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CSF Pleocytosis Etiological Analysis in a Cohort of Pediatric Patients

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ABSTRACT

Background: Cerebrospinal fluid (CSF) analysis is one of the most critical diagnostic tools in pediatric medicine, particularly when investigating central nervous system (CNS) infections and inflammatory conditions. Among its parameters, pleocytosis, defined as an abnormal increase in white blood cells in the CSF, serves as an important indicator of underlying pathology. In children, the presence of CSF pleocytosis often signals potentially life-threatening conditions such as meningitis, encephalitis, or autoimmune disorders, necessitating prompt and accurate diagnosis (Dyckhoff-Shen et al., 2024).

The pediatric population presents unique diagnostic challenges due to differences in immune response, susceptibility to infections, and clinical presentation compared to adults. Infants and young children, for instance, may not exhibit classic symptoms of CNS infections, making CSF analysis a cornerstone in clinical decision-making. Identifying the causes of pleocytosis in this age group is therefore crucial for guiding treatment and predicting outcomes (Moon et al., 2023).

Etiologically, CSF pleocytosis can arise from a broad range of conditions, both infectious and non-infectious. Infectious causes include bacterial, viral, fungal, and parasitic agents, with viral infections often being the most common in pediatric cohorts. Non-infectious causes include autoimmune encephalitis, systemic inflammatory diseases, malignancies, and post-vaccination responses. Distinguishing between these etiologies is essential because treatment strategies and prognoses differ widely (Xu et al., 2019).

In bacterial meningitis, CSF pleocytosis is typically marked by a predominance of neutrophils, reflecting the acute inflammatory response. In contrast, viral infections often produce a lymphocytic predominance, although early viral infections may initially mimic bacterial profiles. Such variations highlight the importance of detailed cytological and biochemical analysis of CSF alongside microbiological testing to identify the precise etiology (Prakapenia et al., 2018).

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Keywords: *CSF, Pleocytosis, Etiological, Analysis, Pediatric, Patients*

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INTRODUCTION

of molecular diagnostic methods, such as polymerase chain reaction (PCR) and next-generation sequencing, has significantly enhanced the accuracy of identifying pathogens responsible for CSF pleocytosis. Despite these advances, conventional methods like culture and Gram stain remain indispensable, especially in resource-limited settings. In many pediatric cases, however, the etiology remains unidentified, underscoring the need for ongoing research to improve diagnostic strategies (Hrishi & Sethuraman, 2019).

Epidemiological studies of CSF pleocytosis in children provide insight into regional and temporal trends in disease prevalence. For example, the distribution of bacterial versus viral meningitis can vary by geography, vaccination coverage, and seasonality. Such data are vital for developing local treatment guidelines, informing vaccine policies, and optimizing empirical therapy in emergency settings (Kang et al., 2023).

Beyond infectious causes, non-infectious etiologies of CSF pleocytosis are gaining increased recognition. Autoimmune conditions such as anti-NMDA receptor encephalitis or systemic lupus erythematosus can present with pleocytosis, often mimicking infections in their clinical course. Malignant infiltration of the meninges, although rare in children, also manifests as CSF pleocytosis and carries a serious prognosis. Differentiating these causes requires integrating clinical, laboratory, and imaging findings (Hawkes et al., 2023).

The prognostic implications of CSF pleocytosis depend heavily on the underlying etiology. Bacterial meningitis, if not rapidly treated, can result in significant morbidity and mortality, while viral meningitis often follows a self-limiting course. Autoimmune and neoplastic causes, on the other hand, may require prolonged and specialized management. Thus, etiological analysis not only guides acute treatment but also influences long-term outcomes and follow-up care in pediatric patients (Al-Qahtani et al., 2022).

Research into the patterns of CSF pleocytosis in pediatric populations also highlights the importance of early recognition and intervention. Misinterpretation of CSF findings or delays in diagnosis can lead to adverse consequences, including neurological sequelae and increased healthcare burden. Systematic analysis of etiological factors provides clinicians with valuable tools for risk stratification and tailored management (Zellweger et al., 2020).

Overall, CSF pleocytosis in children represents a clinical finding with diverse underlying causes, each requiring distinct diagnostic and therapeutic approaches. By analyzing the etiological spectrum in a defined pediatric cohort, researchers and clinicians can enhance diagnostic accuracy, improve treatment strategies, and contribute to better health outcomes. Such investigations are especially relevant in guiding public health initiatives and advancing pediatric neuroinfectious disease research.

1. METHODOLOGY

Study Design

This study was a retrospective observational cohort analysis conducted on pediatric patients who underwent cerebrospinal fluid (CSF) examination due to suspected central nervous system (CNS) involvement.

Study Population

The analysis included **229 children aged 0–18 years** who were found to have CSF pleocytosis.

