Ranking Epilepsy Risk Factors Using Machine Learning

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Research Article

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Abstract

Background

Machine learning methods to predict the risk of epilepsy, including vascular epilepsy, in oncohematological patients are currently considered promising. These methods are actively used in epileptology to predict pharmacoresistant epilepsy, surgical treatment outcomes, to determine the epileptogenic zone and functional neural systems in patients with epilepsy, as well as to develop new approaches to classification and perform other tasks.

This paper presents the results of applying machine learning to analyzing data and developing models of epilepsy in vascular and oncohematological patients.

Methods

We analyzed the hospital database of the V.A. Almazov Scientific Research Center of the Ministry of Health of Russia. The study included 66723 treatment episodes of patients with vascular diseases (I10-I15,I61-I69,I20-I25) and 16383 episodes with malignant neoplasms of lymphoid, hematopoietic, and related tissues (C81-C96 according to ICD-10) for the period from 2010 to 2020.

Results

Data analysis and model calculations indicate that the best result was shown by gradient boosting with mean accuracy cross-validation score = 0.96. f1-score = 98, weighted avg precision = 93, recall = 96, f1-score = 94. The highest correlation coefficient for G40 was achieved with fibrillation, hypertension, stenosis or occlusion of the precerebral arteries (0.16), cerebral sinus thrombosis (0.089), arterial hypertension (0.17), age (0.03), non-traumatic intracranial hemorrhage (0.07), atrial fibrillation (0.05), delta absolute neutrophil count (0.05), platelet count at discharge (0.04), transfusion volume for stem cell transplantation (0.023).

Conclusion

From the clinical point of view, the identified differences in the importance of predictors in a broader patient model are consistent with a practical algorithm for organic brain damage. Atrial fibrillation is one of the leading factors in the development of both ischemic and hemorrhagic strokes. At the same time, brain infarction can be accompanied both by the development of epileptic seizures in the acute period and by unprovoked epileptic seizures and development of epilepsy in the early recovery and in a longer period. In addition, microembolism of the left heart chambers can lead to multiple microfocal lesions of the brain, which is considered to be one of the pathogenetic aspects of epilepsy in elderly patients.

Background

Malignant diseases of the hematopoietic system, despite their relatively low prevalence in the population, are a socially significant group of heterogeneous nosological forms. Neurological complications in this cohort of patients occur both in correlation with disease or with ongoing treatment. These complications may affect patient survival and may determine whether the therapy protocol can be fully implemented [1]. Acute symptomatic seizure (ACS) is one of the most significant neurological complications because of its high incidence and impact on survival [2]. A number of studies have evaluated the risk of ACS in this cohort of patients [1], [3], [4], while assessment of the risks of epilepsy is virtually unreported in the research to date [5], [6].

Arterial hypertension is also considered to be one component in the continuum of cardiovascular complications in oncohematological patients, developing due to both disease-related and treatment-related factors [7], [8]. On the other hand, arterial hypertension has been identified as one of the risk factors for the late-onset epilepsy in the general population [9].

Posterior reversible encephalopathy syndrome (PRES) is a brain lesion associated with hypertension, which may determine the risk of epilepsy by indirect (in relation to arterial hypertension itself) mechanisms [10]. In the general population of patients with PRES syndrome, ACS occurs in 77% of cases [11]. In the cohort of oncohematological patients, the development of PRES syndrome may be accompanied by ACS in 97% of cases [12]. In the general population, arterial hypertension is the main etiological factor in the development of PRES syndrome (72%) [13], retaining its significance as a risk factor for the development of this complication in oncohematological patients as well (HR 14.466, 95% CI 7.107–29.443, $p < 0.001$) [12]. The risk of epilepsy in patients with PRES syndrome is generally assessed as low, but may increase significantly in the presence of signs of cytotoxic edema and ACS in the debut of PRES syndrome [14].

The use of machine learning methods to predict the risk of complications in oncohematological patients has proven to be promising [15]. These methods are actively used in epileptology, for example, to predict the pharmacoresistant epilepsy [16], surgical treatment outcomes [17], to determine the epileptogenic zone [18] and functional neural systems in patients with epilepsy [19], develop new classification approaches [20][21], and perform other tasks [22]. Machine learning models are actively used in decision support systems to treat patients with various forms of epilepsy[23], [24]. At the same time, classical statistical methods of analysis are usually used to identify factors associated with the development of epilepsy within a typical case-control study design. Thus, the factors related with the presence of epilepsy and prognostic tools that substantiate the optimal model for determining the risk of epilepsy in oncohematological patients are not fully understood at the moment.

Objectives

This paper presents the results of applying machine learning to analyzing data and developing models of epilepsy in oncohematological patients. We evaluate factors associated with the development of epilepsy

in oncohematological patients and the effect of arterial hypertension and the number of transplanted hematopoietic stem cells on the risk of epilepsy.

Methods

A single-center retrospective study was conducted. We analyzed the hospital database of the V.A. Almazov Scientific Research Center of the Ministry of Health of Russia. The study included 66723 treatment episodes (Dataset II) with 3723 patients with 16383 treatment episodes (Dataset I) of patients with malignant neoplasms of lymphoid, hematopoietic, and related tissues (C81-C96 according to ICD-10) for the period from 2010 to 2020 with the following comorbidities: 14 % of I60-I69, fibrillation – 6%, epilepsy (G40) – 1,5 %, hypertension – 20 %, females – 49%, Age mean – 52,5 (min – 1, max – 90, std – 19.1, 25% – 40, 50% – 57, 75% – 66), Males – 44%, Females – 56%, Main diagnosis when transplanting the hematopoietic stem cells: C90.0 Multiple myeloma – 10 %, Peripheral blood autologous stem cell concentrate with dimethyl sulfoxide preservative – 46%, Body weight mean – 74, systolic blood pressure 2 hours after transfusion – mean – 117 (std – 13, min – 45.0, max – 165.0, 25% – 110.0, 50% – 120.0, 75% – 124.0).

