DOI: https://doi.org/10.17816/fm16178

The influence of individual characteristics of the research subject on the electrical conductivity parameters of cerebrospinal fluid

Alexey Yu. Vavilov[1], Alexey R. Pozdeev[1], Airat A. Khalikov[2], Sofia M. Bayandina[1], Vadim V. Agzamov[2], Maria A. Pozdeeva[3]

[1] Izhevsk State Medical Academy, Izhevsk, Russia;
[2] Bashkir State Medical University, Ufa, Russia;
[3] Bauman Moscow State Technical University, Moscow, Russia

ABSTRACT

BACKGROUND: The analysis of cerebrospinal fluid has been repeatedly recognized in the scientific literature as a promising forensic tool for addressing critical questions related to fatal traumatic brain injuries, such as determining its age and assessing its severity. Conductometry has long been used in medicine as an objective method for studying biological samples. However, the influence of individual characteristics of the object on the conductometric properties of cerebrospinal fluid remains insufficiently studied.

AIM: To investigate the electrical conductivity properties of cerebrospinal fluid in deceased individuals who died from traumatic brain injuries, considering individual characteristics of autopsy material to substantiate the poteвntial of conductometric analysis as a research tool for determining the time of traumatic impact leading to injury formation.

MATERIALS AND METHODS: The experimental conductometric study was carried out on cerebrospinal fluid samples from 124 corps of persons aged 17 to 93 years who had died from traumatic brain injury and its consequences (with post-injury intervals ranging from 0 to 10 days). The electrical conductivity was measured using the AKIP RLC 6109 device, with an error of 0.1%, at frequencies of 0.1 kHz, 1 kHz, and 10 kHz. The study considered the subject's sex, age, postmortem interval, presence of ethanol in the blood at the time of death, and the ethanol concentration.

RESULTS: The subject's sex was found to be a significant factor influencing the value of electrical conductivity of cerebrospinal fluid. In contrast, the deceased's chronological age did not significantly affect the measured cerebrospinal fluid properties, nor did the postmortem interval within the first 24 hours. The absolute ethanol concentration (in ‰) had no substantial effect on cerebrospinal fluid conductivity. However, the mere presence of ethanol in the sample significantly altered its ability to conduct electrical current.

CONCLUSION: The influence of the above factors must be considered when developing a conductometric method for studying cerebrospinal fluid in those deceased from traumatic brain injury, as it can impact the assessment of injury severity and the age of injury.

Keywords: electrical conductivity; cerebrospinal fluid; traumatic brain injury; biophysical research methods; individual characteristics.

To cite this article:
Vavilov AYu, Pozdeev AR, Khalikov AA, Bayandina SM, Agzamov VV, Pozdeeva MA. The influence of individual characteristics of the research subject on the electrical conductivity parameters of cerebrospinal fluid. *Russian Journal of Forensic Medicine.* 2024;10(4):462–473. DOI: https://doi.org/10.17816/fm16178

Submitted: 16.08.2024 **Accepted:** 09.10.2024 **Published online:** 13.12.2024

ECO•VECTOR

DOI: https://doi.org/10.17816/fm16178

О влиянии факторов индивидуальности объекта исследования на показатели электропроводности спинномозговой жидкости

А.Ю. Вавилов[1], А.Р. Поздеев[1], А.А. Халиков[2], С.М. Баяндина[1], В.В. Агзамов[2], М.А. Поздеева[3]

[1] Ижевская государственная медицинская академия, Ижевск, Россия;
[2] Башкирский государственный медицинский университет, Уфа, Россия;
[3] Московский государственный технический университет имени Н.Э. Баумана (национальный исследовательский университет), Москва, Россия

АННОТАЦИЯ

Обоснование. В современной научной литературе неоднократно указывалось, что изучение спинномозговой жидкости в практике судебно-медицинских экспертов является перспективным для поиска ответов на такие значимые вопросы смертельной черепно-мозговой травмы, как определение её давности и тяжести образования. В качестве одного из методов объективного исследования биологических объектов в медицине достаточно давно используется кондуктометрия. Однако влияние индивидуальных особенностей объекта исследования на кондуктометрические свойства спинномозговой жидкости изучены явно недостаточно.

