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RESEARCH ARTICLE

Evaluation of Serum Eotaxin and Related Biomarkers in Focal and Generalized Epilepsy

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ABSTRACT

Epilepsy is a common brain disorder, characterized by spontaneous recurrent seizures, with associated neuropsychiatric and cognitive comorbidities and increased mortality. Assessment of serum Eotaxin and related biomarkers offers useful information about neuroinflammatory activity and metabolic imbalance in epilepsy, and may have potential value as diagnostic and prognostic tools. The aim of this study was to evaluate the association between Eotaxin, Intelectin-1, Kynurenine, and Proprotein Convertase-1 and epilepsy. The study consisted of 90 subjects who were classified into three groups: 30 healthy controls, 31 patients with focal epilepsy, and 30 patients with generalized epilepsy. Serum samples were obtained, and biomarker concentrations were measured using the ELISA technique. Statistical analysis was performed using GraphPad software. The results of this study show a significant increase in serum Eotaxin, Intelectin-1, and kynurenine concentrations in the epileptic patients' group as compared with the normal group. The results also show a significant decrease in the levels of proprotein convertase in the two epileptic patient groups as compared to healthy subjects. These findings suggest that serum Eotaxin and related biomarkers may provide mechanistic insights into epileptogenic processes, support early detection, and help prevent complications in patients with epilepsy.

Keywords: Epilepsy, Eotaxin, Intelectin-1, Kynurenine, Neuroendocrine convertase

Introduction

Abnormal brain electrical activity can cause epileptic seizures. When a person experiences recurring seizures, this condition is called epilepsy [1,2] which is one of the most prevalent neurological disorders of the central nervous system (CNS). Previous neurological traumas that increase susceptibility to unprovoked seizures are associated with acquired epilepsy. [3,4] Epilepsy is a chronic non-communicable non-infectious disease resulting from disrupted excitatory and inhibitory neural discharges with multiple etiologies. It affects millions of individuals worldwide and is the third most significant contributor to the global disease burden with approximately 50–70 million people affected. [5–7] Epilepsies are classified based on seizure onset into two main types: focal and generalized along with several specialized subtypes. [8] Focal seizures are restricted to a smaller region of the brain with symptoms varying depending on the epileptic focus whereas generalized seizures involve large portions or the entire brain with impaired awareness. Both focal and generalized epilepsies are linked with cognitive deficits that significantly impact quality of life [9] and patients are more likely to experience physical and mental health issues such as anxiety and depression. [10] Epilepsy affects people of all ages in both inpatient and outpatient settings [11,12] is slightly more common in males than females and peaks in the elderly due to higher rates

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of neurodegenerative diseases, tumors, and strokes.[13] Despite the availability of numerous anti-epileptic drugs (AEDs) about one-third of patients continue to experience seizures.[14]

Eotaxin, a member of the C-C motif chemokine family, includes Eotaxin-1 (CCL11), Eotaxin-2 (CCL24), and Eotaxin-3 (CCL26).[15] CCR3, the main receptor for Eotaxin, is found on all eosinophils in the peripheral blood. Human Eotaxin (CCL11) is a 73-aminoacid, 8.3 kDa polypeptide produced by immune cells.[16,17] It attracts eosinophils to inflamed tissues and contributes to inflammatory responses.[18] In the brain, Eotaxin may exert neurotoxic effects and has been associated with age-related cognitive decline.[19,20] Elevated Eotaxin levels have been reported in asthma, allergic rhinitis, neurodegenerative disorders, and other inflammatory conditions.[21–23] Intelectin has mainly two isoforms, intelectin-1 and -2, with isoform-1 being the main form in human blood.[24] Intelectin-1 (ITLN, or Omentin-1), is a secreted adipokine with anti-apoptotic, anti-oxidative, and anti-inflammatory properties,[25] widely expressed in adipose tissue, heart, endothelium, plasma, colon, airway, kidneys, and small intestine.[26,27] The mature protein is a 313-amino-acid glycoprotein of 35 kDa[28] and is involved in endothelial dysfunction, insulin resistance, metabolic disorders, and diseases including obesity, Crohn's disease, asthma, and type 2 diabetes.[29–31] Tryptophan (Trp) is an essential amino acid metabolized via the kynurenine pathway, producing metabolites like kynurenine and kynurenic acid[32–34] that modulate immune and inflammatory responses and are implicated in neurological and metabolic disorders.[35–37] Altered kynurenine levels may reflect metabolic and inflammatory mechanisms in epilepsy.[38] Many proteins are synthesized as inactive precursors and activated by proprotein Convertases (PCs),[39] including Furin and PC1–PC7, which regulate hormones, neuropeptides, growth factors, and receptors.[40,41] Proprotein Convertase-1 (PC1) is crucial for the maturation of prohormones and proneuropeptides.[42–44] Although Eotaxin, Intelectin, Kynurenine, and Proprotein Convertase are linked to inflammation and neurological disorders, their roles in epilepsy remain poorly understood. Investigation of these biomarkers offers mechanistic insight into disease pathogenesis while underscoring their utility as potential diagnostic and prognostic indicators.