Study datasets

Dataset I was formed to develop a detailed descriptive and prognostic model of epilepsy for clinical, anamnestic, and laboratory patient factors in patients with oncohematology.

Inclusion Criteria

1. Age: 1–90 years old

2. Diagnosis: verified malignant neoplasms of lymphoid, hematopoietic, and related tissues

3. Case type: inpatient treatment

Exclusion criteria

Absence of oncohematological or cardiac disease. Outpatient treatment was an exclusion criterion.

A total of 356 factors were extracted for each patient, including gender and constitutional factors, presence of comorbid pathology, factors for hematopoietic stem cell transplantation, and laboratory parameters. Outpatient treatment was an exclusion criterion.

As an endpoint, we analyzed whether the patient had epilepsy (presence of ICD-10 G40 diagnosis).

Dataset II was formed to develop a descriptive and prognostic model of epilepsy in patients with cardiovascular disease to identify vascular factors in the development of epilepsy. Therefore, a group of patients with epilepsy both with and without oncohematological diagnosis was selected for this stage of the analysis to identify the contribution of the presence of oncohematological diagnosis to epilepsy. A

second dataset was generated to analyze epilepsy in a wider patient group of 35634 patients with 66723 treatment episodes with 285 parameters among which: Age mean – 55 (std – 19, min – 1, max 99, 25% – 46, 50% – 60, 75% – 69), presence of comorbid diseases (hypertension, cerebral vascular disease, infarcts, atrial fibrillation and congenital heart disease (CHD), laboratory values, blood pressure, fibrillation (13%), G40–8%, Males – 44%, Females – 56%, BMI mean – 1.87 (std – 0.33, min – 0.17, max – 6.06, 25% – 1.73, 50% – 1.9, 75% – 2.06).

Inclusion Criteria

1. Age: 1–99 years old

Diagnosis: hypertension, acute coronary syndrome (ACS), strokes, coronary artery disease (CAD), congenital heart disease (CHD), verified malignant neoplasms of lymphoid, hematopoietic, and related tissues

2. Case type: inpatient treatment

Exclusion criteria:

1. absence of cardiovascular disease and oncological disease.

2. Outpatient treatment was an exclusion criterion.

A total of 285 features were extracted for each patient in the datasets I and II, including gender and constitutional factors, presence of comorbid pathology, factors for hematopoietic stem cell transplantation, and laboratory parameters

Correlation analysis

The Pearson coefficient was used to assess the correlation of the G40 with the analyzed factors. The chi-squared criterion was applied to the binary values.

Machine Learning Methods

Gradient boosting and random forest models were applied.

Parameters of the model are XGBClassifier (base_score = 0.5, booster = None, colsample_bylevel = 1, colsample_bynode = 1, colsample_bytree = 0.6, gamma = 2, gpu_id=-1, importance_type='gain', interaction_constraints = None, learning_rate = 0.300000012, max_delta_step = 0, max_depth = 5, min_child_weight = 2, missing = nan, monotone_constraints = None, n_estimators = 100, n_jobs = 0, num_parallel_tree = 1, random_state = 0, reg_alpha = 0, reg_lambda = 1, scale_pos_weight = 1, subsample = 0.8, tree_method = None, validate_parameters = False, verbosity = None).

The parameters of the random forest were taken by default.

We also searched for optimal hyperparameters of the model using the greedy search method, RandomizedSearchCV, GridSearchCV with params = { 'min_child_weight': [1, 2, 3, 4, 5, 6, 7, 8, 9, 10], 'gamma': [0.5, 1, 1.5, 2, 5],

'subsample': [0.1,0.2,0.3,0.4,0.5,0.6,0.8,0.9,1.0], 'colsample_bytree': [0.1,0.2,0.3,0.4,0.5,0.6,0.8,0.9,1.0], 'max_depth': [2, 3, 4, 5, 6, 7, 8, 9, 10, 15] }

Cross validation was performed using the built-in sklearn.model_selection train_test_split method by equal 5 folds, and 15% of the sample was cut off for the test. The mean cross-validation score was calculated using the built-in sklearn.model_selection cross_val_score method. The strategy for filling in the gaps was median by the digest of age decades.

Significance of predictors

Using the Shapley index, predictor significance factors were calculated in a model on an epilepsy class in patients with oncohematology and in a sample of patients with Cerebrovascular disease.

Cerebrovascular disease

After the first stage of data analysis, we detailed the parameters of cerebrovascular pathology I60–I69 as a significant factor associated with the presence of epilepsy. The detailing was carried out according to ICD-10 classification subheadings and included a search for specific nosological forms, including that within I67 and I65 nosologies, which showed the greatest significance in the model for the “epilepsy” class.

The ranking of predictors for the presence of an epilepsy diagnosis on Dataset II was performed using the built-in method of predictor significance according to the Gini criterion in sklearn with the setting of “balanced_subsample” weights autobalancing. The weight of each subsample varied according to the class distribution in that subsample. The built-in method provided an estimate of the significance of each individual feature in the model, in contrast to the Shapley index.

Results

Dataset I

As a result of data analysis and model calculations, the best result was shown by gradient boosting with mean accuracy cross-validation score = 0.96, f1-score = 98, weighted avg precision = 93, recall = 96, f1-score = 94.

The highest correlation coefficient for the presence of epilepsy and recurrent seizures (G40) was achieved with stenosis or occlusion of the precerebral arteries (0.16), cerebral sinus thrombosis (0.089), arterial hypertension (0.17), age (0.03), non-traumatic intracranial hemorrhage (0.07), atrial fibrillation (0.05), delta absolute neutrophil count (0.05), platelet count at discharge (0.04), transfusion volume for stem cell transplantation (0.023).

The results of the Shapley index analysis of factors associated with the development of epilepsy in oncohematological patients are presented in Fig. 1.

The results of the Shapley index analysis of the effect of arterial hypertension as a function of patient age on the risk of epilepsy are shown in Fig. 2.

The effect of cerebral venous sinus thrombosis and arterial hypertension on the risk of epilepsy is shown in Fig. 3.