Цель исследования — изучение особенностей электропроводящих свойств спинномозговой жидкости трупов лиц, умерших от черепно-мозговой травмы, обусловленных индивидуальными характеристиками секционного материала, для обоснования перспективности кондуктометрического метода в научных исследованиях при установлении давности травматического воздействия, приведшего к формированию указанной травмы.

Материалы и методы. Проведено экспериментальное кондуктометрическое исследование спинномозговой жидкости от 124 трупов лиц, умерших в возрасте от 17 до 93 лет от черепно-мозговой травмы и её последствий (давность травмы от 0 до 10 суток). Измерение электропроводности проводилось прибором «АКИП RLC 6109» с погрешностью 0,1% на частотах 0,1 кГц, 1 кГц и 10 кГц. В качестве индивидуальных особенностей исследованного субъекта принимались во внимание его половая принадлежность, возраст умершего, давность смерти, факт наличия этилового спирта в крови на момент смерти и величина этанолэмии.

Результаты. Установлено, что фактор половой принадлежности субъекта является значимым с точки зрения влияния его на величину электропроводности спинномозговой жидкости. В то же время паспортный возраст умершего не имеет значимого влияния на изучаемые свойства спинномозговой жидкости, равно как и давность смерти человека, не превышающая 24-часовой период. Абсолютная величина этанолэмии (в промилле) не оказывает существенного влияния на электропроводность спинномозговой жидкости, однако сам факт наличия этилового алкоголя в изучаемом объекте существенно меняет его способность к проведению электрического тока.

Заключение. Все изменения, обусловленные влиянием указанных факторов, необходимо учитывать в ходе разработки методики кондуктометрического исследования спинномозговой жидкости у умерших от черепно-мозговой травмы как влияние, способное изменить оценку тяжести данной травмы и давности её формирования.

Ключевые слова: электропроводность; спинномозговая жидкость; черепно-мозговая травма; биофизические методы исследования; индивидуальность объекта.

Как цитировать:
Вавилов А.Ю., Поздеев А.Р., Халиков А.А., Баяндина С.М., Агзамов В.В., Поздеева М.А. О влиянии факторов индивидуальности объекта исследования на показатели электропроводности спинномозговой жидкости // Судебная медицина. 2024. Т. 10, № 4. С. 462–473. DOI: https://doi.org/10.17816/fm16178

Рукопись получена: 16.08.2024 **Рукопись одобрена:** 09.10.2024 **Опубликована online:** 13.12.2024

DOI: https://doi.org/10.17816/fm16178

关于研究对象个体特征对脑脊液电导率指标的影响

Alexey Yu. Vavilov[1], Alexey R. Pozdeev[1], Airat A. Khalikov[2], Sofia M. Bayandina[1], Vadim V. Agzamov[2], Maria A. Pozdeeva[3]

[1] Izhevsk State Medical Academy, Izhevsk, Russia;
[2] Bashkir State Medical University, Ufa, Russia;
[3] Bauman Moscow State Technical University, Moscow, Russia

摘要

背景。现代科学文献多次提到，在法医学专家实践中研究脑脊液对于解决诸如致命性颅脑损伤的形成时间和严重程度等重要问题具有前景。电导法作为医学中研究生物对象的客观方法之一，已经使用了相当长的时间。然而，研究对象个体特征对脑脊液电导特性的影响研究明显不足。

研究目的。研究死于颅脑损伤的对象脑脊液的电导特性，分析其与研究对象个体特征的关系，为在确定导致颅脑损伤的外力形成时间的科学研究中推广电导法提供理论依据。

材料与方法。通过实验研究了124例死于颅脑损伤及其后果的尸体脑脊液的电导特性。受试者年龄从17至93岁，损伤形成时间为0至10天。电导测量采用“AKIP　RLC　6109”设备（误差为0.1%），测量频率为0.1 kHz、1 kHz和10 kHz。研究对象的个体特征包括性别、年龄、死亡时间、血液中乙醇的存在及其浓度（‰）。

