Original Article

Pharmacogenetic Determinants of Carbamazepine Response in Pediatric Epilepsy: Association of ABCB1, SCN1A, and UGT2B7 Gene Polymorphisms in a Kazakh Population

Moldir Dosbolova[1], Dinmukhamed Ayaganov[1], Sakhanova Svetlana[1], Jaxybayeva Altynshash[2], Marzhan Lepessova[3], Bakhytkul Myrzaliyeva[3], Mammadbayli Aytan Kamal[4], Donayeva Ainur[1]

ABSTRACT

Background

Interindividual variability in response to carbamazepine remains a major challenge in epilepsy management, with pharmacoresistance affecting up to one-third of patients. Genetic polymorphisms influencing drug transport, metabolism, and neuronal excitability may contribute to this variability.

Objective

To evaluate the association between polymorphisms in ABCB1 (rs1045642), SCN1A (rs2298771, rs3812718), and UGT2B7 (rs28365063) genes and clinical response to carbamazepine in pediatric epilepsy patients of Kazakh ethnicity.

Methods

A case–control study was conducted including 363 children with epilepsy and 240 age- and sex-matched controls. Genotyping was performed using PCR-based methods. Clinical outcomes included seizure frequency, pharmacoresistance, and adverse drug reactions. Associations were assessed using χ^2 tests and multivariate logistic regression.

Results

A significant association was observed for ABCB1 rs1045642 ($p < 0.001$), with the GG genotype conferring an increased risk of pharmacoresistance (AOR = 2.87; 95% CI: 1.74–4.73). The AG genotype was also associated with increased risk (AOR = 1.67; $p = 0.011$). For SCN1A rs2298771, overall significance was not reached; however, one genotype demonstrated a protective effect (AOR = 0.296; $p = 0.033$). No statistically significant associations were identified for SCN1A rs3812718 and UGT2B7 rs28365063.

Conclusion

The ABCB1 rs1045642 polymorphism is a significant predictor of carbamazepine resistance in pediatric epilepsy. These findings support the integration of pharmacogenetic profiling into individualized treatment strategies.

Keywords

epilepsy; pharmacogenetics; carbamazepine; ABCB1; SCN1A; UGT2B7; drug resistance; pediatric neurology

INTRODUCTION

Epilepsy is among the most common chronic neurological disorders, affecting an estimated 70 million individuals globally, with a prevalence ranging from 4 to 10 per 1,000 population and a notable peak in incidence during childhood[1,2]. Despite significant advances in treatment, approximately one-third of patients develop pharmacoresistance to antiepileptic drugs (AEDs), which contributes to substantial morbidity, psychosocial challenges, and an elevated risk of sudden unexpected death in epilepsy (SUDEP)[3].

In Kazakhstan, national registry data indicate that 76,678 individuals are living with epilepsy, with children comprising more than one-third of this population. However, comprehensive data on pharmacoresistant epilepsy within the country remain limited[4].

Among available AEDs, **carbamazepine (CBZ)** remains a first-line therapeutic option for focal seizures in both pediatric and adult populations due to its well-established efficacy and safety profile[5]. CBZ primarily acts through inhibition

1. West Kazakhstan Marat Ospanov Medical University , Aktobe, Kazakhstan.
2. National Children`s Rehabilitation Center.
3. Kazakhstan-Russian Medical University», Almaty, Kazakhstan.
4. Azerbaijan Medical University

Correspondence

Donayeva Ainur, Department of Emergency Medical Care, West KazakhstanMarat Ospanov Medical University, Aktobe, Kazakhstan. ainurzhan_ed@mail.ru
ORCID: https://orcid.org/0000-0002-7363-0789

Bangladesh Journal of Medical Science Vol. 25 No. 03 July'26

DOI: https://doi.org/10.3329/bjms.v25i3.90556

of voltage-gated sodium channels (NaV1.1), stabilizing neuronal membranes and reducing repetitive firing[6]. However, its narrow therapeutic index and wide interindividual variability in plasma concentrations contribute to the unpredictable efficacy and risk of adverse drug reactions (ADRs), including serious cutaneous events linked to specific genetic variants such as **HLA-B*15:02** and **HLA-A*31:01**[7].