The effect of the number of transplanted hematopoietic stem cells on the risk of epilepsy is shown in Fig. 4.

Dataset II

For the next stage of the analysis, a group of patients with epilepsy with and without the oncohematological diagnosis was selected to identify the contribution of the presence of oncohematological diagnosis on epilepsy.

Figure 5 shows that children (1–17 years old) are characterized by a slight increase in the risk of epilepsy in the presence of oncohematological disease, but the absence of oncological disease significantly increases the risk of epilepsy.

In the age group of 18–40 years old, there was a gradual decrease in the influence of the “oncohematological disease” factor on the risk of epilepsy. In the age range of 40–60 years old, the presence/absence of oncohematological disease had almost no effect on the risk of epilepsy. At the same time, after the age of 60, the presence of such disease increased the risk of epilepsy in patients.

When ranking the features associated with the presence of epilepsy, atrial fibrillation was found to have the highest weight, and oncohematological disease was the third most important feature (Fig. 7).

Discussion

General

A number of factors (clinical, gender, and laboratory) have been associated with the development of epilepsy in oncohematological patients. These factors can be grouped as follows:

- vital signs (age, body mass index, patient weight);
- cardiovascular pathology, cerebrovascular pathology (arterial hypertension, stenosis or occlusion, occlusion and stenosis of precerebral arteries, cerebral sinus thrombosis, cerebral artery dissection without rupture, cerebral aneurysmatic disease, cerebral infarction);
- laboratory parameters (maximum absolute monocyte count, average hemoglobin content of red blood cells, neutrophil count, platelet count at hospital discharge, minimum hematocrit value,

minimum and average blood sodium levels);

- hematopoietic stem cell transplantation parameters (donor blood group, number of transplanted cells).

A number of factors had no significant effect on the risk of epilepsy. Demographic characteristics such as sex, age, and body weight were generally not significant. In spite of the known features of the age distribution of epilepsy, this relationship was not detected in the group of oncohematological patients. This fact may be related to the peculiarities of etiological factors in this cohort of patients, but further studies are needed to clarify the influence of various factors in different age groups.

Risk factors

Among the laboratory parameters, both granulocytic and erythrocytic hematopoiesis parameters and platelet levels were found to be significant factors influencing the presence of epilepsy in oncohematological patients. Changes in these parameters are influenced by both the blood disease itself and its complications, as well as the administered therapy. A higher neutrophil count may indirectly indicate infectious complications or a more severe/prolonged course. In this regard, we can assume that factors such as infectious complications and hypofunction of the transplant, which are accompanied by significant laboratory changes, may explain the presence of these factors among the parameters influencing the epilepsy in this group of patients. Thrombocytopenia may be a risk factor for primarily intracranial hemorrhages in oncohematological patients [25]–[27]. These complications can lead to the formation of an epileptogenic substrate in the brain. In addition, the lower platelet count could be due to the antiepileptic therapy being taken. Although epidemiological data on the development of epilepsy in patients with cerebral sinus thrombosis are not available, our results concerning the role of this factor in the development of epilepsy are more significant. Unfortunately, extrapolation to the general population is not possible given the sample of patients in our study (oncohematological patients).Thrombocytopenia was not previously considered a risk factor for epilepsy in the general population, as well as in the population of patients with other neurological [28]–[30] or general pathology [31].

The relationship between the development of Cerebral venous sinus thrombosis (CVST) and oncology in general, and oncohematology in particular, has been investigated in a number of scientific papers [32][33][34]. Patients with oncohematologic diseases have a higher risk of CVST (aOR, 25.14; 95% CI, 11.64–54.30) than patients with solid cancer (aOR, 3.07; 95% CI, 2.03–4.65) [35]. Risks are even more severe in the first year after the cancer has been diagnosed (oncohematological OR, 85.57; 95% CI, 19.70–371.69; solid cancer aOR, 10.50; 95% CI, 5.40–20.42) [35]. CVST can account for up to 31.5% of all venous thromboembolic complications, for example, in a cohort of adult patients with acute myeloblastic leukemia[36].

Dimethyl sulfoxide as a factor is considered in the studies and can provoke the development of ACS. It can cause cardiovascular complications including ischemic stroke in the early post-transplant period [37]–[39]. In this regard, it is important to emphasize the contribution of the number of cells injected

during transplantation in the risk of epilepsy that we identified in patients with arterial hypertension. This emphasizes the possible cardiovascular mechanisms of this effect.

The significance of the factor of presence of I67.6 (Nonpyogenic thrombosis of intracranial venous system) including in young patients could be due to indirect mechanisms of stroke development. Epidemiological data on the development of epilepsy in patients with cerebral sinus thrombosis are not available. This emphasizes the significance of our findings regarding the role of this factor in the development of epilepsy.

Arterial hypertension

Arterial hypertension contributed the most to the presence of epilepsy in oncohematological patients (Fig. 1).This, along with the presence of less significant vascular factors (extracranial arteries stenosis/occlusion, cerebral sinus thrombosis, cerebral artery dissection without rupture, cerebral aneurysmatic disease, cerebral infarction), may indicate a significant role of cerebrovascular pathology in the presence of epilepsy in this group of patients. Younger age may be related, on the one hand, to the younger age of oncohematological patients, and on the other hand, to a known peak of higher prevalence of epilepsy specifically in young people in the general population.

This fact may be associated with a higher incidence of complications associated with arterial hypertension at a young age. For example, reversible vasoconstriction syndrome in the posterior cerebral circulation. The presence of arterial hypertension in younger patients (18–23 years old) significantly increased the likelihood of epilepsy, while in older patients (including the elderly, over 65 years of age), its presence had the opposite effect: it reduced the likelihood of epilepsy.

Interestingly, the combined presence or absence of cerebral venous sinus thrombosis and arterial hypertension altered the likelihood of epilepsy in patients.

Cerebral sinus thrombosis

As shown in the Fig. 2, in the absence of Cerebral venous sinus thrombosis (CVST), the presence/absence of arterial hypertension had no significant effect on the risk of epilepsy. While during the development of CVST, arterial hypertension sharply increased its significance as a factor in the presence of epilepsy in the patient.

