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Clinical Manifestations, EEG Findings and CSF/Serum Antibody Load In Children With Subacute Sclerosing Panencephalitis In A Tertiary Care Hospital: An Analytical Cross-Sectional Study

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Abstract

Background: Subacute sclerosing panencephalitis (SSPE) is a devastating late complication of measles infection caused by persistent mutated measles virus in the central nervous system. Its incidence is low in countries with high measles vaccination coverage but remains higher in low- and middle-income settings. Children infected before the age of two years are at greatest risk. Although SSPE has become rare in high-income countries, recent measles outbreaks and vaccination gaps threaten its resurgence. Reliable epidemiological data from Pakistan are limited.

Objective: To assess clinical presentations, electroencephalography (EEG) patterns and cerebrospinal fluid (CSF)/serum measles antibody load among children with SSPE presenting to a tertiary paediatric neurology unit and to identify factors associated with severe disease stages.

Methods: A hospital-based analytical cross-sectional study was conducted at the National Institute of Child Health, Karachi. Thirty-eight children aged 1 month–18 years who met the modified Dyken's criteria for SSPE were enrolled over six months. Data on demographics, measles exposure, vaccination status, clinical manifestations, EEG pattern, neuroimaging findings and CSF/serum measles antibody titres were recorded. Descriptive statistics were calculated. Associations between severe stage (Stage III) and age at SSPE onset, antibody titre and vaccination status were evaluated using logistic regression. Ethical approval and informed consent were obtained.

Results: The mean age at measles infection was 6.45 ± 3.28 years and the mean age at SSPE onset was 12.5 ± 3.48 years, giving a latency of 6.05 ± 0.77 years. Two-thirds of patients were male, and 53 % were unvaccinated. Seizures (82 %), dementia (76 %) and behavioural disturbances (66 %) were the most frequent

presentations. Typical periodic high-amplitude slow-wave EEG patterns were observed in 84 % and white-matter hyperintensities or cerebral atrophy on magnetic resonance imaging in 68 %. Logistic regression showed no significant associations between severe stage and age at onset (odds ratio 0.81, 95 % CI 0.65–1.03), CSF antibody titre (OR 1.03, 95 % CI 0.99–1.07) or vaccination status.
Conclusion: In this cohort, SSPE occurred predominantly in unvaccinated or partially vaccinated children, with long latency after measles infection and high mortality. Early measles infection and absence of vaccination, recognized risk factors in other settings, were common. Strengthening measles immunization and high clinical suspicion in children presenting with cognitive decline, myoclonus and periodic EEG discharges are essential to improve outcomes. Further prospective studies with larger cohorts are warranted.

Introduction

Despite the availability of a safe, effective vaccine, measles is still one of the most contagious viral diseases in the world. Recurrent epidemics have led to a resurgence of interest in late neurological complications of measles, such as subacute sclerosing panencephalitis (SSPE), a rare but universally fatal progressive neurodegenerative disease caused by persistent infection of the CNS with mutated wild-type measles virus. SSPE is a result of viral persistence due to defective clearance from neuronal tissue and progressive neuro-inflammatory damage. The latency period between the primary measles infection and onset of clinical disease of SSPE is usually 7-10 years, but shorter intervals have been observed in children infected in infancy, and in fulminant variants of the disease. SSPE's epidemiology continues to be strongly associated with the epidemiology of measles. The World Health Organization estimates the overall risk of SSPE to be approximately 4–11 cases per 100,000 measles infections, increasing to approximately 18 cases per 100,000 among children infected before five years of age and reaching nearly 28 cases per 100,000 in certain low- and middle-income countries.[4,9] Several regions with historically inadequate vaccination coverage, including South Asia, continue to report a disproportionate burden of disease.[10] Recent evidence from Georgia demonstrated 16 confirmed SSPE cases following major measles outbreaks, corresponding to an estimated risk ranging from 1 in 1,396 to 1 in 13,960 measles infections.[11] Similarly, six fulminant pediatric cases were reported in the United Kingdom between 2022 and 2024, highlighting the re-emergence of this devastating complication even in developed healthcare systems.[12] A nationwide survey from Japan identified 37 surviving patients with SSPE, of whom more than 80% had acquired measles before the age of two years and had a median incubation period of approximately nine years.[13] However, some atypical clinical presentations (psychiatric, visual disturbance, focal neurologic symptom, or atypical EEG) have been reported and are also diagnosed later, which leads to worse outcomes.[17,18] Further, diagnosis relies heavily on the presence of typical clinical features, electroencephalographic (EEG) findings, and serologic evidence of intrathecal production of anti-measles (Rubella, Mumps, and German measles) IgG antibodies (in addition to neuroimaging characteristics), which can be delayed in the absence of these features.