Accumulating data suggest that this variability is largely influenced by polymorphisms in genes encoding drug-metabolizing enzymes and transporters, including **ABCB1**, **SCN1A**, and **UGT2B7**[7,8]. These genes regulate CBZ pharmacokinetics and pharmacodynamics by affecting absorption, blood–brain barrier penetration, and metabolic clearance. For instance, the **ABCB1 rs1045642 (C3435T)** polymorphism influences the expression and function of P-glycoprotein, altering CBZ efflux across the blood–brain barrier and thus its intraneuronal concentration[9]. Variants in **SCN1A** (rs2298771, rs3812718) modify sodium channel sensitivity to CBZ, impacting therapeutic response and seizure control[10,11]. Meanwhile, **UGT2B7 rs28365063** affects glucuronidation and plasma clearance, contributing to pharmacokinetic diversity [12-14].

Ethnic-specific allele frequencies play a critical role in pharmacogenetic interpretation. Studies across European and Asian cohorts have demonstrated population-dependent associations between these polymorphisms and CBZ response, emphasizing the need for population-tailored investigations[15-18]. However, to date, **no comprehensive pharmacogenetic studies of CBZ response have been conducted in the Kazakh pediatric population**, despite known genetic distinctiveness within Central Asian groups [19,20]. Understanding gene–drug interactions relevant to CBZ metabolism in this cohort could enhance treatment precision, reduce ADR incidence, and form the basis for **personalized antiepileptic therapy in children**.

Given this context, the present study aimed to investigate pharmacogenetic determinants of carbamazepine metabolism and response in Kazakh children with epilepsy. Specifically, we analyzed the association of **ABCB1 (rs1045642)**, **SCN1A (rs2298771, rs3812718)**, and **UGT2B7 (rs28365063)** polymorphisms with treatment resistance and clinical outcomes, aiming to identify genotype-dependent patterns that could guide individualized CBZ dosing strategies in pediatric patients.

MATERIALS AND METHODS

Children of Kazakh ethnicity undergoing carbamazepine monotherapy were investigated, and their clinical, demographic, and electroencephalographic features were analyzed according to the type of gene polymorphism. The frequencies of allelic variants for each polymorphism were determined and compared with published allele frequency data from other ethnic groups.

In this study, the main group consisted of 363 children receiving carbamazepine who continued to experience seizures despite treatment and had no structural brain abnormalities that could account for the lack of drug efficacy. The control group included 240 children matched for sex, age, and ethnicity, without a diagnosis of epilepsy.

Inclusion Criteria

1. Children with epileptic seizures;
2. Age between 0 and 18 years;
3. Children receiving carbamazepine;
4. Individuals of Kazakh ethnicity (for the second objective);
5. Absence of structural brain abnormalities (for the second objective).

Exclusion Criteria

1. Age above 18 years;
2. Children of other ethnicities (for the second objective);
3. Children receiving valproate (for the second objective);
4. Presence of structural brain abnormalities (for the second objective).

Determination of gene polymorphisms involved in carbamazepine metabolism and transport: DNA was extracted from blood samples, and DNA concentration was measured using an automated analyzer (SYNERGY LX multi-mode reader, BioTek, USA). Molecular genetic analysis was performed via real-time polymerase chain reaction (Real-Time PCR) using a PCRDTprime4 instrument ("DNA-Technology," Russia), with genotyping of the following polymorphisms: ABCB1 (rs1045642), SCN1A (rs2298771, rs3812718), and UGT2B7 (rs28365063)

2.4 Statistical analysis

Categorical data were described using absolute values and percentages, while quantitative data were presented as mean values with standard deviations. Statistical analysis of qualitative variables was performed using frequency analysis with the Pearson χ^2 test. For quantitative variables, the Mann–Whitney U test was used for comparisons between two groups, and one-way analysis of variance (ANOVA) was applied for comparisons among three or more groups. The presence and strength of associations between two variables were assessed using Spearman's rank correlation coefficient. The statistical analysis included Hardy–Weinberg equilibrium testing, a χ^2 test for genotype distribution, calculation of odds ratios (OR) with 95% confidence intervals, and multivariate logistic regression, with statistical significance defined as $p < 0.05$.

Ethical clearence

This study was conducted in accordance with ethical standards. Ethical approval was obtained from the appropriate institutional review board, and informed consent was secured from all participants prior to data collection.

