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THE SIGNIFICANCE OF COGNITIVE EVOKED POTENTIALS IN THE DIAGNOSIS OF VASCULAR DEMENTIA

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Abstract: Vascular dementia (VaD) is characterized by cognitive decline due to chronic or acute cerebral blood flow impairments and ranks as the second most common form of dementia after Alzheimer’s disease. This study investigates the efficacy and significance of cognitive evoked potentials (CEPs), particularly the P300 component, in the early diagnosis of VaD. The study involved 60 participants (30 VaD patients and 30 healthy controls). CEP results were compared with neuroimaging (MRI) and neuropsychological tests (MMSE, MoCA). Findings revealed that CEPs, through analysis of P300 latency and amplitude, exhibit high sensitivity (88%) and specificity (85%) in detecting cognitive impairments in VaD. CEPs may serve as a valuable supplementary diagnostic tool in clinical practice for identifying mild cognitive impairments in VaD.

Keywords: vascular dementia, cognitive evoked potentials, P300, diagnosis, cognitive dysfunction, neurophysiology, neuroimaging, neuropsychological tests.

Annotatsiya Qon-tomir demensiyasi (VaD) miya qon aylanishining surunkali yoki o‘tkir buzilishlari natijasida kognitiv funktsiyalarning pasayishi bilan xarakterlanadi va Altsgeymer kasalligidan keyin eng keng tarqalgan demensiya turi hisoblanadi. Ushbu tadqiqotda kognitiv chaqirilgan potensiallar (KChP), xususan P300 komponenti, VaDning erta diagnostikasidagi samaradorligi va ahamiyati o‘rganildi. Tadqiqot 60 nafar ishtirokchi (30 VaD bemori va 30 sog‘lom nazorat guruhi) ishtirokida o‘tkazildi. KChP natijalari neyroimaging (MRI) va neyropsixologik testlar (MMSE, MoCA) bilan taqqoslandi. Natijalar KChPning P300 latensiyasi va amplitudasi orqali VaDda kognitiv buzilishlarni aniqlashda yuqori sezgirlik (88%) va o‘ziga xoslikka (85%) ega ekanligini ko‘rsatdi. KChP klinik amaliyotda VaDning engil kognitiv buzilishlarini aniqlashda qo‘shimcha diagnostik vosita sifatida foydali bo‘lishi mumkin.

Kalit so‘zlar: qon-tomir demensiyasi, kognitiv chaqirilgan potensiallar, P300, diagnostika, kognitiv disfunksiya, neyrofiziologiya, neyroimaging, neyropsixologik testlar.

Аннотация Сосудистая деменция (VaD) характеризуется снижением когнитивных функций в результате хронических или острых нарушений мозгового кровообращения и является второй по распространенности формой деменции после болезни Альцгеймера. В данном исследовании изучалась эффективность и значение когнитивных вызванных потенциалов (КВП), в частности компонента P300, в ранней диагностике VaD. Исследование проведено с участием 60 участников (30 пациентов с

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VaD и 30 здоровых лиц контрольной группы). Результаты КВП сравнивались с данными нейровизуализации (МРТ) и нейропсихологических тестов (MMSE, MoCA). Результаты показали, что КВП, благодаря анализу латентности и амплитуды P300, обладают высокой чувствительностью (88%) и специфичностью (85%) в выявлении когнитивных нарушений при VaD. КВП может служить дополнительным диагностическим инструментом в клинической практике для выявления легких когнитивных нарушений при VaD.

Ключевые слова: сосудистая деменция, когнитивные вызванные потенциалы, P300, диагностика, когнитивная дисфункция, нейрофизиология, нейровизуализация, нейропсихологические тесты.

Below is a precise and error-free English translation of the provided text, maintaining the original structure, scientific terminology, and formatting:

Relevance

Vascular dementia is major global helath concern, being the second most common form of dementia after Alzheimer's disease, affecting approximately 15–20% of individuals aged over 65 years worldwide (O'Brien & Thomas, 2019). The increasing prevalence of VaD, driven by aging populations and rising rates of vascular risk factors such as hypertension, diabetes, and stroke, underscores the urgent need for accurate and early diagnostic tools. Early identification of VaD is critical to slow disease progression, improve patients' quality of life, and reduce the substantial socio-economic burden associated with long-t

Current diagnostic methods for VaD, including magnetic resonance imaging (MRI), computed tomography (CT), and neuropsychological assessments like the Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA), often lack sufficient sensitivity to detect mild cognitive impairment (MCI) in the early stages or may be influenced by subjective factors (Sachdev et al., 2014). This limitation highlights the need for objective, reliable, and non-invasive diagnostic approaches that can complement existing methods.

