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Features of EEG Examinations in Patients with Anemia

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Abstract: ***Anaemia is a common haematological disorder that may contribute to neurological symptoms due to impaired cerebral oxygenation. This study investigated the electroencephalographic (EEG) features in patients with different types and severities of anaemia. Fifty-two anaemic patients with neurological complaints underwent standard EEG examination. Abnormalities were observed in 65.4% of cases, most commonly diffuse background slowing and decreased alpha rhythm. The severity of EEG changes was significantly associated with lower haemoglobin levels and more pronounced in patients with megaloblastic anaemia. The results suggest that EEG can reveal functional cerebral disturbances in anaemic individuals, particularly those with moderate to severe anaemia. EEG may serve as a valuable, non-invasive tool for assessing subclinical brain dysfunction in patients with haematological conditions.***
Keywords: Anaemia, EEG, cerebral hypoxia, neurophysiology, brain function, haemoglobin, megaloblastic anaemia

I. INTRODUCTION

Anaemia, a common haematological condition characterised by a reduction in haemoglobin concentration and impaired oxygen-carrying capacity, has wide-ranging systemic effects, including those on the central nervous system (CNS). While the physical manifestations of anaemia such as fatigue, pallor, and tachycardia are well-documented, its neurological and neurophysiological impacts remain underexplored. Emerging clinical observations suggest that patients with moderate to severe anaemia may experience symptoms such as dizziness, cognitive slowing, irritability, and even transient loss of consciousness, raising concerns about underlying brain function alterations [3, 5].

Electroencephalography (EEG) is a non-invasive and sensitive tool for evaluating the functional state of the brain. It provides valuable insights into cortical excitability, neuronal synchronisation, and cerebral bioelectrical activity under both normal and pathological conditions. In anaemic patients, EEG may reflect subclinical or overt neurophysiological disturbances, including diffuse slowing of background rhythms, reduced alpha activity, or paroxysmal discharges—particularly in cases of prolonged hypoxia, vitamin B12 deficiency, or coexisting metabolic encephalopathy [6, 8].

Despite its potential, EEG remains underutilised in the diagnostic evaluation of anaemic patients presenting with cognitive or neurological symptoms. Moreover, few studies have systematically examined the correlation between haemoglobin levels and EEG patterns, particularly in different types of anaemia (iron deficiency, megaloblastic, chronic disease-related). A deeper understanding of these electrophysiological features may aid in early detection of CNS involvement, improve differential diagnosis in complex clinical cases, and inform timely therapeutic intervention.

This study aims to analyse the specific features and patterns observed in EEG recordings in patients with anaemia, with particular attention to the relationship between haemoglobin levels and cortical electrical activity. By comparing EEG findings across varying degrees and types of anaemia, the research seeks to clarify the neurophysiological profile of these patients and highlight the role of EEG as a supportive diagnostic tool in haematology and neurology practice.

II. METHOD

This was a prospective observational study conducted between February and October 2024 at the Neurology and Haematology Departments of the Samarkand Regional Multi-Profile Medical Centre. The study aimed to analyse EEG features in patients diagnosed with anaemia and to identify potential correlations between EEG findings and haemoglobin levels.

A total of 52 patients aged 18 to 65 years with a confirmed diagnosis of anaemia were enrolled. Anaemia was classified based on WHO criteria: haemoglobin <13 g/dL in males and <12 g/dL in females. Patients were further categorised into mild, moderate, and severe anaemia based on haemoglobin concentration. Types of anaemia included iron deficiency anaemia, megaloblastic anaemia, and anaemia of chronic disease, diagnosed through standard laboratory tests, including complete blood count (CBC), serum ferritin, vitamin B12, folic acid levels, and iron studies.

Inclusion criteria were: (1) newly or previously diagnosed anaemia of any type and severity; (2) presence of at least one neurological complaint (e.g., dizziness, fatigue, cognitive disturbance, headache, syncope); and (3) agreement to undergo EEG examination. Exclusion criteria included: (1) known neurological disorders (e.g., epilepsy, brain tumour, prior stroke); (2) active psychotropic medication use; (3) metabolic disturbances such as hypo/hyperglycaemia; and (4) intracranial pathology confirmed by imaging.

All participants underwent a standard 20-minute EEG examination using a digital 21-channel EEG machine with scalp electrodes placed according to the international 10–20 system. Recordings were obtained during wakefulness with eyes closed and open, hyperventilation, and photic stimulation. The EEGs were interpreted independently by two experienced neurophysiologists blinded to clinical and haematological status. Parameters evaluated included background rhythm frequency and symmetry, presence of focal or diffuse slowing, paroxysmal activity, epileptiform discharges, and reactivity.

Clinical and laboratory data, including haemoglobin level, red cell indices, and serum iron profiles, were collected for correlation with EEG findings. Subjective symptoms were recorded using a structured neurological symptom checklist completed before EEG testing.