The objective of this investigation is to examine serum concentrations of Eotaxin, Intelectin-1, Kynurenine, and Proprotein Convertase-1 in patients with focal and generalized epilepsy compared with control groups.

Materials and methods

This cross-sectional study was conducted at Saad Al-Watri Hospital for Neurosciences, Baghdad, Iraq, between August 2024 and January 2025, and included 90 individuals aged 20-50 years: 30 healthy controls (16 females, 14 males), 31 patients with focal epilepsy (17 females, 14 males), and 29 patients with generalized epilepsy (14 females, 15 males). Epileptic patients were diagnosed by the hospital's neurology team or via electroencephalography and were classified as focal or generalized based on clinical history, seizure type, EEG, and neuroimaging results, while healthy controls had no neurological disorders. After a fasting period of 12 hours, five milliliters of venous blood were collected from the cubital vein, allowed to clot at room temperature, centrifuged to obtain serum, transferred into Eppendorf tubes, and stored at -20 ˚C until analysis. Serum levels of Eotaxin, Intelectin-1, Kynurenine, and Proprotein Convertase-1 were measured using standard biochemical assays.

Assessment of biochemical parameters

Serum levels of Eotaxin, Intelectin-1, Kynurenine (alpha-aminoadipate aminotransferase), and Proprotein Convertase-1 (neuroendocrine convertase-1) were measured using specific enzyme-linked immunosorbent assays (ELISAs) according to the manufacturer's instructions. Eotaxin (E0058Hu), Intelectin-1 (E0155Hu), Kynurenine (E5547Hu), and Proprotein Convertase-1 (E2322Hu) were measured using commercially available kits provided by manufacturer by (BT LAB, China), for all assays. All measurements were conducted in duplicate, and the mean values were used for statistical analysis to ensure accuracy and reproducibility.

Statistical analysis

Statistical analysis was conducted using GraphPad Prism 9.0. The data are presented as mean ± standard deviation (SD). One-way ANOVA was performed to compare the three groups. A *P-value* < 0.05 *was regarded as statistically significant.* Receiver operating characteristic (ROC) curve analysis was performed to assess the diagnostic performance of each biomarker in distinguishing control subjects from patients with epilepsy.

Results and discussion

The study population included 90 participants, classified into three groups: healthy subjects (n = 30),

Table 1. Concentrations of Eotaxin, Intelectin-1, Kynurenine and PC-1 in healthy controls and patients with focal and generalized epilepsy.

Group	Control	Focal epilepsy	Generalized epilepsy	*P*-value
Eotaxin (ng/mL)	1461 ± 68.89	2191 ± 118.4	1665 ± 78.33	<0.0001
Intelectin-1 (ng/mL)	99.74 ± 7.019	130.3 ± 6.414	113.7 ± 8.056	<0.0001
Kynurenine (ng/mL)	364.8 ± 42.86	565.8 ± 37.12	470.5 ± 33.68	<0.0001
PC-1(ng/mL)	568.1 ± 39.77	405.2 ± 29.64	478.4 ± 19.61	<0.0001