RESULTS

Polymorphisms of the genes ABCB1 (rs1045642), SCN1A (rs2298771, rs3812718), and UGT2B7 (rs28365063) were studied and analyzed in children with Epilepsy in the Kazakh population. The main group consisted of 363 children, while the control group included 240 children.

Boys accounted for 201 (55.4%) and girls for 162 (44.6%), corresponding to a ratio of 1.2:1.0. The mean age of the children was 9.84 ± 2.34 years. The mean age at onset of epileptic seizures was 2.97 ± 1.01 years. Pharmacoresistant forms of epilepsy were observed in 127 (35%) cases. The control group was comparable in terms of sex and age. Tonic-clonic seizures predominated among all types of seizures.

Analysis of electroencephalographic changes revealed the following: spike–slow wave complexes were observed in 103 cases (28.4%), polyspike–slow waves in 45 cases (12.4%), sharp waves and sharp–slow wave complexes in 147 cases (40.5%), typical and modified hypsarrhythmia in 35 cases (9.6%), and multiregional changes in 33 cases (9.1%) Among 363 children, focal temporal epilepsy predominated (35.8%), followed by focal frontal epilepsy (28.6%) and epileptic encephalopathy with infantile spasms (22.1%).

Genotyping of ABCB1 rs1045642 showed that the GG genotype was the most frequent ($p = 0.0002$), suggesting potential resistance to Carbamazepine. The odds of carrying the GG genotype were 1.94 times higher (OR 1.94; 95% CI: 1.28–2.96).

Clinical analysis by genotype:

AA genotype (n = 74): Pharmacoresistance was observed in 27 children (36.5%). Seizure frequency ranged from once every 11 days to once every 42 days in pharmacoresistant patients, whereas children with a positive response experienced seizures from once every 127 days to once every 298 days. Adverse events were recorded in 17 children (22.9%).

AG genotype (n = 194): Pharmacoresistance occurred in 54 children (27.8%), with seizure frequency from once every 18 days to once every 56 days. Children responding to therapy had lower seizure frequency (once every 140–301 days). Adverse events occurred in 79 children (40.7%).

GG genotype (n = 95): Pharmacoresistance was more frequent (46 children, 48.4%), with seizure frequency ranging from once every 8 days to once every 29 days. Adverse events were recorded in 31 children (32.6%).

Reduced response to carbamazepine was associated with the CC genotype ($p = 0.06$; OR 2.78; 95% CI: 0.92–8.41).

TT genotype (n = 230): Pharmacoresistance in 76 children (36.5%); adverse events in 58 children (25.2%).

TC genotype (n = 116): Pharmacoresistance in 42 children (36.2%); adverse events in 62 children (53.4%).

CC genotype (n = 17): Pharmacoresistance in 9 children (52.9%); adverse events in 7 children (41.2%).

The CC (OR 1.27; 95% CI: 0.86–1.86) and TC (OR 1.05; 95% CI: 0.75–1.45) genotypes were predominant and may require dose adjustment of carbamazepine ($p = 0.09$).

TT genotype (n = 79): Pharmacoresistance in 41 children (51.9%); adverse events in 27 (34.2%).

TC genotype (n = 187): Pharmacoresistance in 70

(37.4%); adverse events in 40 (21.4%).

CC genotype (n = 97): Pharmacoresistance in 16 (16.5%); adverse events in 60 (61.8%).

Homozygous GG and heterozygous AG genotypes were more frequent in children receiving carbamazepine compared with controls (p = 0.17), indicating reduced metabolism of the drug.

AA genotype (n = 267): Pharmacoresistance in 96 children (35.9%); adverse events in 77 (28.8%).

AG genotype (n = 88): Pharmacoresistance in 30 (34.1%); adverse events in 45 (51.1%).

GG genotype (n = 8): Pharmacoresistance in 1 (12.5%); adverse events in 5 (62.5%).

Pharmacoresistance was most frequent in TT carriers of SCN1A rs2298771 (52.9%), followed by CC carriers of SCN1A rs3812718 (51.9%), GG carriers of ABCB1 rs1045642 (48.4%), and AA carriers of UGT2B7 rs28365063 (35.9%). Adverse events were most frequent in AA carriers of UGT2B7 rs28365063 (62.5%), followed by CC carriers of SCN1A rs3812718 (61.8%), TT carriers of SCN1A rs2298771 (53.4%), and GG carriers of ABCB1 rs1045642 (40.7%).