结果。研究表明，研究对象的性别对脑脊液的电导特性具有显著影响，而对象的年龄和不超过24小时的死亡时间对脑脊液电导特性无显著影响。乙醇浓度的绝对值对脑脊液电导性无显著作用，但乙醇的存在显著改变了脑脊液的电流传导能力。

结论。所研究的个体特征对脑脊液电导特性的影响在开发用于研究颅脑损伤的电导方法时应予以考虑，因为这些因素可能会改变对损伤严重程度和形成时间的评估。

关键词：电导率；脑脊液；颅脑损伤；生物物理研究方法；对象个体特征。

引用本文：
Vavilov AYu, Pozdeev AR, Khalikov AA, Bayandina SM, Agzamov VV, Pozdeeva MA. 关于研究对象个体特征对脑脊液电导率指标的影响. *Russian Journal of Forensic Medicine*. 2024;10(4):462–473. DOI: https://doi.org/10.17816/fm16178

收到：16.08.2024 **接受：**09.10.2024 **发布日期：**13.12.2024

BACKGROUND

In forensic medicine, cerebrospinal fluid (CSF) study has been recognized as a promising tool for addressing critical questions in fatal traumatic brain injury (TBI) cases, such as determining the age of the injury and assessing its severity [1–4].

CSF contains biologically active substances that regulate brain functions, neurotrophic support, and neuronal sleep-wake cycles. The electrolyte composition of CSF (including chloride, sodium, potassium, magnesium and iodine) determines its conductive properties [5–7].

Conductometry, the measurement of electrical conductivity in biological fluids, is an objective quantitative method of research, capable of detecting subtle changes with high accuracy. This technique has proven valuable in various areas of medical diagnostics [7–9]. However, the dependence of the conductometric (electroconductive) properties of CSF on several factors that, along with the others, determine the individuality of this biological material remains poorly understood. These factors include the sex and age of the individual from whom the sample was obtained, the cause of death, and the presence or absence of ethanol in the blood and, consequently, in the cerebrospinal fluid at the time of examination.

The limited understanding of these influences restricts the development of conductometric methods for estimating TBI severity and the age of injury. If secondary factors significantly affect CSF electrical conductivity, their influence may obscure the primary determinants of conductivity change — namely, the age and the severity of the injury.

The study aimed to investigate the electrical conductivity properties of CSF in corpses of individuals who died from TBIs, considering individual characteristics of autopsy material, and to evaluate the feasibility of conductometric analysis as a research tool for determination of the age of the injury.

MATERIALS AND METHODS

Study design

This was an experimental, open-label, single-center, cross-sectional, uncontrolled sampling study on the conductometric properties of CSF collected from 124 corpses of individuals aged 17 to 93 years who died from TBIs and its consequences (post-injury intervals ranging from 0 to 10 days). The presence or absence of ethanol in the blood at the time of death was recorded: ethanol was detected in 23 cases (18.5%) and absent in 101 cases (81.5%). The postmortem interval was established through a comprehensive assessment of medical, forensic, and investigative data, ranging from 12.5 to 24 hours.

Eligibility criteria

Inclusion criteria: cases with a confirmed TBI as the immediate cause of death, occurring either in the acute phase or in the delayed period due to post-traumatic complications.

Exclusion criteria: Cases where TBI signs were identified during autopsy in individuals whose cause of death was unrelated to TBI or its consequences.

Study setting

The study was conducted using forensic material from the State Healthcare Institution “Bureau of Forensic Medical Examination of the Yamalo-Nenets Autonomous Area” and the State Healthcare Institution of Perm Territory “Territorial Bureau of Forensic Medical Examination and Pathological Studies”.

Study duration

The research was conducted between 2022 and 2024.

Autopsy sample collection

CSF was collected from each cadaver using a sterile single-use 5.0 mL medical syringe in volumes of 1–2 mL during autopsy while accessing the brain ventricles. To standardize measurement conditions, the syringe was placed in a thermostat at 25oC for temperature stabilization. After 30–45 minutes, CSF was transferred from the syringe into a special cuvette to study its electrical conductivity. Electrical conductivity was measured using an “AKIP RLC 6109” device (Changzhou Eucol Electronic Technology Co. Ltd, China), connected to a computer via an USB interface. The device, registered in the State Register of Measuring Instruments of the Russian Federation (No. 56479-14) and certified for compliance, allows to measure resistance, impedance, capacitance and inductance with a 0.1% error at frequencies of 0.1 kHz, 1 kHz and 10 kHz.