Inclusion Criteria

Pediatric patients (≤18 years) who had a lumbar puncture performed.

Presence of CSF pleocytosis, defined as a **white blood cell (WBC) count >5 cells/mm^3**.

Availability of complete medical records with clinical, laboratory, and diagnostic information.

Exclusion Criteria

Traumatic lumbar punctures with uninterpretable CSF results.

Incomplete medical records.

Cases in which empirical therapy was initiated before CSF sampling, precluding meaningful interpretation.

Data Collection

Data were extracted retrospectively from patient files using a structured sheet. The following variables were recorded:

Demographic data: age and sex.

Clinical presentation: presenting symptoms, including fever, seizures, headache, vomiting, altered consciousness, and focal neurological signs.

Past medical history: documentation of chronic neurological, congenital, or autoimmune conditions.

CSF parameters: leukocyte and red blood cell counts, protein and glucose levels, color, and appearance.

Microbiological and immunological testing: Gram stain, bacterial and fungal cultures, polymerase chain reaction (PCR) meningitis panels, viral cultures, cytology, and autoimmune antibody testing when indicated.

Neuroimaging findings: computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound results when performed.

Final diagnosis: determined through integration of clinical presentation, laboratory findings, imaging results, and discharge documentation. Diagnoses were categorized into infectious, inflammatory/autoimmune, neoplastic, neurodegenerative/congenital, vascular/hematologic, seizure-related, or miscellaneous.

Diagnostic Workup

CSF samples were processed according to standard protocols. Culture and molecular testing were performed selectively based on clinical suspicion. Neuroimaging was obtained at the discretion of the treating physician, and findings were classified as normal or abnormal with specification of the pathological process. The final etiological diagnosis was reached by consensus based on combined clinical, laboratory, and radiological information.

Statistical Analysis

Data were entered into a secure database and analyzed using **SPSS software, version 25**. Continuous variables were summarized as **median (minimum–maximum)**, while categorical variables were presented as **frequencies and percentages**. Results were described using tables and figures. No inferential statistical testing was performed, as the study was exploratory and descriptive in nature.

Ethical Considerations

The study was approved by the Institutional Review Board. Given its retrospective design, the requirement for informed consent was waived. Patient confidentiality was preserved through anonymization of all identifying data.

2. RESULTS

Table (1): Distribution of demographic data in the studied group.

	Studied group N=229
Sex	
Male	131 (57.2%)
Female	98 (42.8%)
Symptoms	
Headache	27 (11.8%)
Vomiting	91 (39.7%)
Behavioral changes	5 (2.2%)
Altered conscious level	28 (12.2%)
Weakness	22 (9.6%)
Seizure	69 (30.1%)
Visual symptoms	6 (2.6%)
Speech impairment	4 (1.7%)
Sensory loss	1 (0.4%)
Gait disturbance	6 (2.6%)
Other symptoms	

Fever	158 (68.9%)
Altered mental status	6 (2.6%)
Decrease in feeding	1 (0.4%)
Pale	1 (0.4%)
Diminished air entry bilaterally	1 (0.4%)
HSM	1 (0.4%)
Drowsiness	1 (0.4%)
Cranial nerve palsy	9 (3.9%)
Hemiparesis	5 (2.2%)
Ataxia	3 (1.3%)
Skin mottling	1 (0.4%)
Stiff neck with photophobia	1 (0.4%)
Skin mottling	2 (0.8%)
Hypotonia	1 (0.4%)
Hemisensory loss	1 (0.4%)
Tonic convulsion	1 (0.4%)
Up rolling of the eyes	1 (0.4%)
Arching of the back	1 (0.4%)
Compressible shunt	1 (0.4%)
LP repeated in the same illness	
Yes	86 (37.5%)
No	143 (62.4%)

This table shows that; males represented a higher proportion than females (57.2% vs. 42.8%). The most frequent presenting symptoms were fever (68.9%), vomiting (39.7%), and seizures (30.1%), followed by altered conscious level (12.2%) and headache (11.8%). Other symptoms such as cranial nerve palsy (3.9%), gait disturbance (2.6%), and visual symptoms (2.6%) were less commonly encountered. Rare manifestations including hypotonia, sensory loss, tonic convulsions, or shunt-related findings were reported in less than 1% of cases. Lumbar puncture was repeated during the same illness in 37.5% of patients.

