

**Review Paper:**

Intraventricular Empyema Features of Surgery and Conservative's Outcome: A Scoping Review
Running title: Exploring Intraventricular Empyema: Surgical Features and Conservative Outcomes
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<b>ABSTRACT</b>  <b>Background and Aims:</b> Intraventricular empyema (IVE), a rare and life-threatening neurological infection, challenges healthcare providers due to its complexity and limited data on optimal management. This scoping review seeks to bridge the existing literature gap by systematically summarizing current knowledge, identifying consensus, and highlighting research opportunities.  <b>Methods and Materials/Patients:</b> The inclusion criteria included all ages diagnosed with IVE based on the population, concept, and context (PCC) framework. The search strategy involved utilizing key words and controlled vocabulary terms in databases, such as PubMed, Science Direct, MEDLINE, Embase, Scopus, and Google Scholar. The study selection process adhered to predefined inclusion and exclusion criteria, with data extraction and mapping performed to summarize key information from the literature, including demographics, symptoms, treatment modalities, and outcomes  <b>Results:</b> Analysis of 12 articles shows that IVE predominantly affects men between the ages of 17 to 81 years, with various symptoms, including headaches, fever, and neurological issues. Infections are found in multiple

ventricular sites, often complicated by drug-resistant strains and negative cerebrospinal fluid (CSF) cultures. While surgical interventions, such as ventriculostomy are common, conservative treatments also show favorable outcomes, emphasizing the need for tailored management and timely interventions in optimizing patient outcomes for central nervous system (CNS) infections.

**Conclusion:** In conclusion, the diagnosis and management of intraventricular infections necessitate a multidisciplinary approach involving clinical evaluation, imaging, and therapeutic interventions. Imaging features like ventricular debris on computed tomography (CT) and magnetic resonance imaging (MRI) aid diagnosis, supplemented by other modalities, such as nuclear scintigraphy. Cerebrospinal fluid analysis is crucial, highlighting increased leukocyte counts and commonly implicated pathogens like gram-negative organisms and *Streptococcus* species.

**Keywords:** Intraventricular empyema (IVE), Surgery, Conservative, Outcomes

**Highlights:**

- Multidisciplinary approach: Diagnosis and management of intraventricular infections require collaboration between clinicians, imaging specialists, and therapeutic intervention teams.
- Imaging features: Ventricular debris on computed tomography (CT) and magnetic resonance imaging (MRI) serve as characteristic findings aiding in diagnosis, with additional modalities, such as nuclear scintigraphy and ultrasonography as supplementary tools.
- Cerebrospinal fluid analysis: Increased leukocyte counts and identification of common pathogens, such as gram-negative organisms and streptococcus species are crucial diagnostic indicators.
- Prompt diagnosis and treatment: Essential to reduce mortality rates associated with intraventricular infections, emphasizing the importance of early intervention.
- Therapeutic interventions: Intraventricular antimicrobial therapy may be considered in refractory cases, alongside long-term antibiotic treatment and follow-up monitoring as standard practice.
- Surgical intervention: Craniotomy or neuroendoscopic lavage may be necessary, especially in emergent situations, to optimize outcomes and prevent complications.
- Need for further research: Precise treatment protocols, particularly for primary bacterial ventriculitis, require additional investigation to guide effective clinical decision-making.
- Proactive approach: Comprehensive understanding and proactive management strategies are essential to mitigate morbidity and mortality risks associated with intraventricular infections.

**Plain Language Summary:**

Dealing with infections inside the brain's ventricles requires a team effort involving doctors, specialists who read brain scans, and those who perform treatments. Brain scans, such as computed tomography (CT) and magnetic resonance imaging (MRI), can show certain things that help diagnose these infections. We also sometimes use other tests, such as nuclear scans and ultrasounds. We also look at the fluid around the brain for clues, such as if the number of white blood cells is higher than usual or if we find certain germs. Prompt diagnosis and treatment of these infections is crucial to avoid serious problems. We may give strong medicines directly into the brain if regular medicines do not work well enough. Surgery may also be needed to clean out the infection. We still need to learn more about the best ways to treat these infections to help patients get better faster and stop them from happening in the first place. Doctors must be proactive and careful when treating these kinds of infections to keep patients safe.