Contemporary information on the clinical spectrum, EEG features, neuroimaging findings and immunologic profile of affected children is limited, and most available literature is isolated case reports or small retrospective series, which provide limited understanding about patterns of illness and prognosis in the local population in Pakistan, where the burden of measles and SSPE remains significant. Moreover, there is a lack of studies in Pakistani cohorts to look into the correlation between age at infection, vaccination status, antibody levels, and disease severity. Hence, the present study was planned to assess the demographic data, clinical features, EEG profile, neuroimaging abnormalities and CSF/serum measles antibody profile of children with

SSPE at the National Institute of Child Health (NICH), Karachi. We suspected that increased antibody titres, lack of vaccination and younger age of infection with measles would be correlated with more advanced disease at the time of presentation. This study will help to provide evidence of some clinical and laboratory markers that can help diagnose the disease earlier, develop better surveillance strategies, and advocate for greater efforts in measles vaccination programs in Pakistan.

Methods

Design and setting studies.

An analytical cross-sectional study was conducted in the pediatric neurology department, National Institute of Child Health (NICH), a tertiary care public sector hospital of Karachi that caters to patients from all over Pakistan. The recruitment period was six months (from January to June 2024) after obtaining approval from the Institutional Ethical Review Board (IERB approval no.Ierb approval number 40/2023 and College of Physicians and Surgeons Pakistan (CPSP). Written informed consent was obtained from caregivers.

Sample Size

During the study period, a total of 38 children with a diagnosis of subacute sclerosing panencephalitis (SSPE) who met the study eligibility criteria were included. A non-probability purposive sampling method was used to recruit all the consecutive patients who came to the Pediatric Neurology Department of the National Institute of Child Health (NICH) in Karachi.

Participants

Children were eligible to be included if they (1 month to 18 years) met the modified Dyken's criteria for SSPE and had progressive cognitive decline, behavioural changes or seizures. Dyken's criteria involve the presence of two major and one minor criteria: (1) typical or atypical clinical features; (2) elevated CSF/serum anti-measles antibody (antibody titre in CSF $\geq$1:4 and in serum $\geq$1:256); and (3) at least one minor criterion (periodic EEG complexes, raised CSF globulin >20 % of total protein, typical histopathology or molecular confirmation). Children who had other known neurodegenerative disorders or whose parents/guardians declined were not included.

Data collection procedure:

Demographic data (age, sex, residence, vaccination status), history of measles infection, age at measles, age at onset and latency of SSPE were recorded with the help of a structured pro-forma after consent. Clinical symptoms were recorded such as behavioural disturbance, seizures, dementia, extrapyramidal symptoms, loss of school function, mutism, abnormal movements, consciousness and vision abnormalities. EEG tests were conducted at NICH's neurophysiology lab and classified as either periodic discharges or atypical patterns. Magnetic resonance imaging (MRI) of the brain was interpreted as normal, cerebral atrophy or white-matter hyperintensities. The level of antibody to measles was determined in CSF and serum by enzyme-linked immunosorbent assay (ELISA) in a reference laboratory; results given as antibody titre (1:16, 1:32). Oligoclonal bands were present. The disease stage was determined based on the staging of the disease by Jabbour: Stage I (Subtle Cognitive decline and behavioural change), Stage II (Myoclonus and seizures), Stage III (The vegetative state and rigidity) and Stage IV (Akinetic mute state).