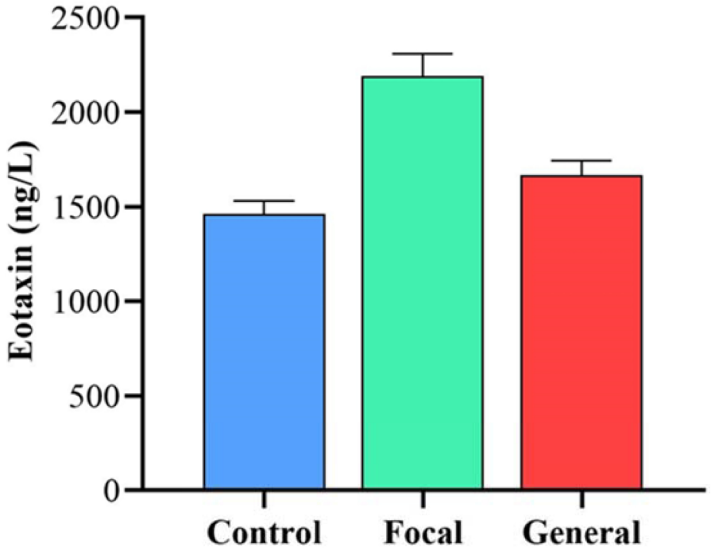

Fig. 1. Concentration of Eotaxin in normal healthy controls, focal, and generalized epileptic patients.

focal epilepsy patients (n = 31), and generalized epilepsy patients (n = 29). The serum concentrations of Eotaxin are presented in Table 1 and Fig. 1. Eotaxin levels were significantly higher in both focal and generalized epilepsy patients compared to healthy controls ($p < 0.0001$). Mean Eotaxin concentrations were 2191±118.4 ng/L in focal epilepsy, 1665 ± 78.33 ng/L in generalized epilepsy, and 1461±68.89 ng/L in controls. One-way ANOVA was used to compare the three groups. Post-hoc Tukey analysis further confirmed that both focal and generalized epilepsy groups exhibited significantly elevated serum levels of Eotaxin, Intelectin-1, Kynurenine, and PC-1 compared with the healthy controls ($p < 0.05$).

The evaluation of cytokine levels in human brain tissue is hindered by multiple factors, including the necessity of surgical intervention for refractory epilepsy to obtain such tissue, which restricts the assessment of brain cytokine levels to a singular instance during disease progression, typically following an extended duration of illness. Additionally, all patients were on anti-epileptic medications, which may influence cytokine levels.[45] Elevated concentrations of Eotaxin have been observed in several neurodegenerative, neuroinflammatory conditions, neuroprogressive disorders and mental disorders.[23] Furthermore, because Eotaxin is conveyed from the bloodstream to the brain through the blood–brain barrier (BBB) and is also produced by microglia, the substantial increase in Eotaxin levels may be associated with deeper penetration of the blood-brain barrier and the recruitment of leukocytes to the epileptogenic region of the brain, which results in impairment of the blood-brain barrier as a pathogenic factor in the etiology of epilepsy. The function of classical neurotransmitters can be swiftly altered by proinflammatory cytokines, which modulate their receptor assembly and phosphorylation at neuronal membranes.[46] Notably, age-related elevations in Eotaxin have been linked to deficits in executive functioning, and also with episodic and semantic memory. As a consequence, this chemokine has been designated as an accelerated brain-aging chemokine or an endogenous cognition-deteriorating chemokine.[21] The serum levels of Intelectin, Kynurenine and Proprotein Convertase-1 in the healthy group and epileptic patients are highlighted in Table 1 and Fig. 2.

Intelectin, or Omentin-1, is a protein found in multiple tissues and is believed to play a role in the modulation of metabolic processes and inflammation. Inflammation is a conserved biological response to

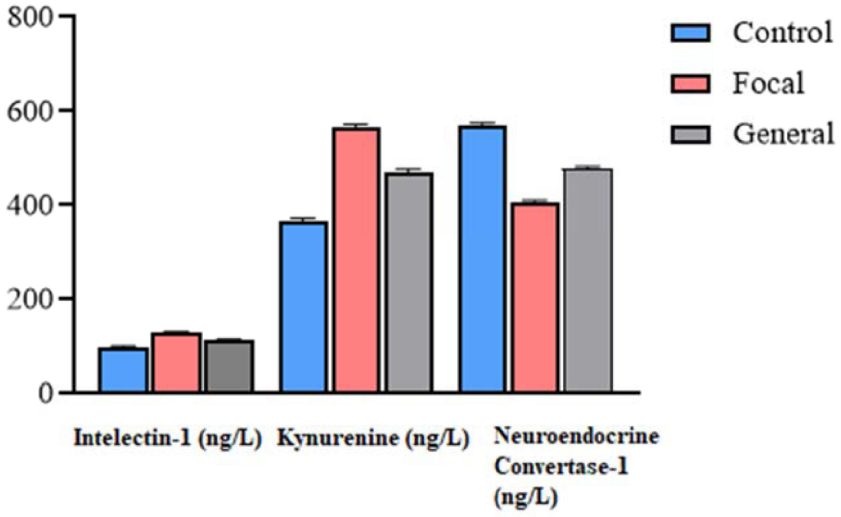

Fig. 2. Serum levels of intelectin, kynurenine and neuroendocrine Convertase-1 in normal healthy group and epileptic patients.