Cognitive evoked potentials (CEPs), particularly the P300 component measured via electroencephalography (EEG), offer a promising neurophysiological approach to assess cognitive functions such as attention, memory, and information processing. The P300 component is a well-established biomarker for cognitive dysfunction, with its latency and amplitude providing insights into the speed and intensity of cognitive processing (Polich, 2007). Given its ability to objectively evaluate brain function, CEPs have the potential to enhance the early diagnosis of VaD, distinguish it from other forms of dementia, and monitor disease progression or treatment efficacy.

The relevance of studying CEPs in VaD lies in their potential to address gaps in current diagnostic practices. By providing a sensitive and specific tool for detecting early cognitive changes associated with vascular pathology, such as white matter hyperintensities or lacunar infarcts, CEPs could facilitate timely interventions. Furthermore, integrating CEPs with

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neuroimaging and neuropsychological assessments may improve differential diagnosis, particularly in distinguishing VaD from Alzheimer's disease or mixed dementia. This study is timely and significant, as advancements in neurophysiological techniques could transform clinical practice, enhance patient outcomes, and contribute to the development of targeted therapeutic strategies for VaD.

This text is written in a concise, scientific, and professional tone, emphasizing the relevance of CEPs in the context of vascular dementia. If you need adjustments, such as a specific length, additional details, or integration into a larger document, please let me know!

Vascular dementia (VaD) is defined as cognitive dysfunction resulting from chronic or acute cerebral blood flow disturbances, such as ischemic strokes, lacunar infarcts, or white matter hyperintensities (WMH). VaD is the second most common type of dementia after Alzheimer's disease, affecting approximately 15–20% of individuals over 65 years globally (O'Brien & Thomas, 2019). Early diagnosis of VaD is critical for slowing disease progression, improving patients' quality of life, and reducing socio-economic costs.

Currently, VaD diagnosis relies on magnetic resonance imaging (MRI), computed tomography (CT), neuropsychological tests (Mini-Mental State Examination [MMSE], Montreal Cognitive Assessment [MoCA]), and clinical evaluations. However, these methods may lack sufficient sensitivity for detecting mild cognitive impairment (MCI) or may be subjective in nature (Sachdev et al., 2014). Consequently, there is a growing need for neurophysiological methods that objectively and functionally assess brain activity.

Cognitive evoked potentials (CEPs) are a method using electroencephalography (EEG) to measure brain responses related to cognitive processes (attention, memory, and information processing). The P300 component of CEPs, in particular, has been widely studied as a key indicator for detecting cognitive dysfunction (Polich, 2007). P300 reflects attention and working memory processes, with its latency (time from stimulus to response) and amplitude (response intensity) used to assess cognitive status. This study investigates the sensitivity and specificity of CEPs in VaD diagnosis, as well as their advantages compared to neuroimaging and neuropsychological tests. The primary aim of the study is to determine the clinical significance of CEPs in the early diagnosis of VaD.

Materials and Methods

The study was conducted at the "Neuromed" clinic in Tashkent from September 2024 to April 2025.

A total of 60 participants were included:

- VaD Group: 30 patients (15 male, 15 female, mean age 68.4 ± 5.2 years) diagnosed with vascular dementia based on NINDS-AIREN criteria. Diagnosis was confirmed using MRI findings (lacunar infarcts, white matter hyperintensities) and clinical evaluations.

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- Control Group: 30 healthy participants (16 male, 14 female, mean age 67.8 ± 4.9 years), matched for age and sex. No neurological or psychiatric disorders were identified in the control group.

Patients with mild to moderate cognitive impairment were included in the VaD group. Participants with Alzheimer's disease, Parkinson's disease, other types of dementia, or conditions interfering with EEG (e.g., hearing or vision impairments) were excluded.