Statistical analysis

The data were loaded into SPSS (version 25) for analysis, and Python (pandas, SciPy and statsmodels) was used to analyze the data. Data are summarised as means and standard deviations or medians (interquartile range) if appropriate and frequencies and

percentages if categorical data. Multivariable logistic regression was used to assess relationships between age at onset of SSPE, CSF antibody titre and vaccination status with severe disease (Stage III). Odds Ratios (ORs) with 95 % Confidence Intervals (CIs) and p-values are presented. Independent-samples t-test was used to compare the mean age of severe and non-severe groups, and chi-square test was used to assess associations between vaccination status and disease severity. A p-value <0.05 was considered statistically significant.

Ethical considerations

The study was approved by the Research Evaluation Unit, College of Physicians and Surgeons Pakistan, as well as the NICH Institutional Ethical Review Board. Informed written consent was sought from the caregivers. Confidentiality of participants was preserved using anonymized identifiers.

Results

Baseline characteristics

Thirty-eight patients were included. The mean age at measles infection was 6.45 ± 3.28 years and the mean age at SSPE onset was 12.50 ± 3.48 years, yielding a mean latency of 6.05 ± 0.77 years. Males comprised 60.5 % (n = 23). Twenty patients (52.6 %) were unvaccinated, 11 (28.9 %) partially vaccinated and seven (18.4 %) fully vaccinated (Figure 1). Stages at presentation were Stage I (18.4 %), Stage II (42.1 %), Stage III (28.9 %) and Stage IV (10.5 %). Mean CSF IgG titre was 29.1 ± 25.2 units (range 4–128); mean serum IgG titre was 227.4 ± 222.7 units (32–1 024). Oligoclonal bands were present in 63 % of cases.

Table 1 – Demographic and clinical characteristics of SSPE patients

Variable	Mean ± SD or n (%)
Age at measles (years)	6.45 ± 3.28
Age at SSPE onset (years)	12.50 ± 3.48
Latency period (years)	6.05 ± 0.77
Male sex	23 (60.5 %)
Vaccination status	Unvaccinated 20 (52.6 %); Partially vaccinated 11 (28.9 %); Fully vaccinated 7 (18.4 %)
Stage of disease	Stage I 7 (18.4 %), Stage II 16 (42.1 %), Stage III 11 (28.9 %), Stage IV 4 (10.5 %)
Mean CSF measles antibody titre	29.1 ± 25.2 units
Mean serum measles antibody titre	227.4 ± 222.7 units

Oligoclonal bands present 24 (63.2 %)

Clinical manifestations

Seizures were the most common presentation (31 patients, 81.6 %), followed by dementia or cognitive decline (29 patients, 76.3 %) and behavioural disturbances (25 patients, 65.8 %). Decline in school performance, abnormal movements and extrapyramidal signs were also frequent (Table 2). Mutism and altered consciousness were documented in 31.6 % and 21.1 % of patients, respectively. Vision abnormalities, including blurred vision and optic atrophy, occurred in 39.5 %.

Table 2 – Frequency of clinical features

Clinical feature	n (%)
Seizures	31 (81.6 %)
Dementia/cognitive decline	29 (76.3 %)
Behavioural disturbance	25 (65.8 %)
Decline in school performance	24 (63.2 %)
Abnormal movements	23 (60.5 %)
Extrapyramidal signs	14 (36.8 %)
Vision abnormality	15 (39.5 %)
Mutism	12 (31.6 %)
Altered consciousness	8 (21.1 %)

EEG and neuroimaging findings

Thirty-two patients (84 %) exhibited the characteristic periodic high-amplitude slow-wave or Radermecker complexes on EEG, consistent with reports that periodic delta waves are a hallmark of SSPE. Six children had atypical EEG patterns mimicking other epileptic disorders. Magnetic resonance imaging showed white-matter hyperintensities in 18 patients (47.4 %) and cerebral atrophy in eight (21.1 %), similar to previous descriptions; 12 children (31.6 %) had normal MRI findings.

Associations with severe stage

Stages III and IV were considered severe. On univariate analysis, the mean age at SSPE onset did not differ significantly between severe and non-severe groups (13.0 ± 3.6 vs 12.3 ± 3.3 years, $p = 0.37$). Mean CSF IgG titre was higher in severe cases (33.9 ± 30.9 vs 25.7 ± 20.1 units) but not statistically significant ($p = 0.25$). Vaccination status was not associated with severity ($\chi^2 = 1.60$, $p = 0.45$).