injury or infection, where reactive oxygen species (ROS) play a critical role by producing rapid, localized signals. As secondary messengers, ROS regulate inflammation through redox-dependent pathways. However, when ROS are produced in excess or redox balance is disrupted, oxidative stress (OS) occurs, amplifying inflammatory responses. These signaling pathways exhibit considerable interference and contribute to the pathophysiology of epilepsy through altering the excitability of neural networks.[47,48] Intelectin-1 levels are increased in epileptic patients when compared to the healthy group and this may be due to OS observed at various stages of epilepsy, which is linked to neuronal loss and neuroinflammation, ultimately leading to cognitive deficits.[49–51] The genetic modifications of the kynurenine pathway (KP) result in disruptions of the pathway and are associated with multiple diseases. The KP involves several enzymes, and most of its metabolites are neuroactive; some exhibit neuroprotective, antioxidant, and anti-inflammatory activities, while others promote free radical formation, leading to neurodegeneration. An imbalance in the pathway is believed to contribute to the development of various diseases.[52,53] In our study, the level of kynurenine is decreased in both epileptic patients group when compared to the healthy group and this may be because kynurenine can be metabolized to kynurenic acid, and this acid is thought to have a neuroprotective function by acting as an antagonist to ionotropic glutamate receptors. However, excessive levels of KYNA may result in inflammation. In this study, the epileptic patient groups had significantly lower levels of proprotein convertase than the control group. PC is an enzyme that plays a role in various biological processes and is crucial for controlling the immune system.[54–56] It facilitates the conversion of inert peptides into their active forms and is primarily expressed in neuroendocrine tissues. Thus, impairment of this enzyme is characterized by inadequate activation of all the hormones such as proinsulin, proglucagon, proopiomelanocortin, pro-gonadotropin-releasing hormone, and prothyrotropin-releasing hormone.[57–59] Fig. 3 illustrates a positive correlation between serum Eotaxin and Intelectin-1 concentrations in epileptic patients. The scatter plot demonstrates that higher levels of Intelectin-1 are associated with increased Eotaxin values, suggesting a potential link between these two biomarkers in the context of epilepsy. Fig. 4 also demonstrated a statistically significant positive relationship between Eotaxin and kynurenine. A significant inverse correlation was observed between Neuroendocrine Convertase 1 and Eotaxin levels ($r = -0.807$, $p < 0.0001$). As Neuroendocrine Convertase 1 increases, Eotaxin levels decrease, indicating a strong negative association between these two variables as shown in Fig. 5.

ROC curve analysis demonstrated that Kynurenine, Eotaxin, Neuroendocrine Convertase-1, and Intelectin-1 effectively discriminate epilepsy patients from controls Fig. 6, Table 2. Eotaxin, Neuroendocrine Convertase-1, Intelectin-1, and Kynurenine were ranked in decreasing order of diagnostic utility, with Kynurenine demonstrating the greatest accuracy among the assessed biomarkers. This study identifies Kynurenine as the most robust serum biomarker, while the other markers also exhibit considerable diagnostic performance. Table 2 illustrates the outcomes of the receiver operating characteristic curve,

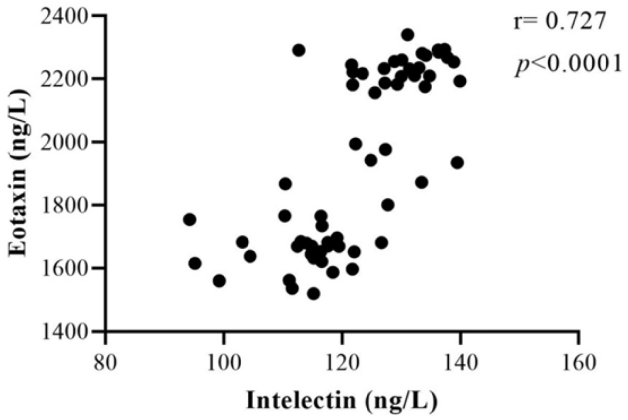

Fig. 3. Correlation of serum Eotaxin concentration with intelectin-1 in epileptic patients.