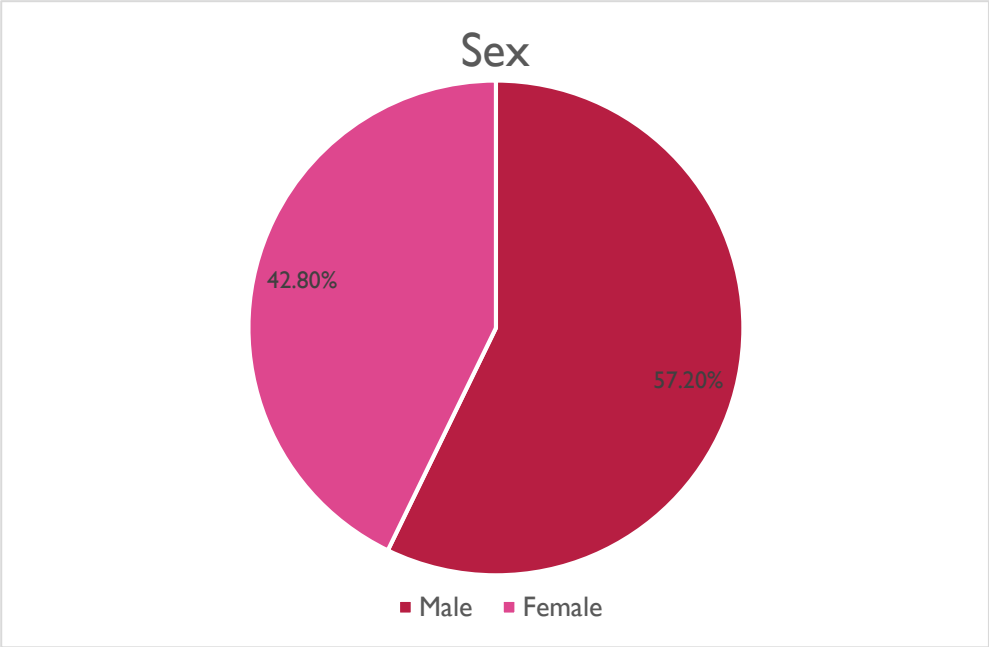

Figure (1): Sex distribution in the studied group

Table (2): Chronic neurological or Autoimmune disorders distribution in the studied group

	Studied group N=229
Any known chronic neurological or Autoimmune disorders	
Yes	47 (20.5%)
No	182 (79.5%)
If Yes, Specify the Condition	
Hydrocephalus, congenital, obstructive, shunted, with IVH, with meningocele, multi-loculated …)	20 (8.7%)
Brain tumors (medulloblastoma, posterior fossa tumor, frontal brain tumor, retinoblastoma, ependymoma, general "brain tumor")	9 (3.9%)
Leukemia (Acute lymphoid / lymphoblastic)	4 (1.7%)
Global developmental delay (GDD)	4 (1.7%)
Myelomeningocele / Meningomyelocele (repair, shunt insertion)	3 (1.3%)
Arnold Chiari malformation (Type II, with meningocele/hydrocephalus)	4 (1.7%)
Seizure disorders (epilepsy, NMDA, neonatal, unspecified convulsion)	5 (2.2%)
Congenital heart disease (TGA, VSD, pulmonary stenosis, situs inversus)	1 (0.4%)
Other specific conditions:	
Autism	1 (0.4%)
IUGR	1 (0.4%)
PHACE syndrome, Dandy Walker syndrome	2 (0.8%)

Rasmussen encephalitis	1 (0.4%)
Panhypopituitarism, failure to thrive	1 (0.4%)
Autoimmune hepatitis (AIH?)	1 (0.4%)
Neurogenic bladder	2 (0.8%)
Spastic quadriplegia	1 (0.4%)

This table shows that, overall, 20.5% of patients had at least one known chronic neurological or autoimmune condition, while 79.5% had none. The most frequent conditions were hydrocephalus (congenital, obstructive, shunted, with IVH, meningocele, or multiloculated) affecting 8.7% of patients, followed by brain tumors (medulloblastoma, posterior fossa tumor, frontal brain tumor, retinoblastoma, ependymoma, or unspecified brain tumors) in 3.9%. Seizure disorders were reported in 2.2%, global developmental delay and Arnold Chiari malformation (Type II) in 1.7% each, and myelomeningocele/meningomyelocele in 1.3%. Less common conditions (<1% each) included congenital heart disease, autism, IUGR, PHACE syndrome, Dandy-Walker syndrome, Rasmussen encephalitis, panhypopituitarism with failure to thrive, autoimmune hepatitis, neurogenic bladder, and spastic quadriplegia.