**1. Introduction:**

Intraventricular empyema (IVE) is a rare and life-threatening condition characterized by the accumulation of infected pus within the brain's ventricular system [1]. This condition poses significant challenges to healthcare providers due to its complexity, potentially devastating outcomes, and limited available data on optimal management strategies [2]. Advances in medical science and technology have led to a growing interest in understanding the best approaches to manage IVE [3]. As a result, medical professionals, researchers, and academicians from various fields, including neurosurgery, infectious diseases, and critical care, have actively pursued investigations to improve the clinical outcomes of patients suffering from this severe neurological infection [4].

Numerous microorganisms, such as bacteria, viruses, fungi, and parasites, can infect the ventricular system. Hematogenous dissemination to the subependyma of the choroid plexus, diffusion by contiguity from a brain abscess, or direct implantation as a result of trauma or surgery are all potential paths for infection of the ventricular system [5]. Hematogenous spread occurs when pathogens enter the bloodstream and are carried to the brain. The subependyma of the choroid plexus, which is responsible for producing cerebrospinal fluid (CSF), is particularly vulnerable to hematogenous spread due to its rich blood supply [6]. Once the pathogens reach the subependyma, they can infect the ventricular system and cause inflammation and damage. Direct implantation is a less common mechanism of infection and occurs when pathogens are introduced directly into the ventricular system through a traumatic injury or surgical procedure [7]. This can happen when a foreign object, such as a bullet or surgical instrument, penetrates the brain and enters the ventricular system.

Timely and effective management is essential not only to save lives but also to reduce healthcare costs and improve the overall quality of life for survivors. Investigating the most up-to-date and comprehensive information on the management and outcomes of IVE is crucial for healthcare providers, policy makers, and researchers to enhance patient care and resource allocation [3], [8].

Despite the growing interest in IVE, a substantial literature gap exists. While individual studies and case reports have contributed valuable insights, a comprehensive synthesis of available knowledge is lacking. To address this void, this scoping review will methodically summarize the current literature, pinpoint areas of agreement, and draw attention to knowledge gaps that can influence future studies. To better understand best practices and potential areas for future research, this study intends to give a comprehensive review of the existing body of information in this field by illuminating the variety of management strategies, their linked outcomes, and developing trends.

## **2. Methods and Materials:**

This review aims to consolidate existing literature on the treatment modalities, outcomes, and evolving trends in IVE management. It will provide an overview of current knowledge and suggest avenues for future research and clinical practice enhancements in this medical domain. The synthesis of literature includes surgical and non-surgical interventions, their respective outcomes, complications, and practice patterns.

### **Research Inquiry:**

The central inquiry of this study delves into the management options and outcomes associated with IVE. The objective is to explore the array of methods utilized, alongside their diagnostic approaches, interventions, outcomes, and any emerging clinical practices. This comprehensive framework lays the groundwork for conducting a scoping review aimed at investigating the management options for IVE and evaluating the current understanding of their efficacy, outcomes, and evolving trends.

### **Inclusion Criteria:**

The inclusion criteria were formulated based on the population, concept, and context (PCC) framework in consultation with academic librarians. The target population encompasses individuals of all ages diagnosed with IVE. Search terms were developed to encompass keywords and controlled vocabulary terms (MeSH terms) to ensure a comprehensive retrieval of relevant literature.

### **Concept:**

This review examines the gamut of management strategies employed for IVE, encompassing surgical interventions, non-surgical approaches, conservative management, minimally invasive techniques, and other therapeutic strategies.

### **Context:**

The medical context under scrutiny is the treatment and management of IVE across various clinical settings, such as hospitals, medical centers, and research institutions. These settings witness the implementation of diverse management approaches to address this specific medical condition.

### **Type of Sources:**

Primary research studies, whether quantitative, qualitative, or mixed methods, were considered for inclusion in this review.

### **Study Selection:**

The inclusion criteria remained relatively stable throughout the review process, including primary research studies available in full text and written in English. The exclusion criteria included studies not directly addressing IVE or lacking relevance to the core of the study.