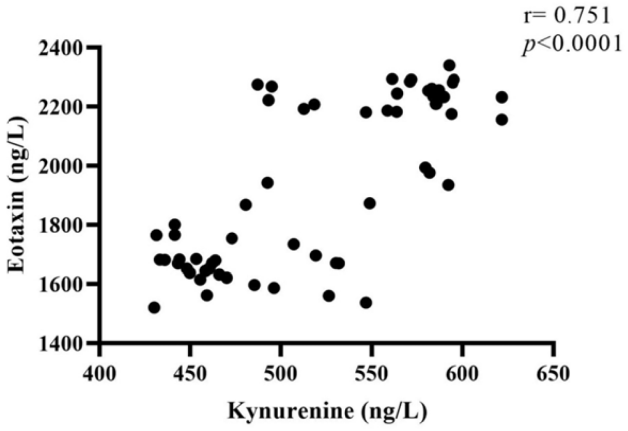

Fig. 4. Correlation of serum Eotaxin concentration with Kynurenine in epileptic patients.

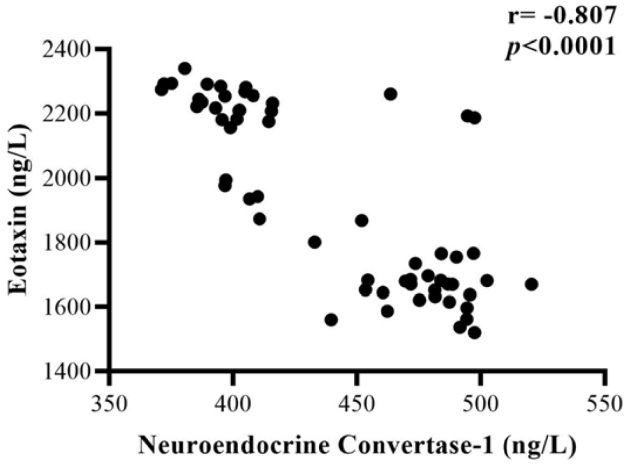

Fig. 5. Correlation of serum Eotaxin concentration with proprotein convertase in epileptic patients.

including AUC (area under the curve), sensitivity, specificity, and cutoff values, which exhibit clinically useful thresholds, highlighting their potential among these biomarkers as diagnostic indicators for the diagnosis of epilepsy.These observations are consistent with previous studies demonstrating the utility of ROC curve analysis in evaluating biomarker performance in neurological disorders. [60]

Table 2. ROC analysis assessed the diagnostic utility of these serum biomarkers in differentiating epilepsy patients from healthy subjects.

Parameter	AUC	Sensitivity (%)	Specificity (%)	Cutoff Value (ng/L)	*p*-value
Eotaxin	0.989	100	90	>1511.57	<0.0001
Intelectin	0.941	92	90	>106.07	<0.0001
Kynurenine	0.994	93	100	>439.40	<0.0001
Neuroendocrine Convertase 1	0.986	98	93	≤502.54	<0.0001