Statistical analysis and predictive modeling:

Comparative genotype frequency analysis showed statistical significance only for ABCB1 rs1045642 (p = 0.0002), while SCN1A rs2298771 showed a trend (p = 0.06). A predictive model for carbamazepine pharmacoresistance was developed using binary logistic regression ($p < 0.05$). Multifactor analysis indicated low explanatory power (Nagelkerke $R^2 = 0.057$), meaning predictors explained 5.7% of outcome variability. Age had no significant effect (B = 0.045; SE = 0.026; p = 0.083; OR = 1.046; 95% CI: 0.994–1.101).

ABCB1 rs1045642 was statistically significant ($p < 0.001$): AG genotype: 1.67-fold increased risk (AOR = 1.667; 95% CI: 1.125–2.470; p = 0.011). GG genotype: 2.87-fold increased risk (AOR = 2.872; 95% CI: 1.743–4.733; $p < 0.001$)

Suggests dose-dependent effect of the G allele on risk.

SCN1A rs2298771 showed a trend-level significance (p = 0.065); CC genotype was associated with reduced probability of pharmacoresistance (AOR = 0.296; 95% CI: 0.096–0.909; p = 0.033), while TC genotype was not significant (p = 0.088).

Table 1 – Frequency of alleles and genotypes of the ABCB1rs1045642

Genotypes	Cases	Controls	χ^2	p	OR	
	n = 363	n = 240			value	95% CI
Genotype AA	0.204	0.329	16.66	0.0002	0.52	0.36 – 0.76
Genotype AG	0.534	0.517			1.07	0.77 – 1.49
Genotype GG	0.262	0.154			1.94	1.28 – 2.96

Table 2 – Frequency of alleles and genotypes of the SCN1A rs2298771

Genotypes	Cases	Controls	χ^2	p	OR	
	n = 363	n = 240			value	95% CI
Genotype T/T	0.635	0.694	3.65	0.06	0.77	0.54 – 1.09
Genotype T/C	0.320	0.289			1.16	0.81 – 1.65
Genotype C/C	0.045	0.017			2.78	0.92 – 8.41

Table 3 – Frequency of alleles and genotypes of the SCN1A rs3812718

Genotypes	Cases	Controls	χ^2	p	OR	
	n = 363	n = 240			value	95% CI
Genotype T/T	0.216	0.271	2.88	0.09	0.74	0.51 – 1.08
Genotype T/C	0.515	0.504			1.05	0.75 – 1.45
Genotype C/C	0.269	0.225			1.27	0.86 – 1.86

Table 4 – Frequency of alleles and genotypes of the UGT2B7 rs28365063

Genotypes	Cases	Controls	χ^2	p	OR	
	n = 363	n = 240			value	95% CI
Genotype A/A	0.735	0.785	1.86	0.17	0.76	0.51 – 1.12
Genotype A/G	0.242	0.198			1.29	0.86 – 1.93
Genotype G/G	0.023	0.017			1.36	0.40 – 4.56

Table 5 - Comparison of Genotype Frequencies by Group

Gene	Groups				p
	Main		Control		
	Abs.	%	Abs.	%	
ABCB1 rs1045642					<0,001*
AA	74	20,4	79	32,9	
AG	194	53,4	124	51,7	
GG	95	26,2	37	15,4	
SCN1A rs2298771					0,078
CC	4	1,7	17	4,7	
TC	69	28,7	116	32,0	
TT	167	69,6	230	63,4	
SCN1A rs3812718					0,250
CC	54	22,5	97	26,7	
TC	121	50,4	187	51,5	
TT	65	27,1	79	21,8	
UGT2B7 rs28365063					0,407
AA	188	78,3	267	73,6	
AG	48	20,0	88	24,2	
GG	4	1,7	8	2,2	

Table 6 – Characteristics of the Association Between Predictors and the Probability of Epilepsy Diagnosis

Predictors	Unadjusted		Adjusted	
	COR; 95% CI	p	AOR; 95% CI	p
Age	1,037; 0,987-1,091	0,150	1,046; 0,994–1,101	0,083
ABCB1 rs1045642				
AA	ref	<0,001*	ref	<0,001*
AG	1,670; 1,132-2,464	0,010*	1,667; 1,125–2,470	0,011*
GG	2,741; 1,671-4,496	<0,001*	2,872; 1,743–4,733	<0,001*
SCN1A rs2298771				
TT	ref	0,092	ref	0,065
TC	1,221; 0,853-1,747	0,276	0,369; 0,118–1,160	0,088
CC	3,086; 1,020-9,338	0,046	0,296; 0,096–0,909	0,033*

DISCUSSION

This study demonstrates a strong association between ABCB1 rs1045642 polymorphism and carbamazepine resistance in pediatric epilepsy. The findings are consistent with the role of P-glycoprotein in limiting drug penetration across the blood–brain barrier.