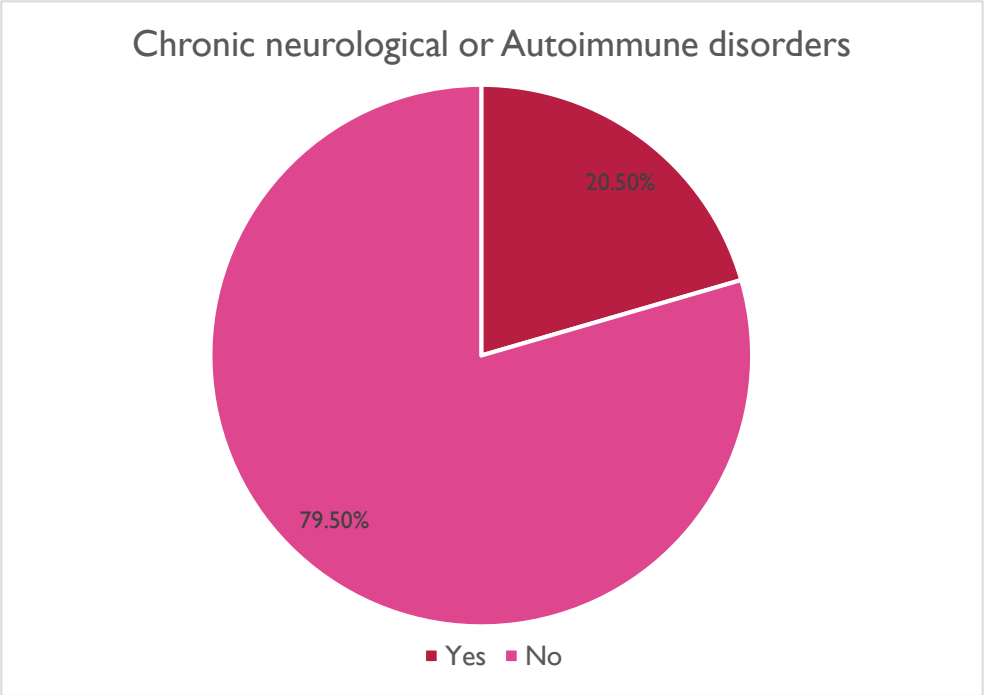

Figure (2): Chronic neurological or Autoimmune disorders distribution in the studied group

Table (3): Diagnosis distribution among patients in the studied group

Major Group	**Examples**	**Studied group N=229**
Central Nervous System (CNS) Infections	Meningitis (all types), Encephalitis, Meningoencephalitis, TB meningitis	43 (18.8%)
Brain and Hematologic Tumors	Brain tumors (malignant, ependymoma, retinoblastoma, rhabdomyosarcoma, lymphoma, leukemia)	14 (6.1%)
General Infections / Sepsis	Sepsis (unspecified/other/newborn), Septic shock	28 (12.2%)

Respiratory Tract Infections	Pneumonia, Bronchopneumonia, Bronchiolitis, Asthma, Respiratory distress syndrome (RDS) of newborn	13 (5.7%)
Non-infectious Neurological Disorders	Epilepsy (grand mal, petit mal, status, focal), Febrile convulsions, Guillain-Barré, Bell's palsy, Neonatal seizure, Polyneuropathy	21 (9.2%)
Congenital Malformations / Hydrocephalus	Congenital/communicating/obstructive hydrocephalus, Spina bifida with hydrocephalus, Holoprosencephaly, Pierre Robin sequence	18 (7.9%)
Renal and Urinary Tract Diseases	AKI, CKD, ESRD, Nephrotic syndrome, UTI (all types)	7 (3.1%)
Liver and Gastrointestinal Diseases	Liver transplant, Oesophageal varices, Gastritis, Constipation, Diarrhea	5 (2.2%)
Hematologic / Immunologic Disorders	Sickle cell anemia, Von Willebrand disease, HIV	6 (2.6%)
Other / Miscellaneous	Mechanical complication of shunt, medical observation, Pharmacotherapy, Firearm injury, Neonatal/preterm/twin/singleton	10 (4.4%)

This table shows that, Central Nervous System (CNS) infections were the most common, affecting 18.8% of patients, including meningitis (all types), encephalitis, meningoencephalitis, and TB meningitis. Non-infectious neurological disorders accounted for 9.2% and included epilepsy, febrile convulsions, Guillain-Barré syndrome, Bell's palsy, neonatal seizures, and polyneuropathy. Congenital malformations and hydrocephalus represented 7.9% of the cohort, encompassing congenital, communicating, and obstructive hydrocephalus, spina bifida with hydrocephalus, holoprosencephaly, and Pierre Robin sequence. Brain and hematologic tumors affected 6.1% of patients, including malignant brain tumors, ependymoma, retinoblastoma, rhabdomyosarcoma, lymphoma, and leukemia. General infections and sepsis were reported in 12.2% of patients, while respiratory tract infections, including pneumonia, bronchopneumonia, bronchiolitis, asthma, and respiratory distress syndrome of newborns, accounted for 5.7%. Renal and urinary tract diseases represented 3.1% and included AKI, CKD, ESRD, nephrotic syndrome, and UTI. Hematologic and immunologic disorders affected 2.6% of patients, including sickle cell anemia, Von Willebrand disease, and HIV. Liver and gastrointestinal diseases were observed in 2.2% of the cohort, including liver transplant, oesophageal varices, gastritis, constipation, and diarrhea. Other miscellaneous conditions, including mechanical complications of shunts, medical observation, pharmacotherapy sessions, firearm injuries, and neonatal/preterm/twin/singleton conditions, accounted for 4.4%.