CVST itself is a well-known risk factor for the development of acute symptomatic epileptic seizures and epilepsy [40][41][42]. Meanwhile, the relationship between CVST and arterial hypertension in terms of epilepsy risk has been described for the first time and may reflect the presence of combined mechanisms of these conditions in oncohematological patients.

A number of hematologic factors can determine the risk of CVST. The development of this complication may be associated with a higher platelet count ($p < 0.001$) and a higher platelet/neutrophil index ($p < 0.001$) [43]. The incidence of ACS in the acute phase of CVST is up to 34% in the general adult population. The incidence of ACS in CVST in children is 37.5–57%. This is often the main manifestation

of the development of thrombosis [44], [45]. The results of a study of the risk of epilepsy in young patients and children show that systemic inflammation, a reflection of which may be the fact of increased platelets, may play a significant role. This role can be both direct and mediated through the development of complications involving the CNS) in the development of epilepsy [46]. Given the heterogeneity of causes leading to the development of elevated neutrophil levels, unambiguous interpretation is difficult and the role of systemic inflammation in the development of epilepsy requires further study [29].

Transplanted hematopoietic stem cells

Among the factors associated with hematopoietic stem cell transplantation, a higher volume of transplanted cells was associated with the presence of epilepsy (Fig. 4). This factor increased its weight in patients with arterial hypertension. This may indicate a possible role of the volume of donor cell infusion, and, accordingly, the volume of cryopreservative injected, on the development of not only acute arterial hypertension, but also other complications, including epilepsy.

Age factor

The factor of age for predicting the presence of epilepsy in oncohematological patients had different significance depending on the age group (Fig. 5). In patients under 18 years old, the presence of a malignant neoplasm of the blood system reduced the likelihood of epilepsy. This may be related to the debut of hereditary genetically determined forms of epilepsy syndromes with no etiological and pathogenetic connection to oncohematological diseases. At the age of 18–20 years, there was an increase in the prognostic significance of the presence of C81–C96 on the risk of epilepsy. This may be related to the transition of patients to adult inpatient care, changes in neoplasm treatment protocols, and possible disruption of continuity between specialists. This leads to a possible increase in the risk of complications. In the age group of 60 years and older, the presence of C81–C96 diseases increased the likelihood of a patient having epilepsy. This is associated with an increased number of complications leading to damage of the brain substance due to the presence of other comorbid pathology (primarily, pathology of the cardiovascular system) and its decompensation against the background of oncological disease therapy.

At the same time, in the same sample of patients, when analyzing the importance of predictors for the oncohematological diagnosis class, we can see that the absence of epilepsy is in no way related and does not contribute to the model for the oncohematological diagnosis class, as opposed to the presence of epilepsy (Fig. 6).

Dataset I VS Dataset II patients

When performing a features-engineering of a model of epilepsy in oncohematological patients, one should be aware that some important model features may be missed, so the model development cycle should include a step to compare the significance of the features with the model for a wider group of

patients. If differences in the importance of predictors are found, validation and interpretation of the results and adjustment of the initial narrow model with the identified limitations are necessary.

From the clinical point of view, the identified differences in the importance of predictors (Fig. 7) in a broader patient model are consistent with a practical algorithm for organic brain damage. Atrial fibrillation is one of the leading factors in the development of both ischemic and hemorrhagic strokes. At the same time, brain infarction can be accompanied both by the development of epileptic seizures in the acute period and by unprovoked epileptic seizures and development of epilepsy in the early recovery and in a longer period. In addition, microembolism of the left heart chambers can lead to multiple microfocal lesions of the brain, which is considered to be one of the pathogenetic aspects of epilepsy in elderly patients. In addition, the presence of precordial fibrillation requires anticoagulant therapy, the use of which increases the risk of both spontaneous and traumatic intracranial hemorrhage. Which, in the case of involvement of the brain substance, forms an epileptogenic substrate in the form of hemosiderin zones.

Limitations of the study

The limitations of this study are related to the neurotoxicity of a number of chemotherapy drugs used to treat oncohematological patients, which increase the risk of ASS (acute symphtomatic seizure) and other neurological complications. This can lead to structural damage to the brain substance (e.g., ischemic stroke and intracranial hemorrhage).This can lead to structural damage to the brain substance (e.g., ischemic stroke and intracranial hemorrhage).

Conclusion

Patients with oncohematological pathology have a number of clinical and laboratory factors that correlate with the presence of epilepsy. In addition, age and a number of factors associated with Hematopoietic cell transplantation also correlate with the presence of epilepsy in patients with malignant neoplasms of lymphoid, hematopoietic and related tissues. This study shows how age characteristics influence the significance of other predictors. Patient age and shelf life of the transplanted cells change the significance. The obtained results of the thrombosis factor in the development of epilepsy have a meaningful effect because this issue has been poorly described previously.

Abbreviations

ACS
Acute symptomatic seizure
ICD-10
International Classification of Diseases, 10th revision
PRES
Posterior reversible encephalopathy syndrome
ASS

acute symphtomatic seizure
CVST
Cerebral venous sinus thrombosis
CI
confidence indicator
BMI
Body mass index
CAD
coronary artery disease
CHF
congestive heart failure
CHD
congenital heart disease
ANN
artificial neuron network
DT
decisions tree
AUC
Area under the Curve
ROC
receiver operating characteristic curve
PDW
platelet distribution width
SVM
support vector machine
HGB
Hemoglobin
LEU
Leukocytes
PLT
Platelets
MPW
Mean platelet volume
MCH
Mean cell hemoglobin
NEUT
Neutrophils
MCV
Mean corpuscular volume
PCT

Procalcitonin
RDW
Red blood cell distribution width
ALT
Alanine transaminase
PDW
Platelet distribution width
HDL
High-density lipoprotein
AST
Aspartate aminotransferase
WBC
White blood count
RBC
Red blood cell count
HCT
Hematocrit
LDL
Low-density lipoproteins
BLD
Blood in urine

Declarations

Ethics approval and consent to participate

The local ethics committee of ITMO university approved the study.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The need for consent was waived by the ethics committee as the study used anonymized data.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

GK and OM were responsible for a literature review, setting up the concept and methods and writing the manuscript. IS was responsible for the data analysis. AP and SY were responsible for clinical interpretations. GK and OM were responsible for writing and reviewing of the manuscript. All authors read and approved the final version of the manuscript.