### **Search Strategy:**

A literature search was conducted across PubMed, Science Direct, MEDLINE, Embase, Scopus, and Google Scholar due to their extensive collections related to IVE. Articles published in full text, involving research on the condition and written in English, were included for evaluation.

### **Data Collection:**

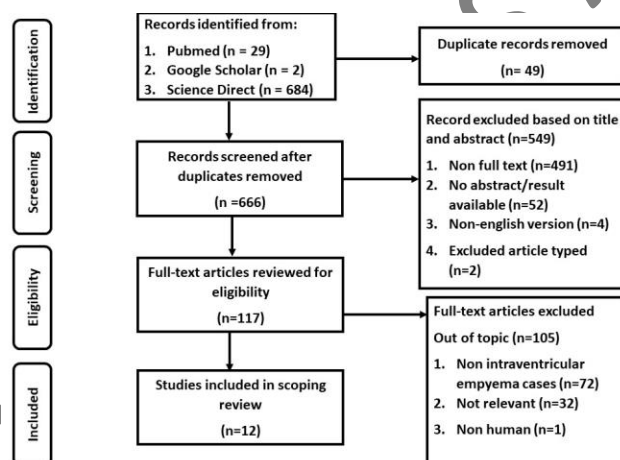
All identified literature underwent data collection and summarization using Microsoft Excel and Zotero. Duplicate articles were eliminated during title review, followed by screening based on titles and abstracts to ensure adherence to inclusion criteria. Relevant articles were then reviewed in full text by two independent reviewers, with disagreements resolved by a third reviewer. The scoping review methodology was documented following the preferred reporting items for systematic reviews and meta-analyses scoping reviews (PRISMA-ScR) guidelines.

#### Data Mapping:

Data mapping involved extracting pertinent information from the literature relevant to the research question. Mapped data included author names, patient demographics, and symptoms, site of empyema, CSF and blood culture results, neurosurgical treatments, antibiotic regimens, and outcomes. A narrative summary was provided to elucidate key findings from each data extraction set with the research objectives.

### 3. Results:

**Article Search Results:** The process of article search consisted of three distinct stages, identification, screening, and feasibility evaluation. The identification phase commenced by conducting a comprehensive search for pertinent publications in three databases, resulting in the retrieval of 715 papers relevant to the review's key words. The article titles were compiled in Microsoft Excel and organized in alphabetical order to identify duplicates. A total of 49 duplicate articles were found and subsequently excluded from the review process. Subsequently, 666 publications underwent a screening process where their titles and abstracts were evaluated to determine their relevance to the predetermined inclusion criteria. A total of 666 publications that satisfied the inclusion criteria were identified, while 549 articles failed to meet the inclusion criteria due to being review articles, lacking abstracts or results, and not being written in English. Out of the 117 papers that underwent the screening procedure, 105 articles were identified as irrelevant to the review topic and were excluded from further assessment. A total of 12 papers about this topic were discovered, leading to the review of twelve articles. Figure 1.

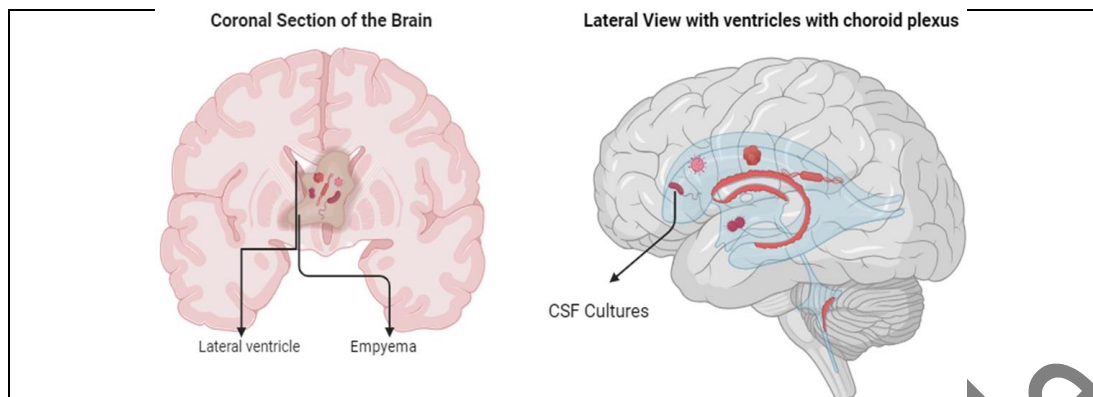


**Figure 1.** Research Study Selection Flow Diagram Based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Scoping Reviews (PRISMA-ScR) Framework