All patients provided informed written consent, and the study was approved by the Ethics Committee of Samarkand State Medical University. Data were analysed using SPSS version 26.0. Descriptive statistics were presented as mean ± standard deviation. The chi-square test was used to assess categorical EEG abnormalities across anaemia types, and Pearson correlation was applied to explore relationships between haemoglobin levels and EEG patterns. A p-value of <0.05 was considered statistically significant.

III. RESULTS

A total of 52 patients diagnosed with anaemia underwent EEG examination as part of the study. The mean age of participants was 43.1 years (±10.5), with a predominance of females (69.2%). The severity of anaemia varied, with 32.7% of patients classified as having mild anaemia, 46.2% moderate, and 21.1% severe, based on WHO haemoglobin thresholds. Iron deficiency anaemia was the most common form, found in 55.8% of cases, followed by megaloblastic anaemia (28.8%) and anaemia of chronic disease (15.4%). Neurological complaints were present in all participants, most commonly fatigue (reported by 75%), headache (53.8%), dizziness (46.2%), and cognitive disturbances such as poor concentration (32.7%). Syncope or presyncope was reported in a smaller subset (15.4%). EEG abnormalities were detected in 65.4% of all participants. The most frequent abnormalities included diffuse slowing of background activity, observed in 42.3% of patients, as well as a reduction in alpha rhythm frequency and amplitude in 36.5%. Focal slowing, predominantly in the frontal and temporal lobes, was noted in 15.4% of patients, while 9.6% exhibited paroxysmal discharges or sharp wave activity, none of which were linked to a clinical seizure history. The prevalence and severity of EEG abnormalities correlated with anaemia severity, with 81.8% of patients with severe anaemia demonstrating abnormal findings, compared to 70.8% of those with moderate and 41.2% with mild anaemia. A statistically significant inverse correlation was found between haemoglobin levels and the presence of EEG abnormalities ($r = -0.49$, $p < 0.01$). Among the different anaemia types, megaloblastic anaemia was associated with the highest rate of EEG disturbances (86.7%), often showing diffuse slowing and reduced reactivity, while anaemia of chronic disease was associated with milder findings and a lower incidence of abnormal patterns. No epileptiform activity suggesting primary seizure disorder was recorded. The EEG changes observed in this study are interpreted as functional brain alterations likely resulting from cerebral hypoxia or metabolic imbalance secondary to anaemia, with potential for reversibility following correction of the haematological condition.

IV. DISCUSSION

The findings of this study suggest that anaemia, particularly in its moderate to severe forms, is associated with distinct and measurable changes in brain bioelectrical activity as recorded by EEG. The high prevalence of EEG abnormalities—identified in more than 65% of patients—highlights the relevance of neurophysiological monitoring in this population, especially in individuals presenting with neurological complaints such as chronic fatigue, cognitive dysfunction, headache, and dizziness. These symptoms, though often attributed to generalised systemic weakness, appear to reflect underlying cerebral hypoxia and functional slowing of neuronal processes.

Diffuse background slowing and attenuation of alpha activity were the most commonly observed EEG abnormalities in our cohort. These changes are consistent with prior studies on cerebral effects of metabolic disturbances and reduced oxygenation. The presence of theta and delta wave activity, as well as decreased reactivity to stimuli, may reflect the brain's compensatory response to chronic oxygen deficit and altered synaptic transmission, especially in grey matter regions that are highly metabolically active. The correlation between haemoglobin levels and EEG findings—particularly the statistically significant inverse relationship—strengthens the hypothesis that cerebral function is sensitive to the severity of anaemia and may deteriorate as oxygen delivery to neurons becomes increasingly impaired.

Interestingly, megaloblastic anaemia was associated with the highest proportion of EEG disturbances, often accompanied by cognitive symptoms. This may be explained not only by hypoxia but also by vitamin B12 deficiency, which is known to impair myelination and neurotransmitter metabolism, both of which could contribute to cortical dysfunction detectable on EEG. In contrast, patients with anaemia of chronic disease exhibited fewer abnormalities, suggesting that the aetiology and chronicity of anaemia influence the degree of neurological involvement.

Importantly, no overt epileptiform activity or seizures were recorded during EEG monitoring, and none of the patients had a history of epilepsy. This supports the view that the changes observed were non-epileptic and primarily related to functional rather than structural brain alterations. While these EEG findings are considered non-specific, their pattern and prevalence in this population point toward a potentially under-recognised aspect of anaemia-related brain dysfunction. Moreover, the reversibility of such changes remains an area of interest, as correction of anaemia could plausibly normalise cortical activity—an outcome that warrants longitudinal investigation.

