectively, making it challenging to adjust the shunt valve pressure threshold.[17] However, if the skull defect is small and covered by a thick temporal muscle, hydrocephalus shunting can be done first followed by cranioplasty. The third group of AIIAH is community-acquired and not linked to craniotomy. The initial stage of the disease lacks clarity regarding etiology, with unknown pathogens causing intracranial infection in patients with other systemic diseases that may compromise their immunity.[6,18] This group includes patients with conditions like liver abscess (Case 26) and syphilis (Case 23), leading to a poor prognosis due to the seriousness of the underlying diseases.[18]

In the second and third groups of patients with AIIAH, hydrocephalus is often a result of intracranial infection, presenting as acute hydrocephalus. These patients frequently require multiple drainage procedures due to the challenge of controlling the infection quickly while avoiding prolonged external drainage to prevent secondary infections. When the drainage tube is removed, hydrocephalus can rapidly worsen, leading to increased intracranial pressure and a decline in the patients' consciousness level, necessitating repeat external drainage.[19] Some experts opt for a permanent shunt operation prior to infection control to manage intracranial hypertension more promptly, but we believe it is safer to utilize various drainage techniques initially and reserve permanent shunt operations for when the cerebrospinal fluid is sterile and clear.[20] Among these two groups, 15 patients underwent CSF drainage more than twice, indicating severe illness and alarmingly high mortality rates. Research is ongoing to discover more effective treatment strategies to reduce mortality.

In this study, six patients underwent Ommaya reservoir implantation to manage intracranial pressure and alleviate hydrocephalus, resulting in positive outcomes. This finding aligns with previous research on using Ommaya reservoirs for treating cryptococcal meningitis.[21,22] The data from this study suggested that if the CSF of patients shows signs of infection, such as purulence, external drainage (EVD or LCD) should be considered. Ommaya reservoir implantation was only performed in the six cases when the CSF appeared clear and intracranial infection was uncertain. Following implantation, multiple punctures and drainage via the Ommaya reservoir were necessary, increasing the risk of secondary infection. As frequent punctures and fluid extraction did not effectively reduce intracranial hypertension, one patient required continuous CSF drainage by retaining the puncture needle in place, essentially mimicking the effect of EVD. Antibiotics are essential in treating AIIAH[19]; however, their use should be coupled with efficient CSF drainage, removal of contaminated implants, elimination of pus and necrotic tissue, alleviation of intracranial hypertension, and preservation of normal tissue.

In conclusion, there is currently no established consensus or guidelines for the surgical management of intracranial infection with hydrocephalus, making treatment decisions highly individualized. Due to the rare occurrence of AIIAH, the study included a small number of cases, all of which presented complex conditions. Despite sharing our experiences, the mortality rate could not be significantly reduced. Therefore, additional research with a larger sample size is necessary.

DISCLOSURE

Conflict of interest: None

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