Main study outcome

Electrical conductivity values of cerebrospinal fluid were obtained from corpses of individuals who died from traumatic brain injury and its consequences. All values were determined at three sinusoidal current frequencies (100 Hz, 1 kHz, 10 kHz).

Subgroup analysis

In the course of mathematical analysis, subgroups were sequentially formed according to the possible influence of the factor under study, including the subject’s sex, age, presence of ethanol in the blood at the time of death, absolute ethanol concentration (‰), and postmortem interval (hours).

Methods for registration of outcomes

Electrical conductivity was measured at electric current frequencies of 0.1 kHz, 1 kHz, and 10 kHz by connecting the electrodes of a cuvette filled with CSF with the input contacts of the measuring device (AKIP RLC 6109) and using the standard device settings at the specified frequencies. The results were automatically recorded through computer interface by Microsoft Excel in real time mode.

Ethical review

All research procedures adhered to bioethical principles relevant to biomedical studies. The study was approved by the Bioethics Committee of Izhevsk State Medical Academy, Ministry of Health of Russia, and formally approved by the Scientific Council on August 31, 2022 (Protocol No. 1).

Statistical analysis

Sample size was not pre-calculated.

The following statistical analyses were performed: mean (M), standard deviation (SD), and standard error (m) calculations; comparative intergroup analysis using the Kruskal–Wallis test; correlation analysis using Kendall's and Spearman's tests. Data were recorded in a Microsoft Excel database (Microsoft Corporation, USA) and processed using IBM SPSS 23.0 (IBM, USA) following statistical research guidelines recommended for biological and medical studies [10].

RESULTS

Participant characteristics

The study analyzed CSF samples from 124 deceased individuals with confirmed TBI as the direct cause of death, both in the early and late post-traumatic periods (up to 10 days after the injury). To assess the influence of individual characteristics on CSF electrical conductivity, the study population was divided into subgroups based on age, sex, presence of ethanol in the blood, and postmortem interval. The distribution of analyzed samples by sex and age characteristics is presented in Table 1.

Table 1. Structure of the studied material with regard to sex and age characteristics of corpses of persons who died from craniocerebral trauma and its consequences

Age, years	Indicator, *n*		
	Men	Women	Total
<20	4	1	5
20–24	6	1	7
25–29	4	5	9
30–34	3	4	7
35–39	7	3	10
40–44	7	5	12
45–49	10	4	14
50–54	9	9	18
55–59	7	4	11
60–64	8	3	11
65–69	5	4	9
70–74	1	2	3
75+	2	6	8
Total	73	51	124

Primary Findings

The hypothesis regarding sex-related differences in CSF electrical conductivity was tested, and the results are summarized in Table 2, with the data distribution matrix shown in Fig. 1.

It was ascertained that differences were recorded between the groups formed on the basis of the sex of the deceased. The results of pairwise comparison between the "male" and "female" groups, conducted using the Kruskal–Wallis test, is presented in Table 3. The comparative study reveals that CSF electrical conductivity value differs between males and females ($p < 0.05$) at frequencies of 0.1 kHz, 1 kHz, and 10 kHz, indicating that sex of the examined subject should be considered a critical factor in conductometric study of his CSF.

Table 2. Electrical conductivity of cerebrospinal fluid taking into account the gender of the corpses of persons who died from traumatic brain injury and its consequences

Sex	Statistical analysis	Electrical conductivity, $S/m^{-1} \times 10^{-4}$		
		0.1 kHz	1 kHz	10 kHz
Male	M	0.696	0.763	0.792
	SD	0.178	0.066	0.069
	m	0.021	0.008	0.008
	n	73	73	73
Female	M	0.773	0.789	0.749
	m	0.183	0.073	0.082
	SD	0.026	0.010	0.011
	n	51	51	51
Total	M	0.728	0.774	0.775
	m	0.183	0.069	0.077
	SD	0.016	0.006	0.007
	n	124	124	124

The mean CSF conductivity values for the age groups (see Table 1) are presented in Table 4.