Multivariable logistic regression (Table 3) showed that neither age at onset nor CSF antibody titre nor vaccination status predicted severe disease. The odds ratio for age at onset was 0.81 (95 % CI 0.65–1.03), suggesting a trend toward lower odds of severe disease with increasing age but without statistical significance. Both unvaccinated and partially vaccinated statuses were associated with lower odds of severe disease compared with fully vaccinated children, but confidence intervals were wide and included unity.

Table 3 – Logistic regression analysis predicting severe disease (Stage III)

Variable	Coefficient	Odds ratio (OR)	95 % CI for OR	p-value
Intercept	1.76	5.82	0.05 – 254.23	0.36
Age at SSPE onset (per year)	–0.21	0.81	0.65 – 1.03	0.088
CSF antibody titre (per unit)	0.03	1.03	0.99 – 1.07	0.157
Partially vaccinated vs fully	–1.22	0.30	0.03 – 3.25	0.320
Unvaccinated vs fully	–1.10	0.33	0.04 – 2.93	0.322

Figures

Figure 1 depicts the distribution of vaccination status among the children. Unvaccinated children constituted just over half of the cohort, with fewer than one-fifth fully vaccinated.

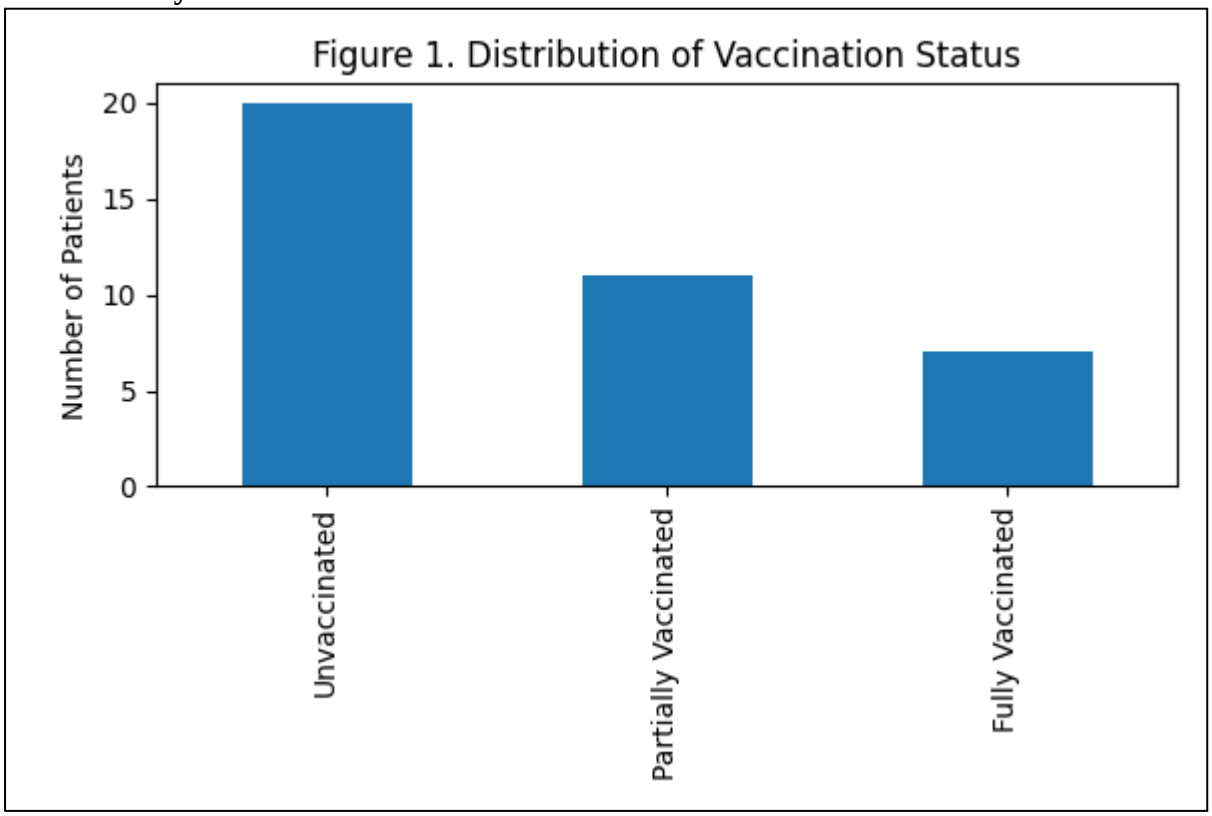


Figure 2 shows the frequency of each clinical manifestation. Seizures and dementia were the most common features, followed by behavioural disturbances and decline in school performance. Altered consciousness and vision abnormalities were less frequent.