#### Article Eligibility Results:

From the 12 kinds of literature, the incidence of IVE predominantly affects men compared to women. The age range of patients with IVE varies from 17 years to 81 years. This suggests that IVE can affect individuals in a wide age range. The condition appears to affect men and women, with a fairly balanced representation in the provided cases. Cases involved men (24, 17, 35, 69, 39, 63, 62, 66, 55, and 49 years) and women (57 and 61 years). This indicates that IVE is not limited to a particular gender.

Headache is a common clinical presentation in several cases, including patients with fever with chills, headache after a trip, intermittent occipital headache, and frontal headache. Fever is another prevalent symptom, often accompanying headache. Patients presented with fever with chills, fever, abnormal movements, and acute headaches with vomiting and fever. Elevated body temperature is a common finding in IVE. Various neurological symptoms were observed, including right hemiplegia, aphasia, facial paresis, and right extensor plantar response. In one case, a patient with intravenous drug abuse presented with a headache and left earache. Some patients experienced gastrointestinal symptoms, such as diarrhea, which could be associated with systemic infection or inflammation. In a few cases, psychiatric symptoms, such as anxiousness, restlessness, and psychomotor retardation were noted, along with generalized weakness and unusual movements (suction, such as mouth dyskinesia). Some patients had comorbidities or other conditions, such as COVID-19.



**Figure 2. Ventricles of the Brain View of Intraventricular Empyema (IVE) Site of Infection**

The sites of empyema within the brain's ventricular system listed in Table 1 indicate a diverse range of locations of pus accumulation and infection. These locations encompass various parts of the ventricular system, including the lateral ventricles, third ventricle, and fourth ventricle, and specific regions within them, such as the occipital horns (figure 2). The presence of empyema in both the left and right lateral ventricles and its involvement in regions, such as the aqueduct of Sylvius highlights the potential for extensive and complex infections. Additionally, the mention of empyema extending into the frontal and parietal lobes underscores the critical nature of diagnosing and managing this condition promptly.

Drug-resistant strains, including methicillin-resistant staphylococcus aureus and klebsiella pneumoniae carbapenemase, indicate the concerning issue of antibiotic resistance in central nervous system (CNS) infections. Several typical pathogens linked to bacterial meningitis, such as Streptococcus pneumoniae and neisseria meningitidis, are also present. Some cases yielded negative CSF culture results, underscoring the diagnostic challenges and potential need for alternative diagnostic methods. Additionally, the presence of polymicrobial infections, as seen with Streptococcus anginosus and Prevotella intermedia, highlights the complexity of CNS infections.

Conversely, patients who received conservative treatment without surgery also demonstrated favorable outcomes, further highlighting the importance of tailored antibiotic regimens. However, it's notable that not all patients survived, as some who underwent procedures, such as bilateral frontal ventriculostomy or microsurgical drainage did not make it, underscoring the complexity and seriousness of CNS infections. The dataset emphasizes the significance of individualized treatment strategies and timely interventions to optimize patient outcomes in cases of central nervous system infections.

#### 4. Discussion:

Inflammation of the ependymal lining of the cerebral ventricular system, commonly known as IVE, ventriculitis, pyogenic ventriculitis, or intraventricular brain abscesses, is a suppurative infection of the ventricles. It typically results from meningitis, a ruptured abscess, or infections related to shunts or catheters. The accumulation of pus and other fluids in these ventricles, caused by an infection, can result in various symptoms and problems. Adults have sporadic cases of this disorder, which mostly affects newborns and infants. The neurologic examination can be a lifesaver in both routine and life-threatening situations. It aids in the diagnosis of neurologic involvement in specific diseases, which in turn allows for more targeted patient care [9].