The clinical implications of this study are significant. EEG could serve as a complementary diagnostic tool in anaemic patients with unexplained neurocognitive complaints, aiding in the differentiation between psychiatric, neurological, and systemic causes of dysfunction. It also reinforces the need for interdisciplinary cooperation between neurologists and haematologists in the management of anaemic patients, particularly those whose symptoms extend beyond fatigue and pallor.

Limitations of the study include its relatively small sample size, single-centre design, and lack of follow-up EEGs after correction of anaemia. Future studies should focus on larger populations, incorporate serial EEG monitoring, and evaluate the potential for EEG changes to serve as biomarkers of neurological recovery following treatment. Additionally, the inclusion of neuroimaging and neuropsychological testing would allow a more comprehensive assessment of CNS involvement in anaemia.

In conclusion, this study highlights the presence of neurophysiological disturbances detectable by EEG in anaemic patients, especially those with moderate to severe haemoglobin deficiency. The degree and nature of EEG abnormalities appear to be influenced by both the severity and type of anaemia. These findings emphasise the importance of considering brain function monitoring in anaemic patients with neurological symptoms, paving the way for more integrated, multidisciplinary diagnostic approaches.

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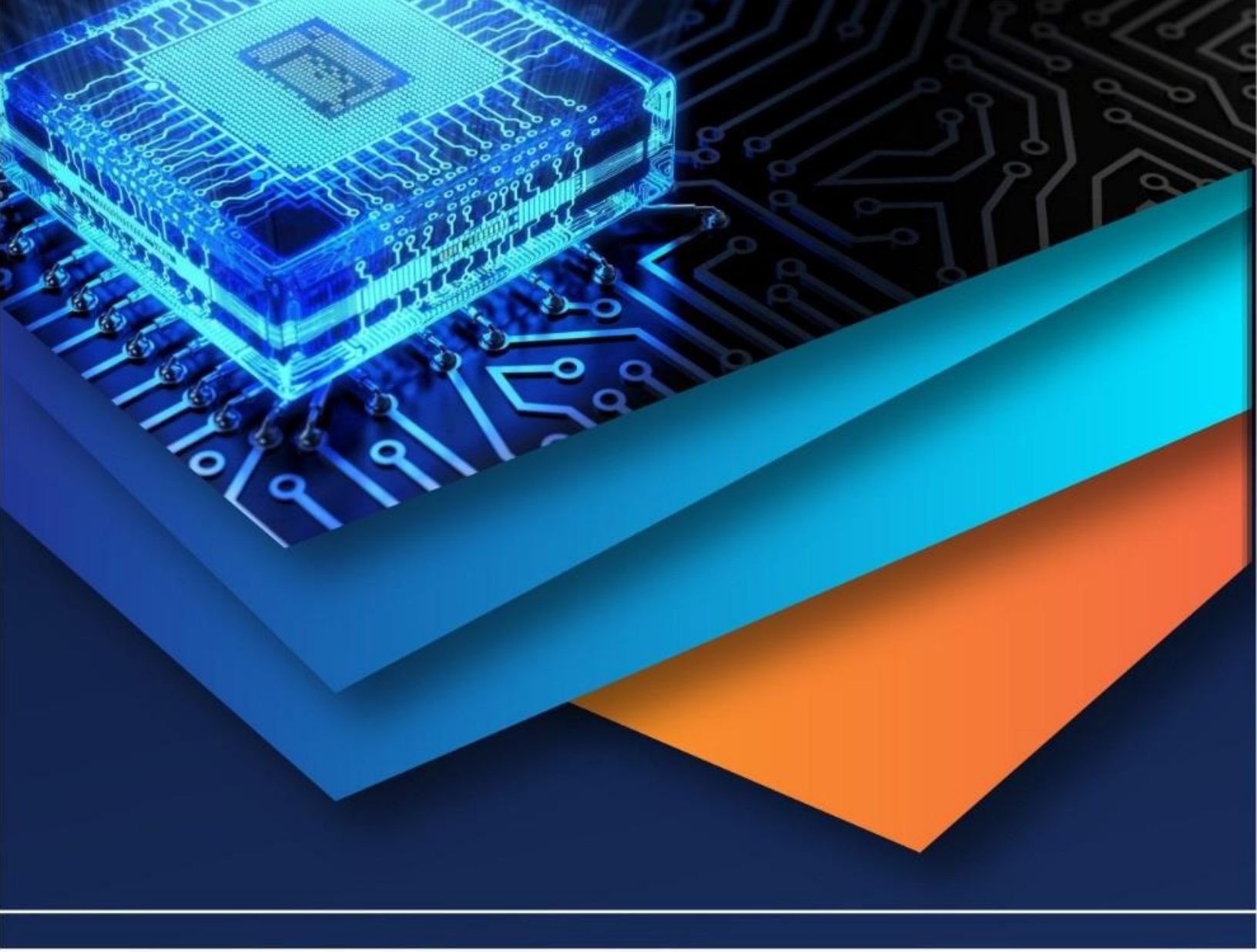

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