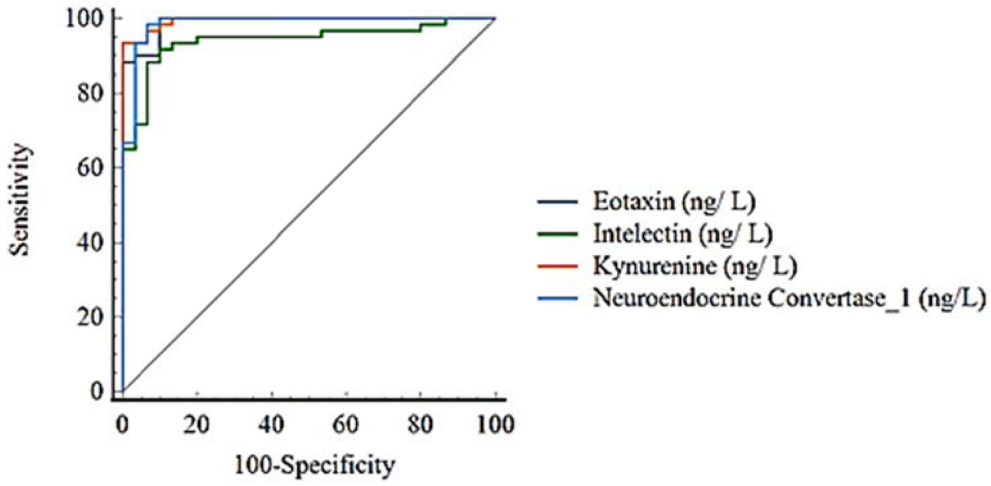

Fig. 6. ROC curves showed the diagnostic performance of serum Eotaxin, Intelectin-1, Kynurenine, and Neuroendocrine Convertase-1 in patients with epilepsy.

Conclusion

The current study exhibited that serum concentrations of Eotaxin, Intelectin-1, Kynurenine, and Proprotein Convertase-1 were markedly elevated in patients with focal and generalized epilepsy compared with healthy subjects, indicating their contribution to epilepsy-related inflammatory and neuroimmune pathways. In this study, Kynurenine and Intelectin-1 demonstrated the greatest diagnostic potential among these biomarkers, as shown by ROC curve analysis. This supports their potential as reliable, non-invasive indicators for the detection of epilepsy. Eotaxin and Proprotein Convertase-1 also demonstrated substantial diagnostic value, reinforcing their relevance to the evaluation of disease status. This research not only strengthens the clinical performance of these biomarkers in enhancing diagnosis and monitoring but also indicates their potential as therapeutic targets.

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Authors' declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images that are not ours have been included with the necessary permission for republication, which is attached to the manuscript.
- No animal studies are present in the manuscript.
- Author(s) signed on ethical consideration's approval.
- Ethical Clearance: The project was approved by the local ethical committee at Salahaddin University.

Authors' contributions statement

F.A.N. wrote the research paper. F.S.A. reviewed and revised the manuscript. Z.A.A. prepared the research proposal. S.A.N. collected data and performed statistical data analysis. F.A.N., F.S.A., and Z.A.A. contributed to data interpretation. F.A.N. and F.S.A. wrote the paper with input from all authors.

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تقييم مستويات الإيوتكسين العوامل البيولوجية المرتبطة به في الصرع البؤري والعام

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الخلاصة

الصرع هو اضطراب عصبي مزمن يتميز بنوبات متكررة، وتشير الأدلة الحديثة إلى أن الوسطاء الالتهابيين والمسارات الأيضية قد تلعب دورًا في الفيزيولوجيا المرضية للصرع. قياس مستويات الإيوتكسين والعوامل البيولوجية المرتبطة به في المصل يوفر رؤى قيمة حول الالتهاب العصبي واضطراب الأيض في الصرع، وقد يكون بمثابة مؤشرات تشخيصية وتنبؤية. هدفت هذه الدراسة إلى تقييم العلاقة بين الإيوتكسين، الإنتلكتين-1، الكينورينين، وبرو بروتين كونفيرتاز-1 والصرع. تم تقسيم 90 مشاركًا إلى ثلاث مجموعات: 30 فردًا صحيًا كمجموعة ضابطة، 31 مريضًا بالصرع البؤري، و30 مريضًا بالصرع العام. تم جمع عينات الدم، وتم قياس العوامل البيولوجية في المصل باستخدام تقنية ELISA. تم إجراء التحليل الإحصائي باستخدام برنامج GraphPad. أظهرت النتائج أن مستويات الإيوتكسين والإنتلكتين-1 والكينورينين في المصل كانت مرتفعة بشكل كبير لدى مرضى الصرع مقارنةً بالمجموعة الضابطة، بينما كانت مستويات برو بروتين كونفيرتاز-1 منخفضة بشكل ملحوظ. تشير هذه النتائج إلى وجود ارتباط قوي لهذه العوامل البيولوجية مع الفيزيولوجيا المرضية للصرع. في الختام، قد يساهم تقييم الإيوتكسين والعوامل البيولوجية المرتبطة به في المصل في تعزيز فهم آليات المرض، ودعم الاكتشاف المبكر، والمساعدة في الوقاية من المضاعفات لدى مرضى الصرع.

الكلمات المفتاحية: الصرع، الإيوتاكسين، الإنتلكتين، الكينورينين، الإنزيم المحول العصبي الصماوي.