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Figures

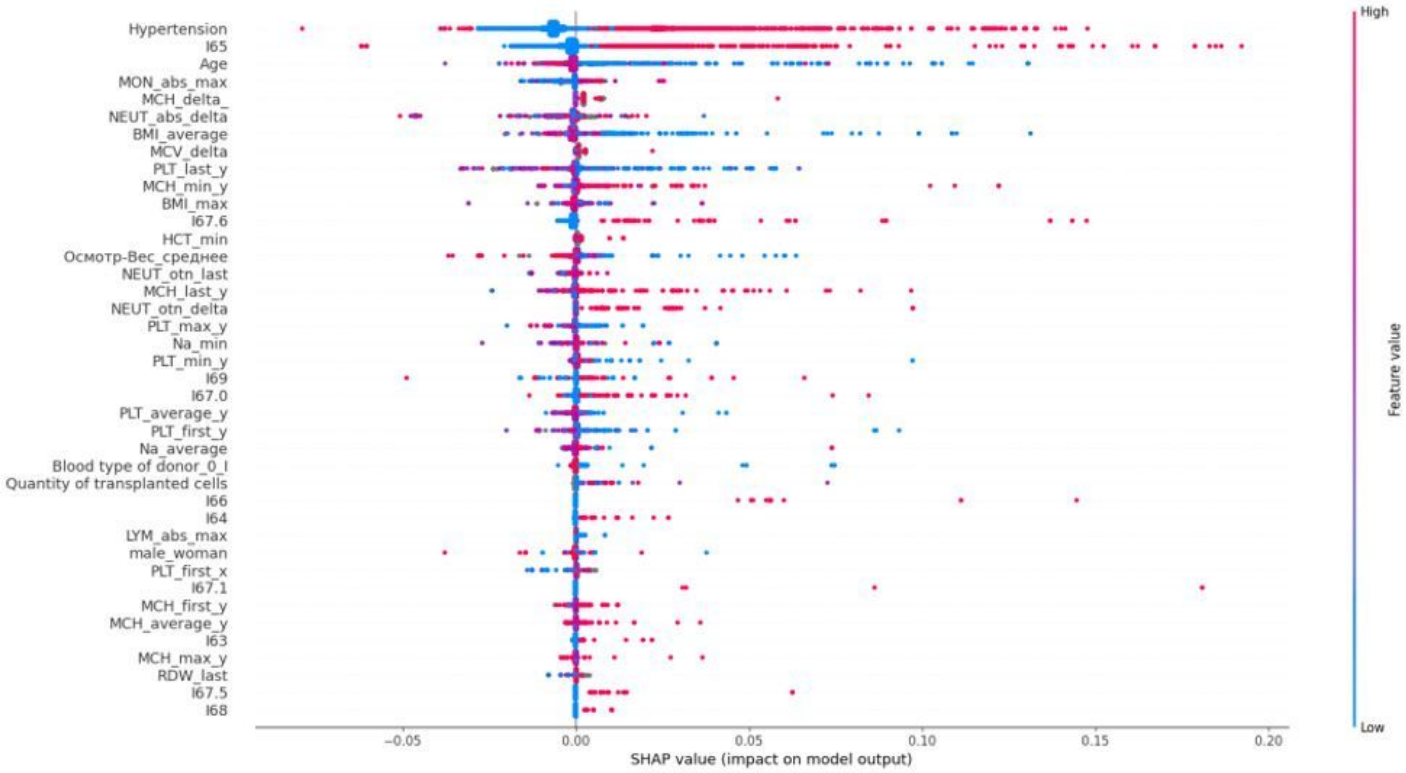

Figure 1

Factors associated with the development of epilepsy in oncohematolog-ical patients