Diagnostic Methods

1 Cognitive Evoked Potentials (CEPs)

◦ Equipment: Neurosoft Neuron-Spectrum-4 EEG system was used.

◦ Protocol: The standard "odd-ball" paradigm was applied. Participants listened to 1000 Hz (frequent) and 2000 Hz (rare) auditory stimuli and responded to the rare stimuli by pressing a button. P300 latency (ms) and amplitude (μV) were measured at Cz, Pz, and Fz electrodes.

◦ Analysis: Mean P300 latency and amplitude were compared between groups.

2 Neuropsychological Tests

◦ MMSE: Used for general cognitive assessment (maximum score: 30).

◦ MoCA: Used for more precise assessment of attention, memory, and executive functions (maximum score: 30).

3 Neuroimaging

◦ T1, T2, and FLAIR sequences were obtained using a 1.5T MRI (Siemens Magnetom). White matter hyperintensities were evaluated using the Fazekas scale.

4 Statistical Analysis

◦ Independent t-tests and one-way ANOVA were used to identify differences between groups.

◦ The diagnostic sensitivity and specificity of CEPs were analyzed using Receiver Operating Characteristic (ROC) curve analysis.

◦ Pearson correlation coefficient (r) was calculated for correlation analysis.

◦ All analyses were performed using SPSS 26.0, with $p < 0.05$ considered statistically significant.

CEP Results

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- P300 Latency: In the VaD group, mean P300 latency was 420 ± 35 ms, compared to 350 ± 25 ms in the control group (t-test, $p < 0.001$), indicating slowed cognitive processing.

- P300 Amplitude: In the VaD group, mean amplitude was 5.2 ± 1.8 μV, compared to 8.5 ± 2.1 μV in the control group ($p < 0.01$), reflecting reduced brain response intensity.

- Differences in P300 were most pronounced at the Pz electrode ($p < 0.001$).

Neuropsychological Tests

- MMSE: Mean score in the VaD group was 22.4 ± 3.2, compared to 28.6 ± 1.5 in the control group ($p < 0.001$).

- MoCA: Mean score in the VaD group was 19.8 ± 2.8, compared to 27.2 ± 1.9 in the control group ($p < 0.001$).

- MoCA (sensitivity: 82%) showed higher sensitivity than MMSE (sensitivity: 78%) for detecting mild cognitive impairment, but both tests performed less effectively than CEPs.

Neuroimaging

- In the VaD group, 27 patients (90%) had white matter hyperintensities (Fazekas scale: grades 2–3), and 22 patients (73%) had lacunar infarcts.

- In the control group, 5 participants (16.7%) showed mild WMH (Fazekas grade 1).

Statistical Analysis

- CEPs demonstrated a diagnostic sensitivity of 88% and specificity of 85% (ROC AUC = 0.90, 95% CI: 0.85–0.95).

- P300 latency showed a moderate correlation with WMH severity ($r = 0.62$, $p < 0.05$).

- P300 amplitude was positively correlated with MoCA scores ($r = 0.58$, $p < 0.05$), confirming its association with cognitive status.

Main Findings and Their Significance

The study results demonstrate that CEPs, particularly the P300 component, have high sensitivity and specificity in VaD diagnosis. Prolonged P300 latency indicates reduced information processing speed, while decreased amplitude reflects weakened cognitive processes. These findings align with the pathophysiological mechanisms of VaD, particularly white matter damage and disrupted neural connectivity (Wardlaw et al., 2019).

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Clinical Significance

The high sensitivity of CEPs makes them a valuable supplementary diagnostic tool for detecting mild cognitive impairments in VaD. This is particularly important for differential diagnosis from conditions such as Alzheimer's disease or mixed dementia (Goodin & Aminoff, 2018). The correlation of CEPs with WMH confirms its association with vascular pathology, enhancing its clinical relevance.

Conclusion

Cognitive evoked potentials, specifically the P300 component, are an effective neurophysiological method for the early diagnosis of vascular dementia, with high sensitivity (88%) and specificity (85%). CEPs offer advantages over neuropsychological tests and neuroimaging in detecting mild cognitive impairments and can be used as a supplementary diagnostic tool in clinical practice. Wider adoption of this method could improve treatment outcomes and facilitate early identification of aggravating factors in VaD.

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