Visually, no apparent differences were observed between the different age groups. To ensure objective analysis, the Kruskal–Wallis test was applied, with results shown in Table 5.

As the presented data show, the electrical conductivity of CSF in corpses at the tested frequencies does not exhibit a dependence on the subject's age group. However, it should be noted that the conducted analysis has certain limitations, as age is a dynamic characteristic of an individual, and any division into age periods (age groups) is inherently arbitrary. Given this limitation, correlation analysis was deemed the most appropriate approach to determine the relationship between two dynamically changing parameters — age of an individual and CSF electrical conductivity.

Prior to correlation analysis, data distribution within the study groups was found to deviate from a normal distribution.

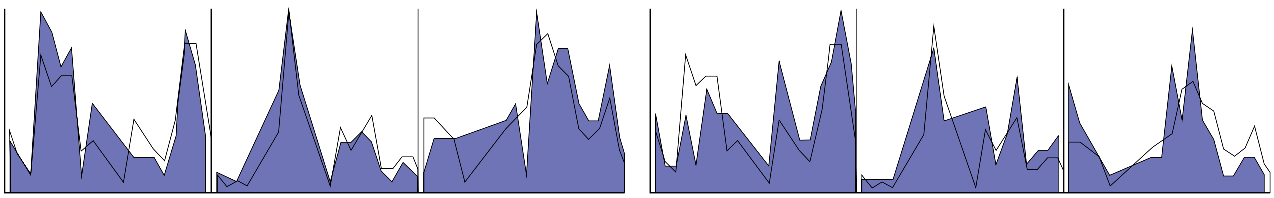

Fig. 1. Sorted observations of cerebrospinal fluid conductivity by the variable "gender".

Table 3. Kruskal–Wallis test for assessing the influence of gender on cerebrospinal fluid conductivity (analysis results in SPSS 23.0)

Frequency, kHz	Kruskal–Wallis Criterion	Significance
0.1	0.026	Significant differences
1.0	0.019	Significant differences
10	0.003	Significant differences

Table 4. Electrical conductivity of cerebrospinal fluid taking into account the distribution by age groups of corpses of persons who died from traumatic brain injury and its consequences. average (M)

Age Group. years	Electrical conductivity, $S/m^{-1} \times 10^{-4}$		
	100 kHz	1 kHz	10 kHz
<20	0.580±0.058	0.771±0.028	0.818±0.023
20–24	0.710±0.066	0.771±0.029	0.814±0.018
25–29	0.922±0.021	0.837±0.010	0.743±0.023
30–34	0.750±0.071	0.786±0.022	0.754±0.037
35–39	0.719±0.068	0.758±0.018	0.758±0.036
40–44	0.708±0.051	0.765±0.021	0.781±0.019
45–49	0.732±0.056	0.780±0.023	0.754±0.025
50–54	0.664±0.044	0.748±0.014	0.771±0.019
55–59	0.698±0.053	0.783±0.018	0.794±0.019
60–64	0.724±0.052	0.747±0.020	0.804±0.020
65–69	0.691±0.053	0.768±0.028	0.790±0.025
70–74	0.944±0.006	0.745±0.066	0.764±0.016
75+	0.782±0.060	0.817±0.025	0.742±0.021
Total	0.728±0.016	0.774±0.006	0.775±0.007

Table 5. Kruskal-Wallis test for assessing the effect of age on cerebrospinal fluid conductivity

Frequency, kHz Kruskal–Wallis	Criterion	Significance
0.1	0.056	No significant differences
1.0	0.183	No significant differences
10	0.299	No significant differences

Therefore, nonparametric methods were applied — Kendall's and Spearman's correlation analysis. The use of two methods at once should more reliably confirm the presence (or absence) of correlation relations (Table 6).

The calculations confirmed that CSF conductivity within the tested frequency range was not correlated with age.