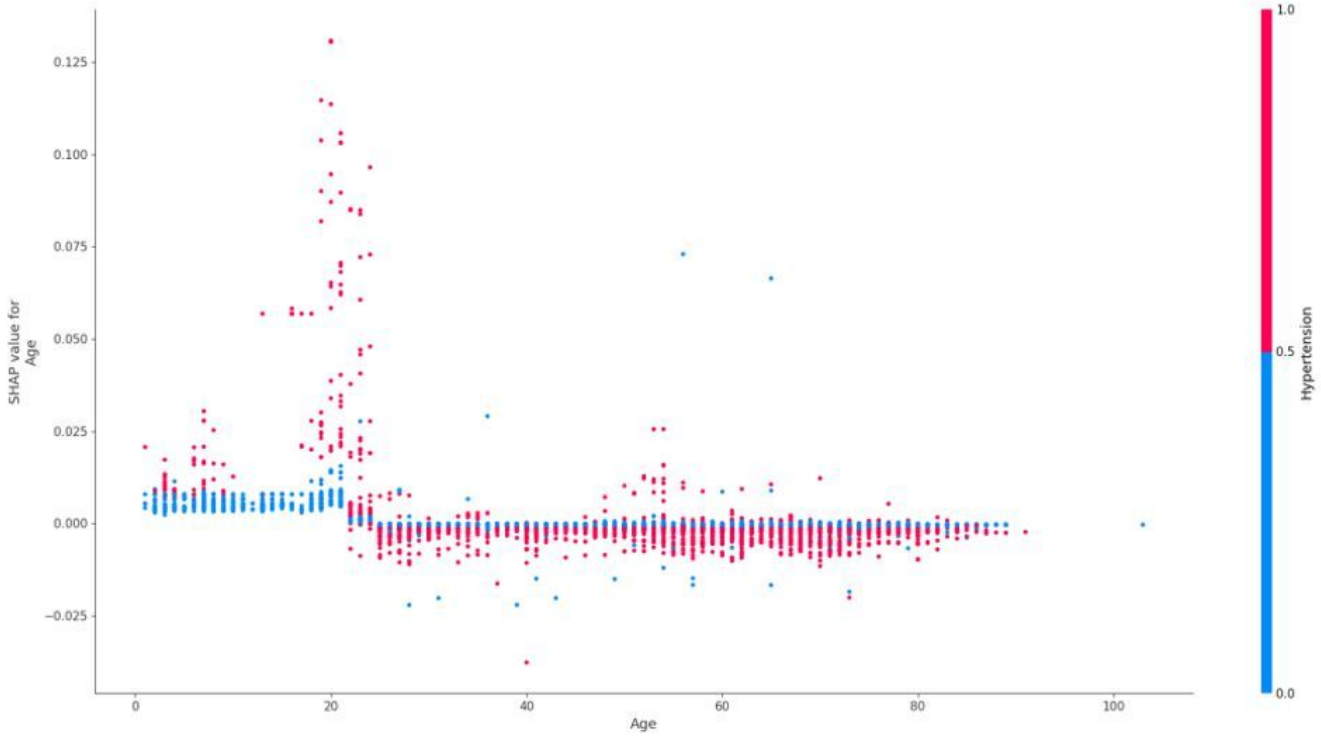

Figure 2

Effect of arterial hypertension on the risk of epilepsy depending on the age of patients

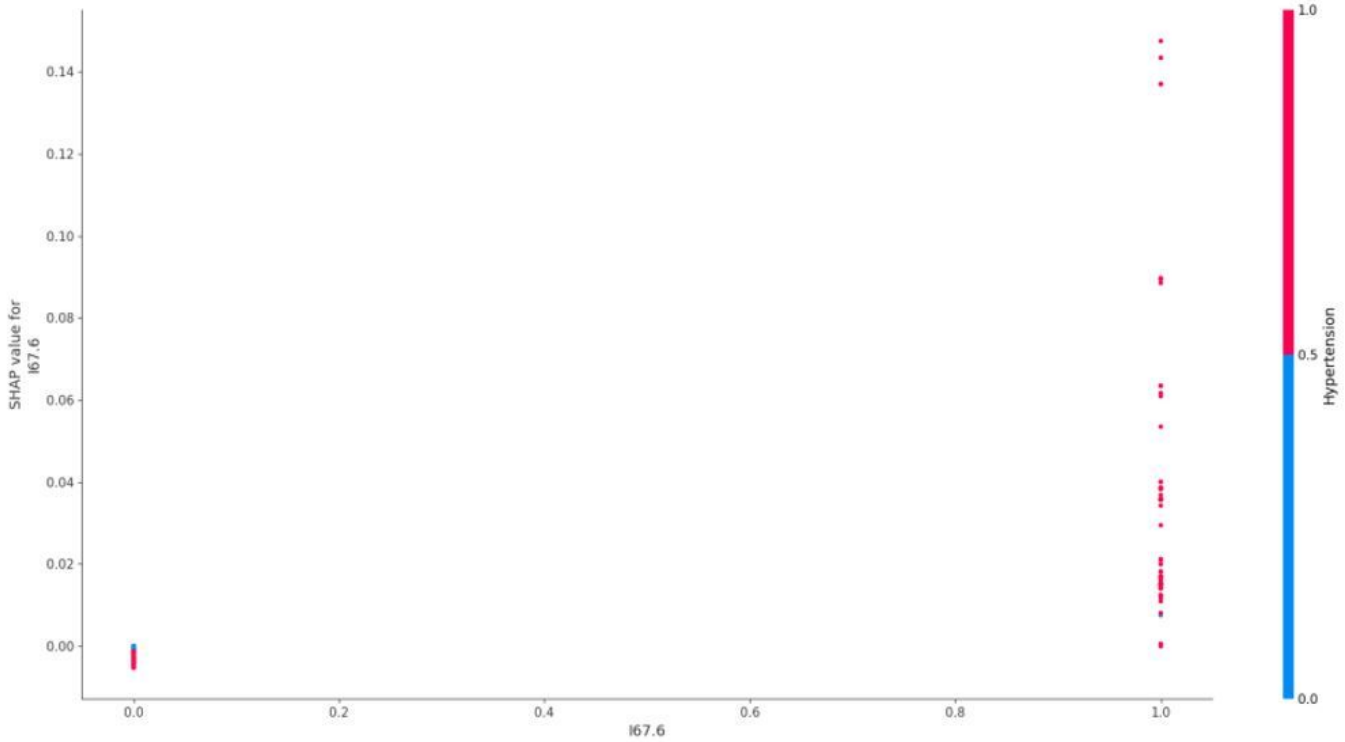

Figure 3

Effect of cerebral venous sinus thrombosis and arterial hypertension on the risk of epilepsy