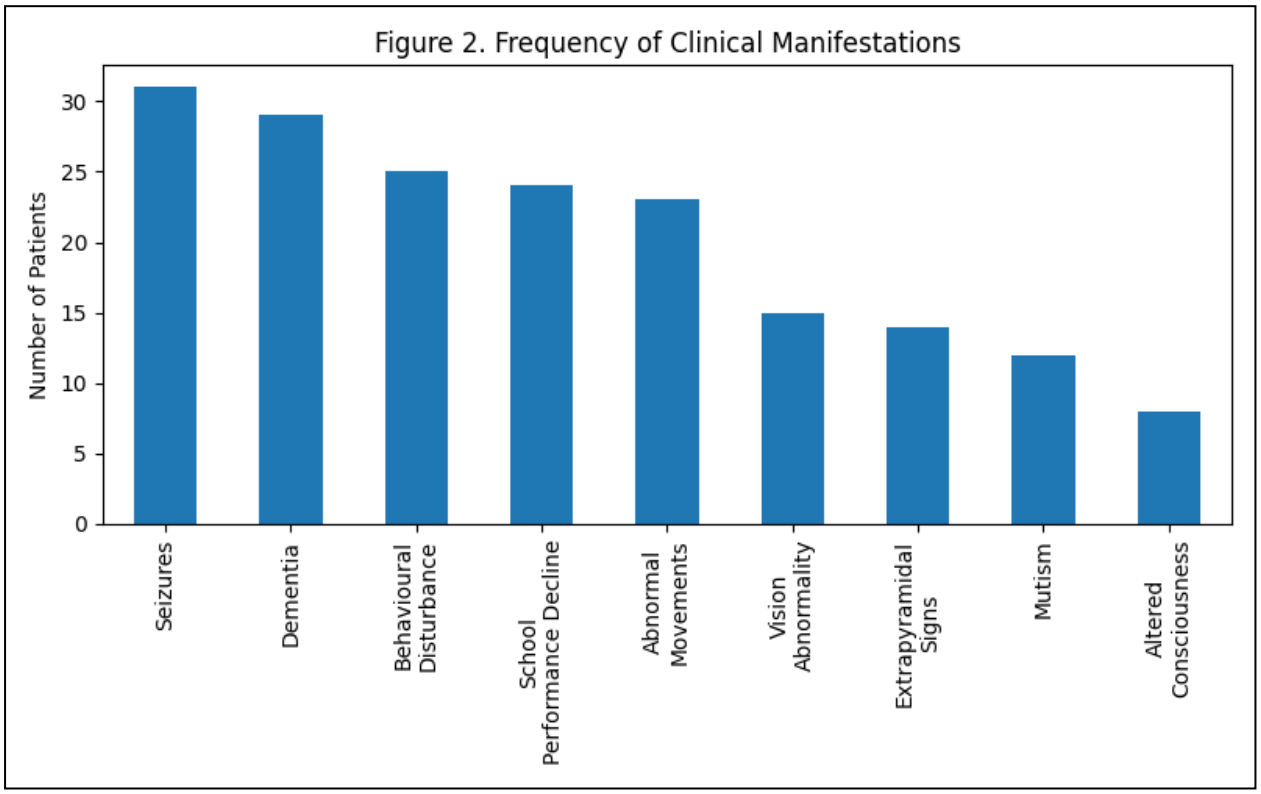
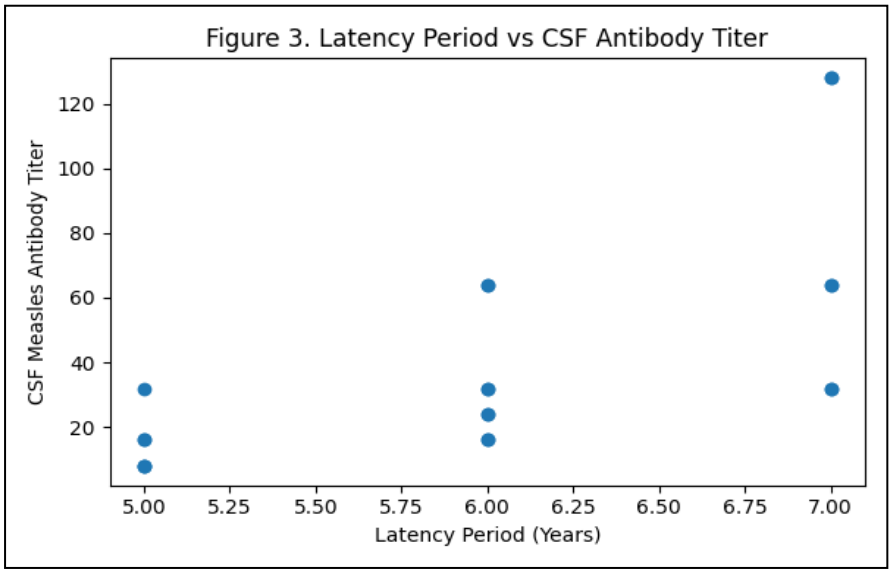