Based on the data tabulated in this study, various symptoms can be experienced, such as a headache, left earache, fever with chills, right hemiplegia, difficulty speaking, extreme tiredness, rigors, frontal headache, nuchal rigidity, facial paresis, right extensor plantar response, random bouts of heat and sweat, dizziness, nausea, vomiting, and fever [10], [11], [12], [13], nausea, vomiting, altered mental status, and seizures [14]. Severe headaches are a common symptom, often accompanied by increased intracranial pressure. Furthermore, depending on the extent and location of the inflammation, patients may develop neurological symptoms, such as weakness, numbness, or visual disturbances. Fever is a common symptom of many infections due to the number of events resulting in IVE. Alongside symptoms, such as anxiousness, restlessness, psychomotor retardation, generalized weakness, and suction-like mouth dyskinesia [10], [11], [13].

Additionally, intermittent occipital headaches, right ankle swelling, and abnormal movements of the extremities were also observed. The diagnosis of COVID-19 suggests that some of these symptoms may have been related to the viral infection. The right hemiplegia and aphasia may have required further evaluation to rule out neurological conditions. Improving patient survival rates and making quick decisions about patient care are both made possible by accurate and timely evaluations of the extent of injuries and neurologic involvement in emergencies [15].

To better detect pyogenic ventriculitis and effect rapid therapy, it is necessary to identify computed tomography (CT) and magnetic resonance imaging (MRI) characteristics of the condition. Ventricular debris was observed. Due to the high protein concentration and, potentially, necrotic material, the shape of this substance may

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be uneven. The most common ventriculitis imaging sign (94%) was the presence of ventricular debris [16]. Imaging studies, such as CT scans and MRI can help diagnose IVE, but they may not always be conclusive. Among the imaging methods that have been used for these ventriculitis cases include nuclear scintigraphy, ultrasonography, and CT scans [17]. The CT scan reveals an augmentation in ventricular size, while the patient exhibits an elevated count of white blood cells [8]. Brain imaging confirms the diagnosis by a CT scan, which is recently insensitive. MRI is more reliable than a CT scan in identifying pus in the cerebral ventricular system and ependymal inflammation. MRI can distinguish between blood and pus and reveals abnormal ventricular detritus [18]. Only diffusion MRI sequences showed purulent material in the ventricles for diagnosing pyogenic ventriculitis [4].

In these current case report studies, IVE mostly occurs in bilateral ventricles of the brain. Others may occur in the left or right ventricle, aqueduct of Sylvius, third, fourth, and occipital horns of the lateral ventricle. In some cases, a lumbar puncture may be necessary to obtain a sample of CSF for analysis. An increase in the number of white blood cells (leucocytes) in the CSF can indicate an infection in the brain or its surrounding structures. When neutrophils predominate in a bacterial infection, lymphocytes predominate in a viral one, and vice versa. Our results corroborate the results of Adhikari and Marineli, who demonstrated the significance of patient leucocytosis screening. Following a negative neurological evaluation two weeks later, the CSF leukocyte count dropped to 64/mm<sup>3</sup>. Previously, it had been 1000/mm<sup>3</sup>, with normal values ranging from 0 to 5 [4]. CSF analysis was consistent with the bacterial infection including neutrophilic leukocytosis (2,300/mm<sup>3</sup> of leukocytes with 83% polymorphonuclear leukocytes [PMNs]), after three days of antimicrobial therapy, the patient improved significantly and leukocytosis was back to baseline [18].

Gram-negative meningitis was the most common form of infection associated with pyogenic ventriculitis (nine [60%] of 15 cases in which an organism was established by culture or Gram stain), followed by Staphylococcus species [16]. Streptococci constitute the most cases (44.9%) of which S pneumoniae is the primary cause of ventriculitis in patients with bacterial meningitis. Additionally, milleri group streptococci were identified as a significant source of ventriculitis associated with brain abscesses [19].