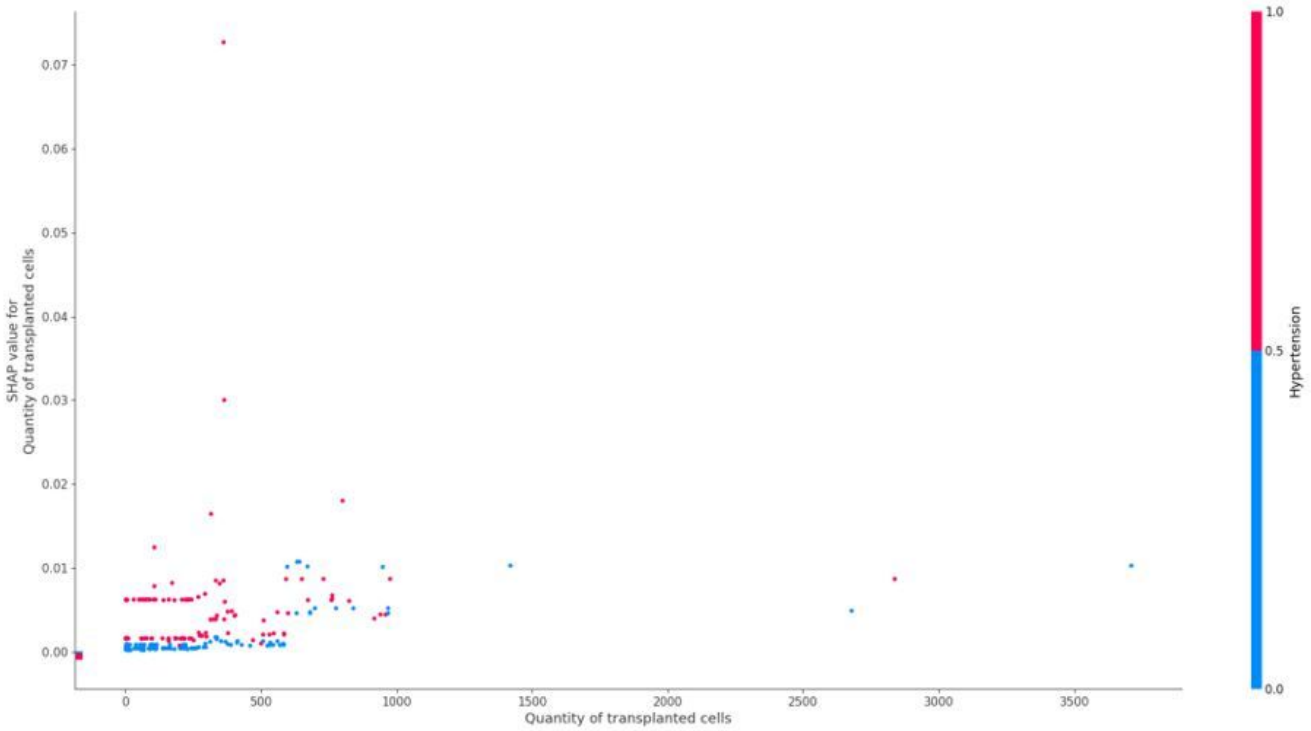

Figure 4

Plot of dependence of the number of transplanted hematopoietic stem cells on hypertension in the model of an epilepsy class

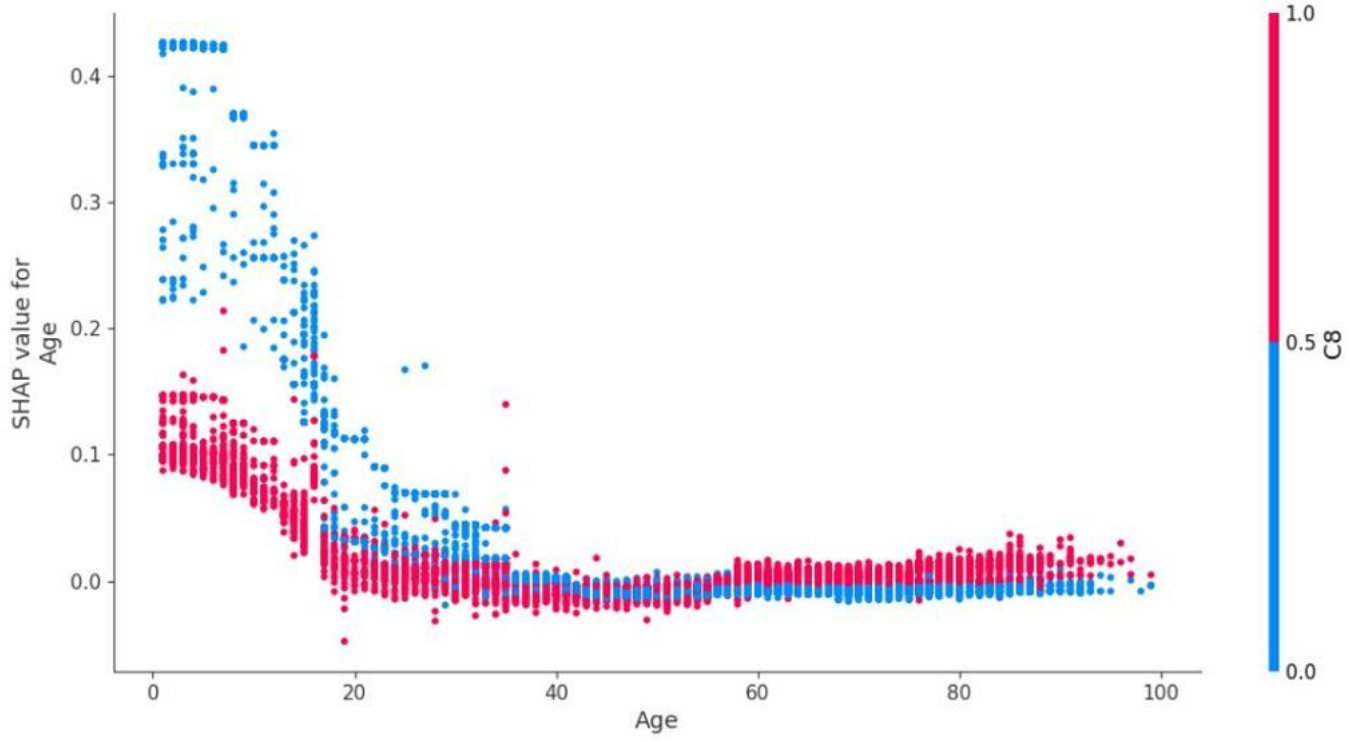

Figure 5

Plot of dependence of epilepsy on age and presence of oncohematolog-ical diagnosis

