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Short Term Neurocognitive and Behavioral Outcome of Acute CNS Infection in Children in a Tertiary Neurology Hospital

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Abstract

Background:

Acute central nervous system (CNS) infections remain a major cause of childhood morbidity and mortality worldwide. Although neurocognitive and behavioral sequelae are well recognized, data from Bangladesh are limited.

Objective:

This study evaluated short-term neurocognitive and behavioral outcomes among children hospitalized with acute CNS infections.

Methods:

A prospective cohort study was conducted in the Paediatric Neurology Department at the National Institute of Neuroscience and Hospital from July 2021 to June 2022 on 120 children with acute CNS infections. Demographic data, clinical features, neurological status, and neurocognitive and behavioral performance were assessed at discharge, 1–2 weeks, and 3 months post-discharge using structured questionnaires. Data were analyzed with SPSS 24.

Results:

The mean age was 6.3±4.3 years, with male predominance (71.7%); most children were from rural areas. Nearly half presented within one week of symptom onset, commonly with seizures (60.8%), fever (55%), Kering's sign (50.8%), and neck rigidity (41.6%). Encephalitis (50%) and meningitis (42.5%) were the predominant diagnoses, with Streptococcus pneumoniae and Neisseria meningitidis frequently identified. More than half had stage-II disease on admission. Moderate clinical outcomes were observed in 56.6% at discharge. Motor deficits were common in encephalitis, while seizures predominated in meningitis. Disease severity was strongly associated with final clinical outcome ($p<0.001$), and hospital stay varied significantly by infection type ($p<0.001$). Neurocognitive and behavioral scores were mostly impaired at baseline but improved across follow-ups. Disease severity did not significantly influence cognitive trajectories. Behavioral outcomes at discharge differed by disease stage ($p=0.020$) and were associated with clinical outcomes. Logistic regression showed no independent effect of meningitis, encephalitis, or hospital stay on cognitive or behavioral outcomes.

Conclusion:

Encephalitis and meningitis were the leading CNS infections, with most children experiencing moderate clinical improvement by discharge. Although disease severity predicted clinical outcomes, neither infection type nor hospital stay reliably predicted neurocognitive or behavioral recovery. Younger children showed poorer baseline functioning, but substantial improvement was observed over time. Clinical outcome at discharge emerged as the strongest correlation of short-term cognitive and behavioral progress.

Keywords: Acute CNS infection, Short term outcome, Neurocognitive, Behavioral

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Introduction:

Acute central nervous system (CNS) infections are life-threatening conditions in children and continue to cause substantial global morbidity and mortality.[1] Their epidemiology varies widely due to geographic diversity of pathogens and challenges in achieving definitive microbiological diagnosis, especially in resource-limited settings.[2,3] The incidence of acute encephalitis syndrome in children is estimated at 10.5–13.8 per 100,000, with case fatality rates approaching 30% and neurological sequelae in one-third of survivors.[2,4,5] Major etiologies include N. meningitidis, H. influenzae type B, S. pneumoniae, Japanese Encephalitis Virus- which causes ~68,000 cases and 13,600–20,400 deaths annually[6] and other bacterial, parasitic, and fungal pathogens.[2,7-9] Clinical presentations in young children are often nonspecific, requiring high diagnostic vigilance.[10] Survivors frequently experience neurological, cognitive, and behavioral complications such as reduced IQ, learning and behavioral difficulties, and internalizing or externalizing disorders.[11-13] Short-term neuropsychological outcomes are understudied, although evidence shows early developmental delays after Human Parechovirus infection[14] and reduced quality of life following encephalitis or aseptic meningitis.[15] Neuroinflammatory mechanisms, including cytokine-mediated injury, contribute to long-term neurobehavioral and psychiatric risks.[16,17] Given the large burden in low- and middle-income countries and significant developmental and socioeconomic consequences,[9,18] short-term cognitive and behavioral sequelae following childhood CNS infections warrant systematic evaluation. This study therefore aimed to assess early neurocognitive and behavioral outcomes in children with acute CNS infections admitted to a tertiary neurology hospital.