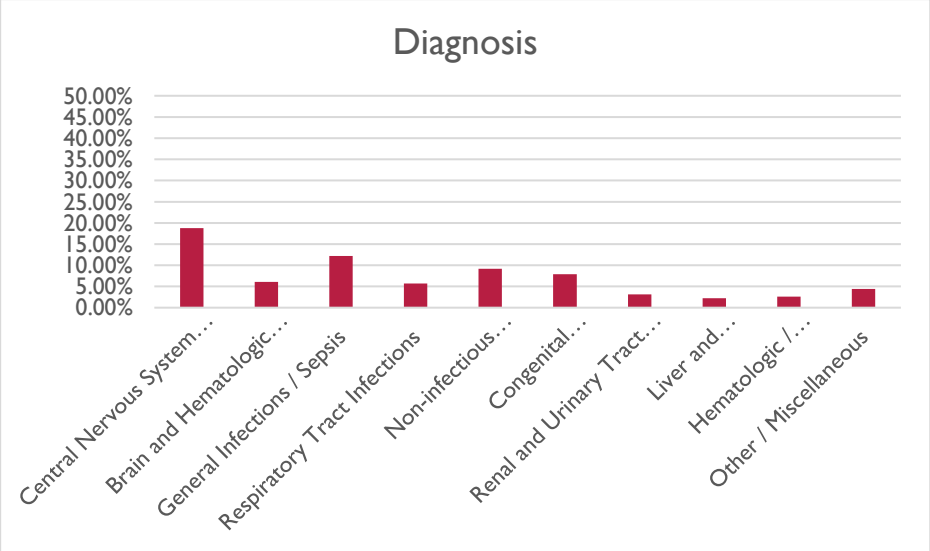

Figure (3): Diagnosis distribution among patients in the studied group

Table (4): Distribution of CSF analysis results in the studied group.

	Studied group N=229
CSF Leukocyte (WBC) Count Median (min-max)	20 (1 - 12400)
CSF RBCs (Cells / mm^3) Median (min-max)	56.5 (0 - 2566000)
CSF Protein Level (g/L) Median (min-max)	0.72 (0.05 - 68)
CSF Glucose Level (mmol/L) Median (min-max)	3.2 (0.1 - 8.5)

CSF: Cerebrospinal fluid; WBC: white blood cells; RBCS: red blood cells.

The study included 229 patients. The median CSF leukocyte (WBC) count was 20 cells/mm^3 (range: 1–12,400), and the median CSF red blood cell (RBC) count was 56.5 cells/mm^3 (range: 0–2,566,000). The median CSF protein level was 0.72 g/L (range: 0.05–68), while the median CSF glucose level was 3.2 mmol/L (range: 0.1–8.5), **as shown in Table (1)**.

Table (5): Distribution of imaging studies in the studied group.

	Studied group N=229
Types of Imaging Performed	
CT C-	40 (17.5%)
CT C-, CT C+	10 (4.4%)
CT C-, CT C+, Ultrasound	2 (0.87%)
MRI C-	1 (0.44%)
MRI C-, CT C-	6 (2.6%)
MRI C-, CT C-, CT C+, Ultrasound	1 (0.44%)
MRI C-, MRI C+	7 (3.1%)
MRI C-, MRI C+, CT C-	24 (10.5%)
MRI C-, MRI C+, CT C-, CT C+	4 (1.7%)
MRI C-, MRI C+, CT C-, CT C+, Ultrasound	2 (0.87%)
MRI C-, MRI C+, CT C-, Ultrasound	1 (0.44%)
MRI C-, MRI C+, Ultrasound	2 (0.87%)
MRI C-, Ultrasound	1 (0.44%)
MRI C+	4 (1.7%)
MRI C+, CT C-	19 (8.3%)
MRI C+, CT C-, CT C+	5 (2.2%)
MRI C+, CT C+	1 (0.44%)