To examine the effect of ethanol consumption prior to death on CSF electrical conductivity, the study population was divided into two groups: "Without Ethanol" (ethanol absent in blood) and "With Ethanol" (ethanol detected in blood). The absolute ethanol concentration (‰) was not considered, as it represents a relative measure [11]. Additionally, only cases without signs of decomposition were included in the study, thereby excluding the possibility of ethanol formation [12]. The mean CSF conductivity values for the two groups are presented in Table 7, demonstrating visible differences at 0.1 kHz and 10 kHz. However, the Kruskal–Wallis test (Table 8) confirmed statistically significant differences between the two groups at all tested frequencies.

This finding raised the question of whether absolute ethanol concentration should also be considered. To test this hypothesis, correlation analysis was conducted using the previously applied coefficients (Table 9). The results indicated that CSF electrical conductivity was not significantly correlated with absolute ethanol concentration (‰) but was significantly affected by the mere presence of ethanol.

Since postmortem interval (PMI) is a dynamic characteristic, correlation analysis is considered to be the most appropriate method to determine the relationship between two changing variables: time since death and CSF electrical conductivity. As previously, the choice was made in favor of nonparametric methods of analysis, the results of which are presented in Table 10. A weak negative correlation (–0.159±0.02) was identified at 0.1 kHz, necessitating additional analysis using one-way analysis of variance (ANOVA) (Table 11). The calculations indicated no statistically significant influence of postmortem interval on CSF conductivity values (p >0.05).

Table 6. Correlation coefficients of age and electrical conductivity cerebrospinal fluid

Correlation analysis	Electrical conductivity, $S/m^{-1}\times10^{-4}$		
	100 kHz	**1 kHz**	**10 kHz**
Kendall's Correlation Coefficient	0.031	–0.042	–0.019
Significance	0.619	0.502	0.768
Spearman's Correlation Coefficient	0.041	–0.058	–0.022
Significance	0.648	0.520	0.807

Table 7. Cerebrospinal fluid conductivity in selected groups. average (M)

Group	Electrical conductivity, $S/m^{-1}\times10^{-4}$		
	0.1 kHz	**1 kHz**	**10 kHz**
Without ethanol	0.786±0.007	0.683±0.017	0.761±0.007
Ethanol present	0.720±0.015	0.926±0.010	0.831±0.008
Mean	0.775±0.007	0.728±0.016	0.774±0.006

Table 8. Kruskal–Wallis test to assess the impact of ethanolemia on the conductivity of cerebrospinal fluid

Frequency, kHz	Kruskal–Wallis Criterion	Significance
0.1	0.001	Significant differences
1.0	0.001	Significant differences
10	0.001	Significant differences

Table 9. Correlation coefficients between ethanol concentration and conductivity of cerebrospinal fluid

Correlation analysis	Electrical conductivity, $S/m^{-1}\times10^{-4}$		
	100 kHz	**1 kHz**	**10 kHz**
Kendall's Correlation Coefficient	0.124	-0.026	-0.038
Significance	0.252	0.813	0.730
Spearman's Correlation Coefficient	0.166	-0.035	-0.083
Significance	0.265	0.816	0.580

DOI: https://doi.org/10.17816/fm16178

Table 10. Results of correlation analysis for conductometry cerebrospinal fluid

Correlation analysis	Electrical conductivity, S/m^{-1}×10^{-4}		
	100 kHz	1 kHz	10 kHz
Kendall's Correlation Coefficient	−0,159*	−0.06	0.05
Significance	0.02	0.41	0.49
Spearman's Correlation Coefficient	−0,212*	−0.07	0.07
Significance	0.02	0.44	0.45

Note. * Correlation is significant at the 0.05 level.

Table 11. Univariate analysis of variance (ANOVA) effects age of death by the amount of electrical conductivity cerebrospinal fluid

Parameters		Sum of squares	df	Mean square	F	*p*
0.1 kHz	Between groups	0.80	18	0.044	1.39	0.15
	Within groups	3.34	105	0.032	-	-
	Total	4.14	123	-	-	-
1 kHz	Between groups	0.13	18	0.007	1.57	0.08
	Within groups	0.47	105	0.004	-	-
	Total	0.59	123	-	-	-
10 kHz	Between groups	0.11	18	0.006	0.99	0.48
	Within groups	0.62	105	0.006	-	-
	Total	0.73	123	-	-	-

DISCUSSION

Summary of the primary study results

The study results demonstrated that the objects contained a sufficient quantity of dissolved ions, which determine the electrical conductivity of CSF. At the same time, objects obtained from corpses of individuals of different sex, age, with or without ethanol in the blood, showed variations in the absolute values of the measured parameter. This necessitated an investigation into the effects of these individual characteristics on cerebrospinal fluid conductivity.