Methods:

This longitudinal observational study was conducted in the Paediatric Neurology Department of the National Institute of Neuroscience and Hospital, Dhaka, over 12 months (July 2021–June 2022). Children aged 1 month–14 years presenting with clinical features of acute CNS infection (e.g., fever, seizures, altered sensorium, focal deficits) or diagnosed as meningitis, encephalitis, brain abscess, or subdural empyema were screened; 166 were evaluated and 120 were enrolled through purposive sampling after written informed consent. Children with CNS tuberculosis, autoimmune encephalitis, neuro-metabolic or psychiatric disorders, CNS tumors, or systemic disease–related CNS manifestations were excluded. Clinical, neurological, laboratory (including CSF), EEG, and neuroimaging findings were documented using structured forms. Disease severity was graded on admission using the BMRC staging system,[19] and discharge outcomes were categorized as good, moderate, or poor.[20] Neurocognitive and behavioral assessments were performed at discharge, 1–2 weeks, and 3 months using age-appropriate standardized tools (WISC-IV, WPPSI-III, Bayley-III, SDQ)[21-24] by a trained child psychologist. All data were quality-checked, coded, and analyzed using SPSS version 24.

Results:

The mean age of the participants was 6.29±4.32 years with a range from 0.17 years to 14 years. Around half of the participants belonged to 1 year to <6 years age group, followed by 6 years to 10 years age (26.3%), 11 years to 14 years (23.7%), and <1 year (6.8%) group (Figure-1).

Most of the participants had a duration of symptoms <1 week (48.3%) followed by 1-<2 weeks (27.7%), 2 to <3 weeks (14.5%) and ≥3 weeks (10.5%).

Among the participants studied majority were in stage II (57.5%) followed by stage III & I (Figure-3). Encephalitis (50%) and Meningitis (42.5%) were the most common diagnoses, followed by brain abscess (4.1%) and subdural empyema (3.3%) (Table-I)

Among the participants, 56.6% had a moderate outcome, followed by good (30.8%) and poor outcome (12.5%) (Figure-4).

Children with good outcomes were mostly in stage I (51.4%), while those with poor outcomes were mainly in stage III (80.0%). The severity of the disease was significantly linked to the final clinical outcome at discharge (p<0.001) (Table-II).

Table-I: Types of acute CNS infection among the respondents (N=120)

Diagnosis	no. (%)
Encephalitis	60 (50)
Meningitis	51 (42.5)
Brain abscess	5 (4.1)
Subdural empyema	4 (3.3)

Table-II: Relationship between severity of disease and clinical outcome at discharge (N=120)

Severity	Good (n=37) no. (%)	Moderate (n=68) no. (%)	Poor outcome (n=15) no. (%)	p-value
Stage I	19(51.4)	5(7.4)	0(0)	<0.001
Stage II	16(43.2)	49(72.1)	3(23.1)	
Stage III	2(5.4)	14(20.6)	12(80.0)	

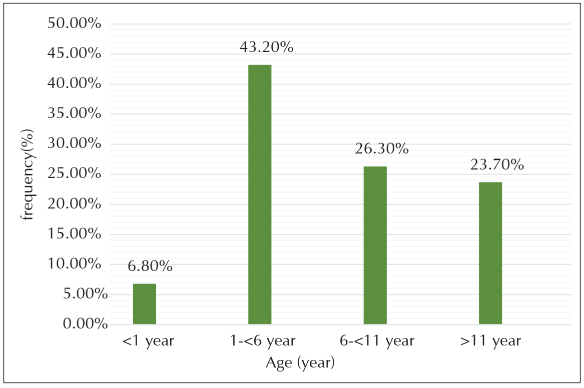

Figure-1: Age distribution of the study participants (N=120)

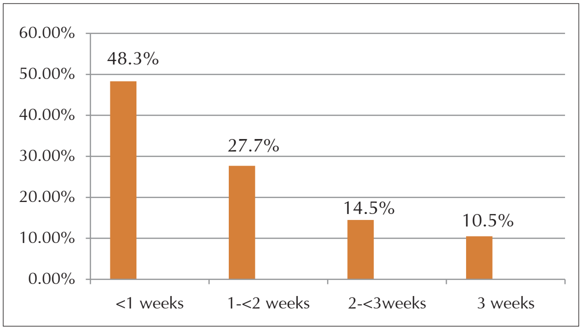

Figure-2: Duration of symptoms before admission among the studied participant (N=120)