Reducing the mortality rate associated with empyema requires prompt diagnosis, treatment, and careful management of the illness. When patients experience a poor response to systemic antimicrobial therapy alone for healthcare-associated ventriculitis and meningitis, intraventricular antimicrobial therapy should be investigated [20].

Current best practices include administering antibiotics for an extended time, monitoring neurological symptoms, and conducting neuroimaging [18]. The administration of antibiotics at an earlier stage and over an extended time yields more favorable results, obviating the necessity for neurosurgical intervention [21]. How exactly antibiotics get to an intraventricular brain abscess is a mystery. Because there is less blood supply to the brain in an intraventricular abscess, antibiotic delivery may be less effective than intraparenchymal [22]. It is difficult to practice intraventricular antibiotics in neonates, although they may be effective in treating ventriculitis caused by multidrug-resistant bacteria [23].

As the IVE condition is an emergency from the outset, operative treatment must be done immediately. A craniotomy is one of the operative options to address this problem. The data tabulation of this study also mentioned that the surgical procedures used included craniotomy, ventriculostomy, EVD, microsurgery, and endoscopy [8], [24], [25].

Achieving cerebrospinal fluid sterility rapidly is possible with neuroendoscopic lavage, minimally invasive treatment for purulent ventriculitis in neonates [26].

Reports indicate that the neuroendoscope has shown efficacy in treating a ruptured brain abscess within the lateral ventricles [27]. From the tabulated data, we conclude that surgery is still a necessary and immediate option following the patient's diagnosis. Thorough action will achieve optimal results to save the patient from the threat of brain infection. Hence, it cannot be refuted that performing surgical removal of the intraventricular brain abscesses at an earlier stage could have potentially averted the occurrence of isolated ventricular dilatation [22]. Clear guidelines have been established for the management of ventricular catheter-related ventriculitis. However, there is a lack of specific recommendations or expert opinions regarding the optimal treatment regimen or duration for primary bacterial ventriculitis. Further clinical competence is necessary to determine the most appropriate treatment (surgical versus conservative) for these cases.

#### **5. Conclusion:**

Most patients who underwent a conservative approach combined with surgery survived their infections. This suggests that a surgical intervention, when complemented by appropriate conservative measures, can be effective in managing these conditions.

#### **Ethical Considerations**

Compliance With Ethical Guidelines:

This study is a review, and therefore does not require ethical considerations.

**Funding:** None

**Authors' Contributions:**

Conception and design: Farhad Balafif, Donny Wisnu Wardhana, Tommy Alfandy Nazwar  
Data collection: Farhad Balafif, Mustofa Mustofa  
Data analysis and interpretation: Farhad Balafif, Donny Wisnu Wardhana, Tommy Alfandy Nazwar  
Drafting the article: Tommy Alfandy Nazwar, and Mustofa Mustofa  
Critically revising the article: Farhad Balafif, Donny Wisnu Wardhana, Tommy Alfandy Nazwar, Mustofa Mustofa.  
Reviewing submitted version of manuscript: Mustofa Mustofa  
Approving the final version of the manuscript: Farhad Balafif, Donny Wisnu Wardhana, Tommy Alfandy Nazwar, Mustofa Mustofa.

**Conflict of Interest:**

Authors declared no conflict of interest.

**Acknowledgments:**

We thank you for all SMF Bedah Saraf RSSA Malang members and staff.