MRI C+, Ultrasound	1 (0.44%)
MRI C-, MRI C+, CT C-	1 (0.44%)
Ultrasound	19 (8.3%)
None	78 (34.1%)
MRI Findings if done	
Normal	16 (7%)
Benign enlargement of subarachnoid spaces / incomplete brain maturation	1 (0.44%)
Not done	149 (65.1%)
Mildly prominent ventricles and extra-axial CSF spaces	1 (0.44%)
Meningeal enhancment	22 (9.6%)
Hyperintensity signals	38 (16.6%)
hypointense lesion with peripheral rim enhancement in the clivus	1 (0.44%)
Restricted diffusion	21 (9.2%)
Cortical involvement	8 (3.5%)
Subcortical involvement	27 (11.8%)
Cerebellum involvement	22 (9.6%)
CT brain Findings if done	
no evidence of acute brain insult	22 (9.6%)
Crowding of the foramen magnum, possible impending tonsillar herniation	1 (0.44%)
not done	113 (49.3%)
hyperdensities	33 (14.4%)
meningeal enhancement	7 (3.1%)
subcortical involvement	30 (13.1%)
odema	26 (11.3%)
calcifications	8 (3.5%)
Cortical involvement	9 (3.9%)
Subcortical involvement	30 (13.1%)
Cerebellar involvement	18 (7.9%)
no evidence of a cure brain insult	1 (0.44%)

The study included 229 patients. Imaging was performed in 151 cases (65.9%), while 78 patients (34.1%) had no imaging studies. MRI was performed in 80 patients (34.9%), and CT was performed in 120 patients (52.4%), with 19 patients (8.3%) undergoing ultrasound only. Among those who underwent MRI, common findings included hyper-intensity signals (16.6%), meningeal enhancement (9.6%), restricted diffusion (9.2%), and sub-cortical involvement (11.8%). On CT, hyper-intensity (14.4%), sub-cortical involvement (13.1%), cerebral edema (11.3%), and cerebellar involvement (7.9%) were frequently observed.

Table (6): Distribution of CSF findings in the studied group.

		Studied group N=229
Other Findings in CSF		
Color	colorless	88 (38.4%)
	slightly cloudy	4 (1.7%)
	pale red	1 (0.44%)
	pale yellow	25 (10.9%)
	yellowish	11 (4.8%)
	red	29 (12.7%)
Appearance	Slightly Cloudy	40 (17.5%)
	Clear	147 (64.2%)
	Cloudy	12 (5.2%)
	Turbid	13 (5.7%)
Volume Median (min-max)		0.5 (0.1 - 6)
Other CSF labs		
Not Done		18 (7.9%)
OCB, Bacterial and fungal culture-SF		1 (0.44%)
Anti NMDA antibodies		1 (0.44%)
Bacterial and fungal culture		204 (89.1%)
CSF - No organism		13 (5.7%)
CSF - Negative		14 (6.1%)
CSF - No growth		3 (1.3%)
CSF - Positive organism		2 (0.87%)
CSF Cytology (blast cells)		2 (0.87%)
Gram stain positive		3 (1.3%)
Molecular CMV		6 (2.6%)
PCR meningitis panel		49 (21.4%)
Routine viral culture		39 (17%)

The study included 229 patients who underwent cerebro spinal fluid (CSF) analysis. The CSF was colorless in 88 patients (38.4%), while 29 samples (12.7%) were red, and 25 (10.9%) appeared pale yellow. Other observed colors included yellowish (4.8%), slightly cloudy (1.7%), and pale red (0.44%). Regarding appearance, the CSF was clear in 147 cases (64.2%), slightly cloudy in 40 (17.5%), turbid in 13 (5.7%), and cloudy in 12 (5.2%). The median CSF volume collected was 0.5 mL (range: 0.1–6 mL).

Additional CSF investigations were performed in the majority of patients. Bacterial and fungal cultures were conducted in 204 patients (89.1%), while PCR meningitis panels were performed in 49 patients (21.4%) and routine viral cultures in 39 patients (17%). Positive findings included gram stain positive in 3 cases (1.3%), cytology showing blast cells in 2 (0.87%),

and detection of organisms in 2 samples (0.87%). Molecular testing for CMV was performed in 6 cases (2.6%). CSF testing was not done in 18 patients (7.9%), and isolated tests such as OCB, anti-NMDA antibodies, or limited cultures were performed in a small subset (each 0.44%).

Table (7): Distribution of Final Diagnosis Associated with CSF pleocytosis in the studied group.

	Studied group N=229
Infectious	
bacterial meningitis	20 (8.7%)
viral meningitis/encephalitis	38 (16.6%)
meningitis	3 (1.3%)
sepsis	38 (16.6%)
Tuberculosis of lung	1 (0.44%)
Brucellosis	1 (0.44%)
human immunodeficiency virus [HIV] disease	1 (0.44%)
Bacterial pneumonia	5 (2.2%)
Bronchopneumonia	2 (0.87%)
viral pneumonia	2 (0.87%)
acute bronchiolitis	6 (2.6%)
UTI	4 (1.7%)
Inflammatory	
Autoimmune or inflammatory condition (e.g., ADEM, MS)	3 (1.3%)
subarachnoid haemorrhage	1 (0.44%)
Intracranial abscess and granuloma	1 (0.44%)
viral cerebelitis	1 (0.44%)
Neoplastic	
neoplastic (malignant) condition	22 (9.6%)
atypical choroid plexus papilloma	1 (0.44%)
Vascular	
Von willebrand's disease	1 (0.44%)
Oesophageal varices without bleeding	1 (0.44%)
Sickle-cell anaemia without crisis	3 (1.3%)
Neurodegenerative	
hydrocephalus	22 (9.6%)
communicating	5 (2.2%)
Arnold chiarie syndrome	1 (0.44%)
Holoprosencephaly	1 (0.44%)