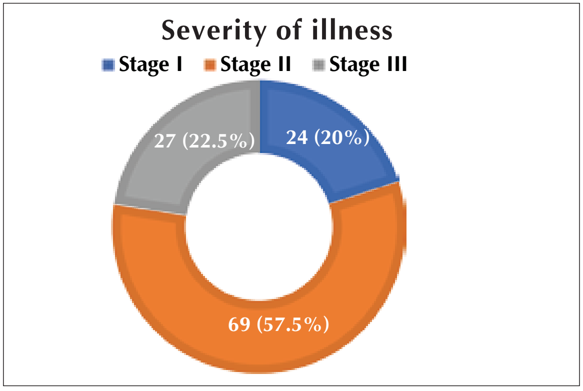

Figure-3: Severity of illness on admission of the studied population according to BMRC staging of severity of illness (N=120)

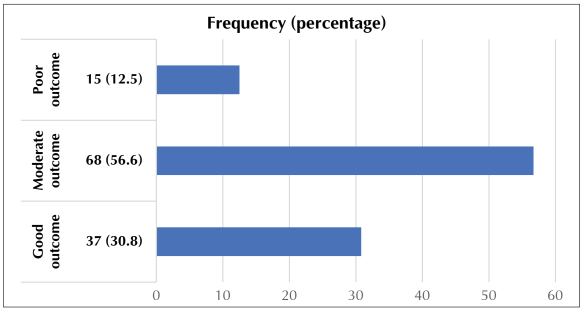

Figure-4: Clinical outcome at discharge among the studied population (N=120)

Table-III: Level of cognitive function and behavior function among the studied population aged 1 to 42 months (n=49)

Variable	Extremely low no. (%)	Border-line no. (%)	Low average no. (%)	Average no. (%)	High average no. (%)	Superior no. (%)	Very superior no. (%)	Lost of follow up / death no. (%)
Cognitive function								
Baseline	47(95.9)	2(4.1)	-	-	-	-	-	2(4) Death
1st follow-up	44(89.8)	4(8.1)	-	-	-	-	-	1(2)
2nd follow-up	35(71.45)	9(18.3)	1(2)	-	-	-	-	4(8.1)
Behavior function								
Baseline	49(100)	-	-	-	-	-	-	2(4) Death
1st follow-up	47(95.9)	1(2)	-	-	-	-	-	1(2)
2nd follow-up	43(87.7)	2(4.1)	-	-	-	-	-	4(8.1)

The Bayley III Scales of Infant and Toddler Development were used for assessment. Initially, 95.9% of patients had extremely low cognitive scores, improving to 89.8% and 71.45% in follow-ups. All patients had low social behavior scores, which also improved. Two patients died before assessment, and four were lost to follow-up later (Table-III).

Scales used for assessment include the Wechsler Preschool and Primary Scale of Intelligence, Third Edition, and the Wechsler Intelligence Scale for Children, Fourth Edition. At discharge, 95.6% of children had extremely low cognitive function. Follow-ups showed slight improvement, with 10.1% showing borderline function and 1.4% average function (Table-IV).

After adjusting for age, sex, and disease severity, neither meningitis, encephalitis, nor hospital stay showed an independent association with cognitive or behavioral outcomes at any time point (all p>0.05), except a mild association between shorter hospital stay and better behavioral outcome at 1st follow-up (p=0.008) (Table-V).

Table-IV: Cognitive function of the study participants ≥42 months of age (n=69)

Cognitive function	Extremely low no. (%)	Border-line no. (%)	Low average no. (%)	Average no. (%)	Loss to follow up no. (%)
Baseline	66(95.6)	3(4.3)	-		-
1st follow-up	61(88.4)	7(10.1)	-		1(1.4)
2nd follow-up	59(85.5)	7(10.1)	-	1(1.4)	2(2.8)

Table-V: Possible predictors of cognitive and behavioral outcome among the studied population in relation to types of CNS infection and hospital stay (n=118) (Adjusted for age, sex, and disease severity; n=118)

Predictor	At Discharge Adjusted OR (95% CI)	p-value	1st Follow-up Adjusted OR (95% CI)	p-value	2nd Follow-up Adjusted OR (95% CI)	p-value
A. Cognitive Function						
Meningitis	0.081 (0.594–2.009)	0.998	0.415 (0.067–2.574)	0.345	0.611 (0.136–2.740)	0.520
Encephalitis	2.05 (0.228–18.51)	0.552	1.315 (0.217–7.970)	0.766	1.03 (0.284–3.782)	0.956
Hospital stay	1.09 (0.594–1.723)	0.776	0.797 (0.446–1.420)	0.445	1.05 (0.753–1.460)	0.767
B. Behavioral Function						
Meningitis	0.793 (0.193–3.25)	0.747	0.560 (0.122–0.617)	0.339	1.00 (0.231–4.38)	0.992
Encephalitis	0.523 (0.159–1.723)	0.287	0.659 (0.345–1.360)	0.195	1.46 (0.439–4.900)	0.534
Hospital stays	0.891 (0.647–1.227)	0.480	0.592 (0.402–0.872)	0.008	0.806 (0.567–1.146)	0.230