Figure 3 illustrates the relationship between latency period and CSF antibody titre. No clear linear association is evident, consistent with the non-significant regression results.



Discussion:

This is one of the few contemporary studies to evaluate the clinical spectrum, electroencephalographic features, neuroimaging abnormalities and immunological abnormalities of the children suffering from subacute sclerosing panencephalitis (SSPE) in Pakistan. Although it is a vaccine-preventable disease, SSPE is a serious public health problem in areas where measles remains endemic, but vaccine uptake is low. The results of this study support the continued impact of SSPE in developing

countries and the importance of better surveillance and prevention measures. The mean time between infection with measles and onset of SSPE in our group was about six years, and the difference was marked in favour of males. In addition, over a third of our patients had been infected with measles at an early age, and as with previous studies, the rate of SSPE development was much higher in those infected at young ages than it was in those infected at older ages.[5,6] Lastly, the male predominance seen in our patients may have been caused by biological susceptibility, sociocultural patterns of access to health care, or referral bias; however, the reasons remain unclear.
A key epidemiological observation in our study was the vaccination status. Over half of children were "no shots," and only a few were fully immunized for measles. Lack of vaccine coverage continues to sustain measles outbreaks and the incidence of SSPE in children in Pakistan, and several studies have shown that the children who are infected with measles in infancy have the highest risk of developing SSPE at a later age when they are eligible to be vaccinated. Socio-economic inequalities, population displacement, and disruptions in immunization services continue to be significant hurdles in the path of measles elimination in Pakistan.
Clinical signs seen in our patients were mostly typical of SSPE. The most frequent presenting complaints were seizures, cognitive decline, behavioural disturbances and loss of school function. The high prevalence of dementia and cognitive impairment seen in our patients is comparable to that reported by Wasim et al, Ali et al and Garg et al who found that myoclonic jerks, cognitive deterioration and progressive abnormal behaviours are hallmark presentations of the disease, which is a result of the progressive neuronal destruction and diffuse cortical dysfunction resulting from persistent measles virus infection within the central nervous system.[2,12,13] About 40% of patients had visual abnormalities. The lower prevalence reported here compared to other recent reviews may be due to differing stages of presentation of the disease or under-resourcing of subtle ophthalmological abnormalities. EEG continues to be one of the most useful tests in SSPE. Six children had atypical EEG abnormalities, which is similar to the rates seen in previous studies (70% to 95%).[12,16] These atypical findings were considered to be periodic discharges, or Radermecker complexes, reflecting widespread cortical synchronization with diffuse degeneration caused by the virus. Hence, clinicians need to have a high index of suspicion for SSPE in children with progressive cognitive decline despite lack of classic EEG features and should avoid missing a diagnosis.
Also, our neuroimaging results are consistent with the published literature. The most frequent MRI abnormalities encountered were white matter hyperintensities and cerebral atrophy. Actually, about one-third of subjects exhibited normal MRI scans, but met the SSPE diagnostic criteria after persistent measles virus infection. This finding agrees with earlier reports that MRI may be normal in the early stages of disease and should not be a requirement for diagnosis.[18,19] A major aim of this research was to determine factors that correlated with advanced disease severity. Logistic regression showed a trend of lower chances of a severe disease from increasing age at onset, although this was not statistically significant, nor was there any significant association between age, CSF antibody titre or vaccination status and disease stage. The absence of significant predictors might be explained by the small sample size, limited statistical power. In larger multicentre studies, associations have been reported between age at infection with measles and the more aggressive forms of SSPE, and between shorter latency periods and more aggressive disease progression, which have suggested that immaturity of the immune response may allow a greater amount of viral persistence and/or neuroinvasion to occur.
The differences in the epidemiology of SSPE are also underlined by comparison with international data. The massive success of measles control and the resulting dramatic decrease in viral circulation in Japan has led to a median latency period of about nine years and a mean age at diagnosis of more than 30 years among the patients who