The lack of strong associations for SCN1A and UGT2B7 polymorphisms may reflect population-specific genetic architecture or insufficient statistical power.

Importantly, the modest predictive value of the regression model suggests that pharmacoresistance is a multifactorial phenomenon requiring integration of genetic, clinical, and environmental factors.

CONCLUSION

The ABCB1 rs1045642 polymorphism is significantly associated with carbamazepine resistance in children with epilepsy in the Kazakh population.

These findings support the clinical utility of pharmacogenetic testing in optimizing antiepileptic therapy and advancing precision medicine approaches.

6. Strengths and Limitations

Strengths:

First study in Kazakh pediatric population

Comprehensive clinical and genetic analysis

Limitations:

Limited number of polymorphisms

Moderate explanatory power

Lack of replication cohort

7. Future Perspectives

Future studies should incorporate:

Genome-wide approaches

Multi-center cohorts

Integration with clinical prediction models

Funding: No Funding

Conflict of Interest: The authors declare no conflict of interest.

Authors's contribution

Data gathering and idea owner of this study: Moldir Dosbolova, Dinmukhamed Ayaganov,

Study design: Sakhanova Svetlana, Jaxybayeva

Altynshash,

Data gathering: Marzhan Lepessova, Bakhytkul Myrzaliyeva,

Writing and submitting manuscript: Mammadbayli Aytan, Donayeva Ainur

Editing and approval of final draft: Donayeva Ainur

REFERENCES

1. Beghi E. The Epidemiology of Epilepsy. *Neuroepidemiology.* 2020;**54**(2):185-191. doi: 10.1159/000503831. Epub 2019 Dec 18. PMID: 31852003.
2. World Health Organization. *Epilepsy Fact Sheet.* 2022. https://www.who.int/news-room/fact-sheets/detail/epilepsy
3. Löscher W., Potschka H., Sisodiya S.M., Vezzani A. *Drug resistance in epilepsy: clinical impact, mechanisms, and new treatments. Pharmacol Rev*. 2020;**72**(3):606–638.
4. Akhmedullin R, Kozhobekova B, Gusmanov A, Aimyshev T, Utebekov Z, Kyrgyzbay G, Shpekov A, Gaipov A. Epilepsy trends in Kazakhstan: A retrospective longitudinal study using data from unified national electronic health system 2014-2020. *Seizure.* 2024 Nov;122:58-63. doi: 10.1016/j.seizure.2024.09.022. Epub 2024 Sep 30. PMID: 39368328.
5. Matricardi S., Farrell J., Operto F.F., Coppola G., Verratti A. What are the problems of pharmacological treatment of epilepsy in patients with attention deficit hyperactivity disorder (ADHD)? *ExpopinPharmacotere* . (2020) **21** :737-9. 10.1080/14656566.2020.1732351
6. Nickel S. K.K., Zaccariello M.J., Hamivka L.D., Worrell E.K. Cognitive diseases and concomitant diseases of the nervous system in childhood epilepsy. *Nat is a preparatory Neuro* . (2016) **12** : 465-76. 10.1038/ nov.2016.98
7. Myers CT, MeffordHC.The genetic spread of epilepsy in the epoch genome.*GenomeMed*. 2015; 7:91 .doi: 10.1186/s13073-015-0214-7.
8. Cárdenas-Rodríguez N, Carmona-Aparicio L, Pérez-Lozano DL, Ortega-Cuellar D, Gómez-Manzo S, Ignacio-Mejía I. Genetic variations associated with pharmacoresistant epilepsy (Review). *Mol Med Rep*. 2020 Apr;**21**(4):1685-1701. doi: 10.3892/mmr.2020.10999. Epub 2020 Feb 24. PMID: 32319641; PMCID: PMC7057824.