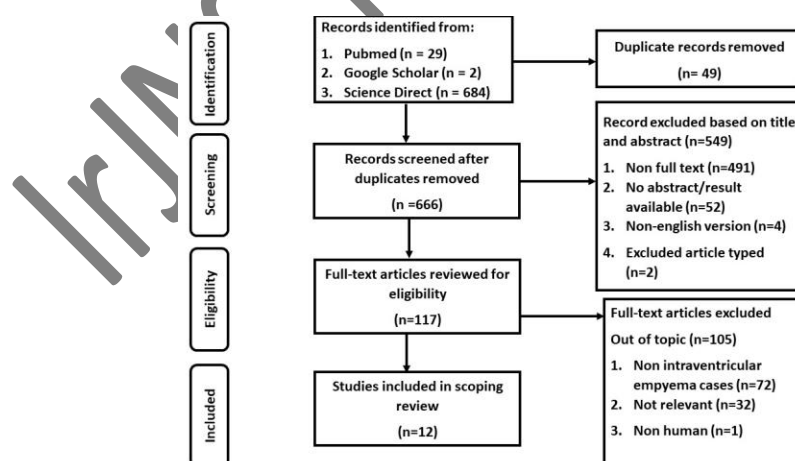
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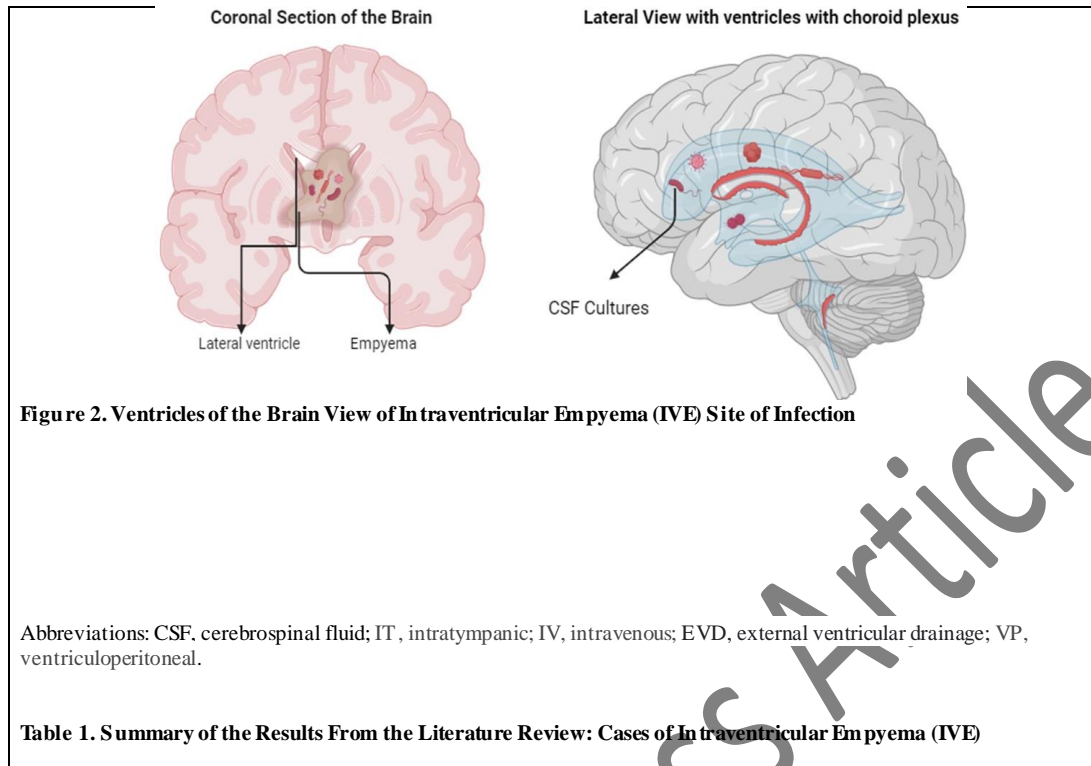
**Tables:**

**Figures:**



**Figure 1.** Preferred Reporting Items for Systematic Reviews and Meta-Analyses Scoping Reviews (PRISMA-ScR) Flow Chart of the Study Selection Process





**Figure 2. Ventricles of the Brain View of Intraventricular Empyema (IVE) Site of Infection**

Abbreviations: CSF, cerebrospinal fluid; IT, intratympanic; IV, intravenous; EVD, external ventricular drainage; VP, ventriculoperitoneal.