survived to the time of the report, in contrast to historical data from Papua New Guinea, where up to 56 cases per million children were reported, and to retrospective studies in Germany, where one case of SSPE was reported for every 1,700–3,300 measles cases.

Strengths and Limitations

The present study possesses several important strengths. First, all patients fulfilled standardized diagnostic criteria, ensuring diagnostic consistency. Second, comprehensive assessment of clinical, electroencephalographic, neuroimaging, and serological parameters provided a multidimensional characterization of SSPE. Third, the study represents one of the few recent reports describing SSPE from Pakistan, where contemporary data remain limited.

Nevertheless, several limitations should be acknowledged. The relatively small sample size may have reduced the ability to detect significant associations between clinical variables and disease severity. The single-centre design limits generalizability to other regions of Pakistan. Selection bias is also possible because only children presenting to a tertiary referral centre were included. In addition, longitudinal outcomes, treatment response, and survival data were not evaluated. Finally, molecular characterization of measles virus strains and host genetic susceptibility factors were beyond the scope of the present investigation.

Clinical Implications and Future Directions

The findings of this study have important implications for public health policy and clinical practice. Given that SSPE is almost entirely preventable through effective measles vaccination, strengthening routine immunization programs remains the most effective strategy for disease prevention.[5,7] Addressing vaccine hesitancy, improving outreach to underserved populations, and maintaining high herd immunity are essential for reducing future SSPE cases. Early recognition of characteristic neurological symptoms may facilitate timely diagnosis and initiation of supportive therapy.

Future research should focus on multicentre prospective cohorts with larger sample sizes to identify robust prognostic markers of disease progression. Longitudinal studies evaluating treatment outcomes and quality of life are also needed. Furthermore, emerging evidence suggests that host genetic polymorphisms involving immune-regulatory pathways may influence susceptibility to SSPE, warranting further investigation.[27] Novel antiviral and immunomodulatory therapies, including favipiravir, ribavirin, interferon-α, and aprepitant, should be evaluated through well-designed randomized controlled trials to determine their therapeutic potential.[28]

Conclusion

Subacute sclerosing panencephalitis remains a devastating and universally fatal neurological complication of measles infection despite being entirely preventable through vaccination. In this cohort of Pakistani children, SSPE predominantly affected unvaccinated or partially vaccinated individuals and was characterized by a prolonged latency period, high frequency of seizures and cognitive decline, elevated CSF measles antibody titres, and characteristic EEG abnormalities. Although no independent predictors of severe disease stage were identified, the study highlights the continued burden of SSPE in settings where measles transmission persists.

The findings reinforce the critical importance of strengthening measles vaccination programs, improving disease surveillance, and promoting early recognition of neurological symptoms suggestive of SSPE. Clinicians should maintain a high index of suspicion in children presenting with progressive cognitive deterioration, behavioural abnormalities, myoclonic seizures, or characteristic EEG findings, particularly when there is a history of measles infection or incomplete vaccination.

Continued research into disease pathogenesis, prognostic biomarkers, and novel therapeutic strategies is essential to improve outcomes and ultimately eliminate this preventable neurological disorder.

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