9. Balestrini S, Arzimanoglou A, Blümcke I, Scheffer IE, Wiebe S, Zelano J, Walker MC. The aetiologies of epilepsy. *Epileptic Disord.* 2021 Feb 1;**23**(1):1-16. doi: 10.1684/epd.2021.1255. PMID: 33720020.
10. Falco-Walter JJ, Scheffer IE, Fisher RS. The new definition and classification of seizures and epilepsy. *Epilepsy Res.* 2018 Jan;**139**:73-79. doi: 10.1016/j.eplepsyres.2017.11.015. Epub 2017 Nov 28. PMID: 29197668.
11. Yang LZ, Guo Y, Wang ZQ, Zhang CQ. A population-based analysis of the global burden of epilepsy across all age groups (1990-2021): utilizing the Global Burden of Disease 2021 data. *Front Neurol*. 2024 Dec 12;**15**:1448596. doi: 10.3389/fneur.2024.1448596. PMID: 39726763; PMCID: PMC11669576.
12. PatelP, MoshéSL. The evolution of the concepts of seizures and epilepsy: What's in a name? *Epilepsia Open.* 2020 Jan 10;**5**(1):22-35. doi: 10.1002/epi4.12375. PMID: 32140641; PMCID: PMC7049807.
13. Hampel KG, Garces-Sanchez M, Gomez-Ibanez A, Palanca-Camara M, Villanueva V. Desafiosdiagnosticos en epilepsia [Diagnostic challenges in epilepsy]. *Rev Neurol.* 2019 Mar 16;**68**(6):255-263. Spanish.doi: 10.33588/rn.6806.2018242. PMID: 30855710.
14. Xu C, Gong Y, Wang Y, Chen Z. New advances in pharmacoresistant epilepsy towards precise management-from prognosis to treatments. *PharmacolTher.* 2022 May;**233**:108026. doi: 10.1016/j.pharmthera.2021.108026. Epub 2021 Oct 28. PMID: 34718071.
15. Reza, Z., M, S., K, H. Z., & Parsipur, S. (2021). Perspective of people with epilepsy about Epilepsy. *Bangladesh Journal of Medical Science*, **20**(2), 374–378. https://doi.org/10.3329/bjms.v20i2.51551
16. Auvin S, Specchio N. Pharmacotherapeutic strategies for drug-resistant epilepsy in children. Epilepsy Behav. 2024 Dec;**161**:110139. doi: 10.1016/j.yebeh.2024.110139. Epub 2024 Nov 7. *PMID*: 39515006
17. Johannessen Landmark C, Johannessen SI, Patsalos PN. Therapeutic drug monitoring of antiepileptic drugs: current status and future prospects. *Expert Opin Drug MetabToxicol*. 2020 Mar;**16**(3):227-238. doi: 10.1080/17425255.2020.1724956. Epub 2020 Feb 13. PMID: 32054370
18. Zhang X, Liu J, Ye J. Association between SCN1A polymorphism and carbamazepine responsiveness in epilepsy: A meta-analysis. *Epilepsy Res.* 2021 Oct;**176**:106627. doi: 10.1016/j.eplepsyres.2021.106627. Epub 2021 Jun 2. PMID: 34218210.
19. Bayanova M, Bolatov AK, Bazenova A, Nazarova L, Nauryzbayeva A, Tanko NM, Rakhimova S, Satvaldina N, Samatkyzy D, Kozhamkulov U, Kairov U, Akilzhanova A, Sarbassov D. Whole-Genome Sequencing Among Kazakhstani Children with Early-Onset Epilepsy Revealed New Gene Variants and Phenotypic Variability. *Mol Neurobiol*. 2023 Aug;**60**(8):4324-4335. doi: 10.1007/s12035-023-03346- Epub 2023 Apr 24. Erratum in: *Mol Neurobiol*. 2025 May;**62**(5):6628. doi: 10.1007/s12035-024-04544-3. PMID: 37095367; PMCID: PMC10293429.
20. Yerezhepov, D. ., Gabdulkayum, A., Satvaldina, N., Rakhimova, S., Bayanova, M., Kairov, U., & Akilzhanova, A. (2025). Whole-Genome Sequencing Reveals Genetic Variants in Pediatric Epilepsy Patients of Kazakhstan. *Eurasian Journal of Applied Biotechnology*, (3s). https://doi.org/10.11134/btp.3s.2025.12