Discussion:

Central nervous system (CNS) infections in children continue to pose a major health burden, contributing significantly to morbidity and mortality. These infections often lead to severe neurological sequelae, including cognitive and behavioral impairments. In this prospective cohort study, we aimed to assess the short-term neurocognitive and behavioral outcomes of children with acute CNS infections. A total of 120 children from the Paediatric Neurology Department of the National Institute of Neuroscience and Hospital, Dhaka, were enrolled in this study. Two patients died, and six were lost to follow-up.

Baseline characteristics of the study participants revealed a mean age of 6.29±4.32 years. most participants were in the 1 to <6 years age group, consistent with previous studies by Shilo S et al.[25] The majority of children in this study presented with symptoms for less than one week before admission, which mirrors findings from Vasavada HJ et al.[26] Seizures, fever, and altered sensorium were the most common presenting symptoms, aligning with prior research by Vasavada HJ et al and Page AL et al.[26, 27]

Regarding the severity of illness, most patients were admitted with stage II disease severity, followed by stage III and stage I. This distribution of disease severity reflects the challenging nature of CNS infections in this cohort, with a substantial number of patients presenting in more severe stages. Similar findings have been reported in previous studies by Aida M. Salonga et al[19] The most common diagnoses in this cohort were encephalitis (50%) and meningitis (42.5%), consistent with studies by Bozzola et al[13] and Sumpter et al[11] who also identified these infections as predominant causes of childhood CNS infections.

Despite efforts to identify pathogens, the organisms responsible for CNS infections were not always clearly identified, due to the limited sensitivity of CSF cultures and PCR tests.

In terms of clinical outcomes, the majority of children experienced moderate outcomes at discharge, with disease severity playing a significant role in predicting outcomes. Children with stage I disease were more likely to have a good outcome, while those with stage III disease had a higher likelihood of poor outcomes, which is consistent with findings from Michaeli et al.[20] These results underscore the critical role of early intervention in improving clinical outcomes.

Neurocognitive and behavioral recovery was assessed using standardized tools such as the Bayley-III, WPPSI, and WISC IV. At baseline, most children exhibited extremely low cognitive and behavioral scores. There was notable improvement in cognitive function over time, with 71.45% of children still having extremely low scores at the second follow-up, compared to 95.9% at discharge. In contrast, 30.4% of children showed normal behavioral function at the second follow-up, a significant improvement from baseline (26% normal behavioral function in older children ≥42 months). However, a substantial portion of children still exhibited cognitive and behavioral deficits, suggesting that full recovery was not achieved within the 3-month follow-up period.

The severity of illness significantly affects children's behavior, with those having more severe disease at discharge more likely to show poor behavioral function. Even after cognitive improvements, severe illness impacts ongoing behavioral recovery, leading many children to have low behavioral function at follow-up. Logistic regression shows that encephalitis patients are 2.05 times more likely to have very poor cognitive and behavioral outcomes than meningitis patients, indicating greater neurocognitive impairments. However, factors such as infection type, hospital stay, motor deficits, cranial nerve issues, seizure disorders, and speech problems do not independently predict outcomes.

Conclusion:

This study found that encephalitis and meningitis were the most prevalent acute CNS infections, with the majority of survivors experiencing moderate clinical outcomes at discharge. Disease severity was significantly associated with clinical outcomes, but the type of CNS infection did not influence recovery. At discharge, most children exhibited extremely low cognitive function, while younger children had significantly impaired behavioral outcomes. Cognitive function at the first follow-up and behavioral outcomes at discharge were strongly linked to clinical outcomes. However, factors such as CNS infection type, disease severity, hospital stay, and neurological impairments were not significant predictors of cognitive and behavioral recovery in the short term. Future research should include larger cohort studies with long-term follow-up to better assess cognitive and behavioral outcomes in children with acute CNS infections. Multi-center studies across the country are needed to provide a comprehensive understanding of disease patterns and outcomes.

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