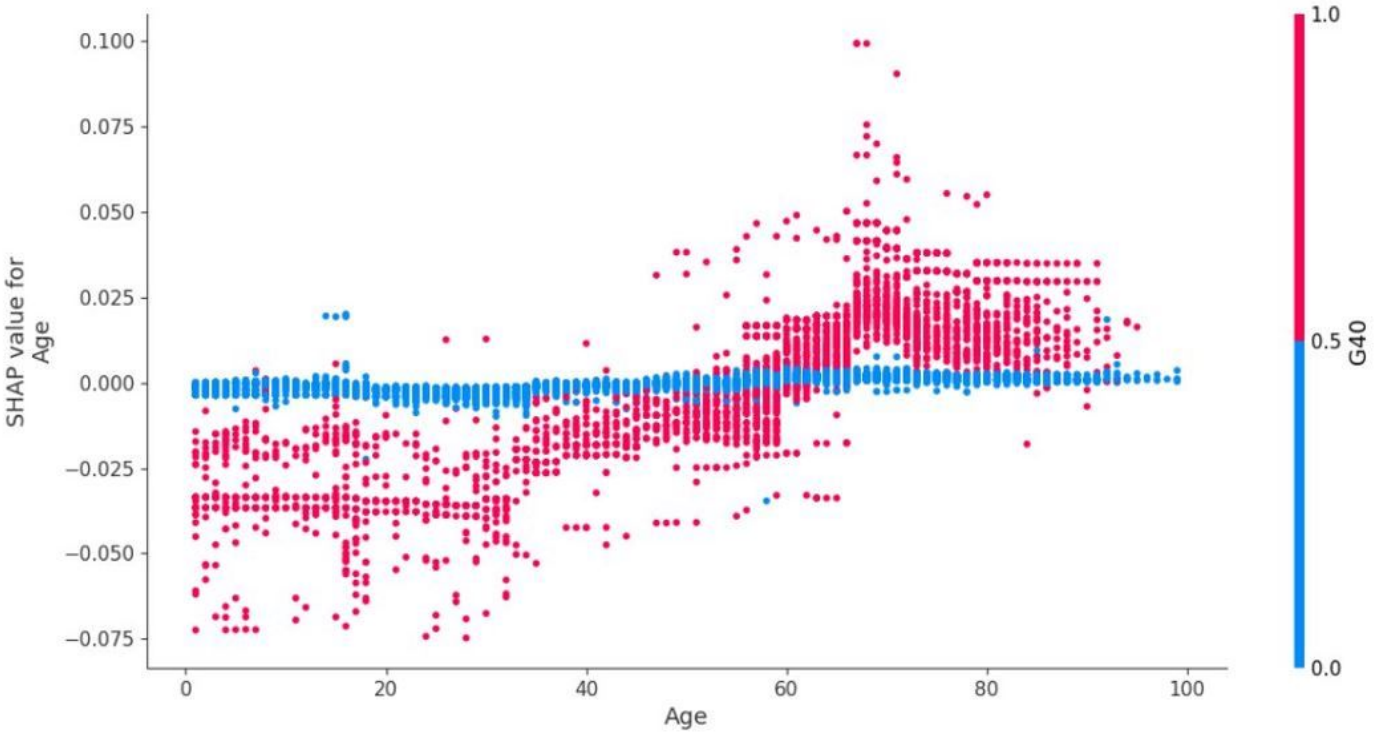

Figure 6

Plot of dependence of oncohematological diagnosis on the presence of epilepsy and age

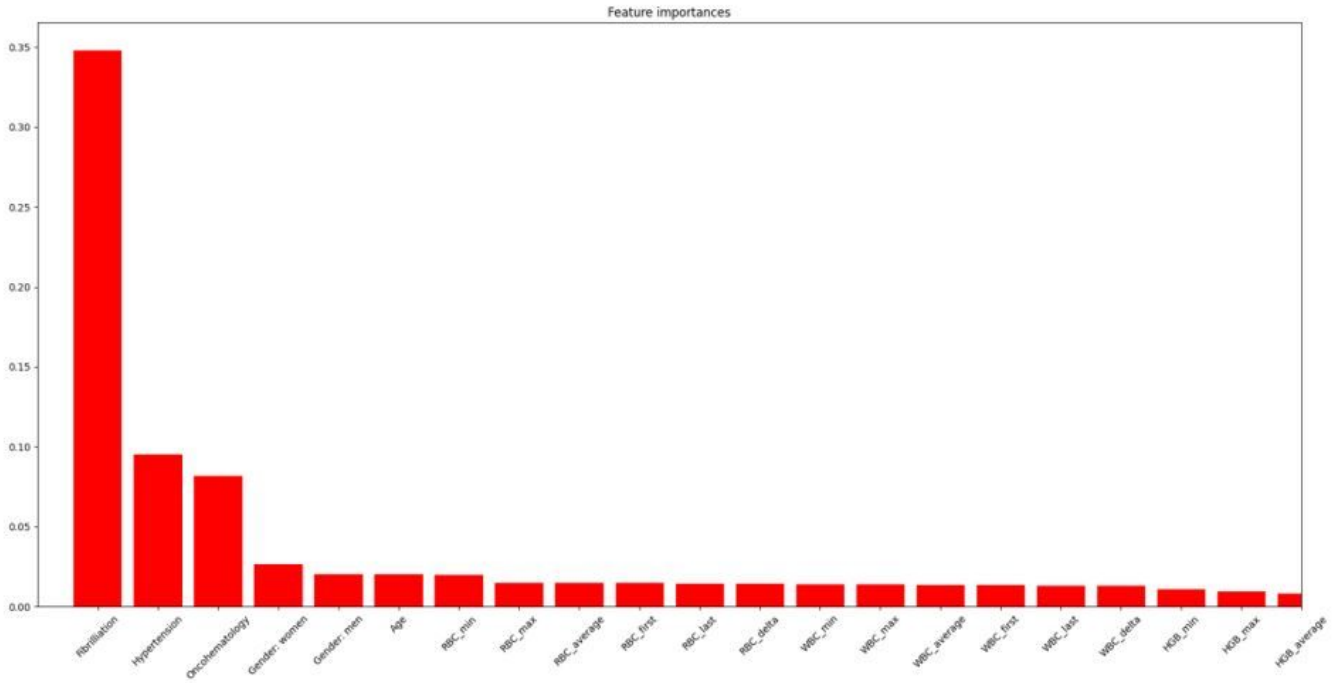

Figure 7

Predictor ranking for epilepsy diagnosis on Dataset II