Lumbar spina bifida	1 (0.44%)
Thoracic spina bifida with	1 (0.44%)
Pierre Robin sequence	1 (0.44%)
epileptic syndromes	5 (2.2%)
Status epilepticus	4 (1.7%)
Febrile convulsion	7 (3.1%)
Grand mal seizures	6 (2.6%)
bells palsy	1 (0.44%)
polyneuropathies	1 (0.44%)
ventricular intracranial	1 (0.44%)
Congenital	4 (1.7%)
Obstructive	2 (0.87%)
Miscellaneous	
Acute kidney failure	1 (0.44%)
Chronic kidney disease	1 (0.44%)
Nephrotic syndrome	1 (0.44%)
respiratory distress	1 (0.44%)
Apnea	1 (0.44%)
Liver transplant status	1 (0.44%)
Choanal Atresia	1 (0.44%)
Gastritis	1 (0.44%)
jaundice	1 (0.44%)
fever	1 (0.44%)
Constipation	1 (0.44%)
Firearm shooting	1 (0.44%)
tetanus	1 (0.44%)
Hypoglycaemia	1 (0.44%)

The study analysis included 229 patients who underwent cerebrospinal fluid (CSF) analysis for various clinical indications. Infectious causes were the most common, seen in 121 patients (52.8%), with viral meningitis/encephalitis and sepsis each reported in 38 cases (16.6%), and bacterial meningitis in 20 (8.7%). Other infections included acute bronchiolitis (2.6%), bacterial pneumonia (2.2%), and a few cases of tuberculosis, brucellosis, HIV, and other infections.

Neoplastic conditions were found in 23 patients (10%), mostly malignant (9.6%), with one case of atypical choroid plexus papilloma. Neurodegenerative and congenital anomalies were noted in 22 patients (9.6%), including hydrocephalus (2.2% communicating), Arnold Chiari syndrome, and holoprosencephaly. Epileptic and seizure-related disorders were also seen in 22 patients (9.6%), including febrile convulsions (3.1%), grand mal seizures (2.6%), and status epilepticus (1.7%).

Inflammatory or autoimmune disorders were observed in 6 cases (2.6%), while vascular and hematologic conditions, such as sickle cell anemia and von Willebrand's disease, were found in 5 patients (2.2%). Miscellaneous diagnoses, including kidney failure, respiratory distress, tetanus, hypoglycemia, and firearm injury, accounted for 13 cases (5.7%).

3. DISCUSSION

The present study analyzed the etiological spectrum of cerebrospinal fluid (CSF) pleocytosis in a pediatric cohort, highlighting both infectious and non-infectious causes. Infectious etiologies predominated, accounting for more than half of cases, while neoplastic, neurodegenerative, autoimmune, and miscellaneous conditions comprised the remainder. This aligns with prior reports demonstrating that infections remain the most common contributors to CSF pleocytosis in children, though non-infectious causes are increasingly recognized (Dyckhoff-Shen et al., 2024).

A key finding in our cohort was that **viral meningitis/encephalitis and sepsis each accounted for 16.6% of cases**, confirming the central role of viral infections in pediatric CSF abnormalities. Al-Qahtani et al. (2022) similarly reported that viral meningitis constitutes the most frequent etiology of pediatric pleocytosis, usually with a benign course but occasionally with significant diagnostic challenges. Early viral disease may mimic bacterial meningitis, complicating management and underscoring the value of molecular diagnostics.

Bacterial meningitis was diagnosed in 8.7% of our patients, consistent with global reports where vaccination has reduced its incidence but not eliminated the burden (Xu et al., 2019). The high morbidity associated with bacterial meningitis emphasizes the importance of rapid recognition and treatment. Our findings support the view that neutrophilic pleocytosis with elevated protein and reduced glucose should continue to prompt strong suspicion for bacterial infection (Hrishi & Sethuraman, 2019).

Interestingly, **sepsis without overt meningitis** was also a major contributor to pleocytosis in this cohort. This supports the concept that systemic infections can alter CSF parameters, particularly in neonates and infants with immature blood–brain barriers (Moon et al., 2023). Such findings reinforce the need to interpret CSF pleocytosis in conjunction with systemic clinical features, rather than attributing it solely to direct CNS infection.