**Table 1. Summary of the Results From the Literature Review: Cases of Intraventricular Empyema (IVE)**

Author and Year	Age / Sex	Symptoms	Site of Empyema	CSF Germ	Blood Culture	Neurosurgical Treatment	Antibiotics Regimen	Outcome
Lang et al., 2018	24/M	No description	Left lateral ventricle	ESBL-Klebsiella pneumoniae	N/A	Burr-hole craniotomy and neuroendoscopic	IT colistimethate plus vancomycin and meropenem	Survived
	17/M	No description	Right lateral ventricle, aqueduct of Sylvius, third ventricle, fourth ventricle	Klebsiella pneumoniae	N/A	Burr-hole craniotomy and neuroendoscopic	IT gentamicin plus vancomycin and meropenem	Survived
	35/M	No description	Lateral, third, and fourth ventricles	Pseudomonas aeruginosa	N/A	Burr-hole craniotomy and neuroendoscopic	IT gentamicin plus cefepime and vancomycin	Survived
	69/M	No description	Left lateral ventricle, fourth ventricle, aqueduct of Sylvius	Enterobacter cloacae	N/A	Burr-hole craniotomy and neuroendoscopic	IT gentamicin plus vancomycin and meropenem	Survived
Adhikari P et al., 2022	57/F	Intravenous drug abuse presented with headache and left earache	Occipital horns of the lateral ventricle	CSF culture was negative	Streptococcus pneumoniae	Conservative	Ceftriaxone, vancomycin, ampicillin, and acyclovir.	Survived
Bajaj D et al., 2019	61/F	Fever with chills	Both lateral ventricles	Neisseria meningitidis	N/A	-	IV vancomycin, IV ceftriaxone, and Dexamethasone	Survived
Lee HK 1977	81/F	Right hemiplegia, aphasia	Left lateral ventricle	CSF Bloodculture not performed	S. aureus	No surgery treatment	Oxacillin (3), Chloramphenicol (3)	Died
Barloon TJ et al., 1990	39/M	Fatigue, fever, rigors, frontal headache, nuchal rigidity, facial paresis, right extensor plantar response	Left lateral ventricle	Peptostreptococcus spp.	E. faecalis, E. coli, Peptostreptococcus spp.	Ventricle drainage	Not documented	Survived
Vajramani GV et al., 2007	63/M	Headaches, feeling intermittently hot and sweaty, clumsiness, unsteadiness, diarrhoea and fever	Right lateral ventricle	S. intermedius	Negative	EVD, later VP drain	Cefotaxime (42), metronidazole (42) Rifampicin (14)	Survived
Ito H et al., 2008	62/M	Fever + headache after trip to Japan	Right lateral ventricle	L. monocytogenes	Negative	EVD	Vancomycin (8), ceftriaxone (8),	Survived

							ampicillin, gentamicin	
Marinelli L et al., 2014	66/M	Fever, anxiousness, restlessness, psychomotor retardation, generalized weakness and Suctionlike mouth dyskinesia	Lateral ventricles	S. aureus	Methicillin Resistant	No	Vancomycin (5) followed by linezolid (49)	Survived
Gronthoud	55/M	Fever, Intermittent occipital headache and right ankle swelling	Lateral ventricles	N. meningitidis	Not performed	No	Piperacillin/tazobactam (1) and Clarithromycin (2) followed by ceftriaxone (41) and rifampicin (9)	Survived
Mahammedi A et al., 2018	57/M	Fever and abnormal movements of his extremities	Left frontal and right parietal	Streptococcus viridans	N/A	Bilateral frontal ventriculostomy	Vancomycin, ceftriaxone, and flagyl	Died
Kalbarczyk A et al., 1999	62/M	Acute headaches, vomiting, and fever	Right lateral ventricle	Streptococcus anginosus and prevotella intermedia	N/A	Endoscopic stereotactic operation	Ceftriaxone and metronidazole	Survived
Meguins et al., 2021	49/M	Diagnosed with COVID-19	IV ventricle	Klebsiella pneumoniae carbapenemase and multidrug-resistant Pseudomonas aeruginosa	N/A	Microsurgical drainage	Antibiotic therapy	Died
Pang et al., 2021	70/F	Headache, vomiting and fever.	Bilateral ventricles	Streptococcus suis	Streptococcus suis	EVD + Vp shunt	Meropenem (2 g IV q8h), mannitol (250 mL IV q6h) and methylprednisolone (80 mg IV qd)	Survived