Neoplastic causes represented 10% of cases, primarily malignant brain and hematologic tumors. This mirrors the growing recognition that malignant infiltration of CSF can present with pleocytosis in children (Dyckhoff-Shen et al., 2024). While rare compared with infections, such cases have profound prognostic implications. CSF cytology was positive in only a minority of patients, reflecting its limited sensitivity and the need for adjunctive molecular and imaging modalities (Prakapenia et al., 2018).

Autoimmune and inflammatory disorders accounted for a smaller but significant subset (2.6%), including cases of acute disseminated encephalomyelitis and multiple sclerosis. Recent studies have highlighted that antibody-mediated CNS diseases are increasingly diagnosed in children and often mimic infectious pleocytosis (Kang et al., 2023). The detection of anti-NMDA receptor antibodies in one patient further illustrates the importance of considering autoimmune etiologies, particularly in cases where standard microbiological tests are negative.

Neurodegenerative and congenital conditions, including hydrocephalus, Arnold–Chiari malformation, and holoprosencephaly, comprised nearly 10% of the diagnoses. These conditions may cause pleocytosis either through shunt complications, secondary infection, or inflammatory responses to structural abnormalities (Hawkes et al., 2023). The relatively high frequency in our cohort emphasizes the importance of a broad differential when interpreting pleocytosis in children with known structural CNS abnormalities.

Seizure-related disorders were also linked with pleocytosis, with febrile convulsions, status epilepticus, and epilepsy observed in nearly 10% of cases. Transient CSF leukocytosis following seizures has been described, although its mechanisms remain unclear (Hrishi & Sethuraman, 2019). Clinicians should be cautious not to misclassify seizure-associated pleocytosis as infection, particularly in afebrile children without systemic signs.

Imaging findings in our study showed that 65.9% of children underwent CT or MRI, with abnormal results including meningeal enhancement, restricted diffusion, and subcortical involvement. These radiological features correlated well with infectious and inflammatory etiologies. Prior work has demonstrated that imaging not only aids diagnosis but also helps in prognostication, particularly for bacterial and viral encephalitides (Zellweger et al., 2020).

The median CSF WBC count in our cohort was 20 cells/mm³, though values varied widely up to 12,400. Elevated protein and reduced glucose were observed in bacterial infections, while viral cases showed more modest alterations. These findings align with established diagnostic patterns and reinforce the continued value of routine biochemical analysis alongside molecular tests (Hrishi & Sethuraman, 2019).

Our microbiological yield was limited, with organisms identified in fewer than 1% of cultures, and PCR panels performed in only 21.4% of patients. This reflects diagnostic challenges frequently reported in pediatric cohorts (Dyckhoff-Shen et al., 2024). Molecular diagnostics are more sensitive but not universally available. The reliance on negative cultures further highlights the difficulty in distinguishing etiologies solely from conventional CSF studies.

Geographical and temporal factors also influence the distribution of etiologies. Vaccination programs have reduced bacterial meningitis incidence in many regions, shifting the balance toward viral and non-infectious causes (Kang et al., 2023). Our findings support this global trend, though bacterial meningitis remains a critical diagnosis to exclude due to its

severity.

The demographic analysis revealed a male predominance (57.2%) and fever as the most common presenting symptom (68.9%). These findings are consistent with prior pediatric pleocytosis studies, where fever and seizures are leading presenting features (Moon et al., 2023). Such symptomatology should continue to serve as clinical red flags prompting CSF evaluation.

Importantly, nearly 20% of patients had pre-existing neurological or autoimmune disorders, including hydrocephalus, tumors, and epilepsy. This comorbidity burden may predispose children to pleocytosis through infection susceptibility, shunt complications, or underlying inflammation (Hawkes et al., 2023). Clinical context remains vital when interpreting abnormal CSF findings in such populations.

Overall, our study underscores the heterogeneous nature of CSF pleocytosis in children. Infectious causes remain dominant, but a significant proportion of cases arise from non-infectious conditions, including neoplasms, autoimmune disorders, and congenital anomalies. Integration of clinical, biochemical, microbiological, and radiological data is therefore essential for accurate diagnosis, guiding therapy, and predicting outcomes (Al-Qahtani et al., 2022).

4. CONCLUSION

This study demonstrated that CSF pleocytosis in pediatric patients results from a wide spectrum of etiologies, with infectious causes most frequent but non-infectious conditions also contributing significantly. Accurate diagnosis requires a multimodal approach combining clinical features, laboratory data, and imaging findings. Recognizing the diverse presentations of pleocytosis is essential to avoid misdiagnosis, guide timely treatment, and improve outcomes in the pediatric population

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