Statistical analysis revealed that sex was a significant factor affecting CSF electrical conductivity, whereas chronological age had no statistically significant influence on the studied properties of autopsy material.

Additionally, while absolute ethanol concentration (‰) did not significantly affect CSF conductivity, the existence of ethanol in the object under study significantly altered its ability to conduct alternating electric current.

Postmortem examinations conducted within the first 24 hours after death did not require adjustments for postmortem interval, as no significant changes in the conductometric properties of CSF occurred within this timeframe.

Discussion of the primary study results

As shown in Tables 2–6, CSF electrical conductivity did not correlate with the subject's age within the tested frequency range.

According to numerous researchers, ethanol existence in the blood can alter various biophysical and biochemical properties of tissues, organs, and bodily fluids [13], including changes in the trace element and protein composition of blood [14]. These factors may theoretically affect CSF composition and properties. The calculation in Tables 7–9, indicates that the CSF conductivity is not significantly correlated with ethanol concentration (‰), although the existence of ethanol in blood has a notable effect on conductometric measurements.

The postmortem interval (time since death) could potentially influence CSF properties due to ongoing postmortem processes, such as autolysis and decomposition. For this reason, the present study focused exclusively on the first 24 hours postmortem. However, even within the 24-hour postmortem interval, changes in the electrical conductivity properties of CSF may occur as the postmortem interval increases. Based on the results of our study, the absolute time elapsed between death and CSF extraction for conductometric analysis may be disregarded, provided it falls within the studied 24-hour interval.

Adverse events

No adverse events were observed in the course of this study.

Study limitations

When planning and conducting the study, the sample size to achieve the required statistical power of the results was not calculated. Therefore, the sample may not be fully representative, and the findings should not be extrapolated to the general population outside the study.

CONCLUSION

Conductometric analysis of CSF allows for the reliable detection of changes in CSF properties caused by factors that determine the individual characteristics of the subject from whose corpse it was removed for study.

All changes caused by the mentioned factors must be considered when developing a conductometric analysis methodology for CSF in individuals who died from traumatic brain injury, as they may affect the assessment of injury severity and the age of the injury.

ADDITIONAL INFORMATION

Funding source. This study was not supported by any external sources of funding.

Competing interests. The authors declare that they have no competing interests.

Authors' contribution. All authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work. V.V. Agzamov, S.M. Bayandina, M.A. Pozdeeva: data collection; A.Yu. Vavilov, A.R. Pozdeev writing the manuscript; A.Yu. Vavilov, A.R. Pozdeev, S.M. Bayandina: scientific editing of the manuscript; A.Yu. Vavilov, A.R. Pozdeev, S.M. Bayandina, V.V. Agzamov, M.A. Pozdeeva review and approval of the final version of the manuscript.

REFERENCES

1. Viter VI, Surkov YG, Pozdeev AR, et al. Assessment of craniocerebral trauma severity by specific electrical conductivity spectra of cerebrospinal fluid in the early postmortem period. *Problemy ekspertizy v meditsine.* 2004;4(3):12–14. EDN: OKGUTZ

2. Gaivoronskaya VI. *Crystallographic method of diagnostics of craniocerebral trauma and some pathological conditions in forensic medical practice* [dissertation abstract]: 14.00.24. Place of protection: Russian Centre of Forensic Medical Examination. Moscow; 2001. 30 p. (In Russ.)

3. Mainovskaya OA. *Forensic medical assessment of craniocerebral trauma in living persons by crystallographic characteristics of cerebrospinal fluid* [dissertation abstract]: 14.00.24. Moscow; 2001. 21 p. (In Russ.) EDN: ZLCDDF

4. Chumutin AN. Study of liquor impedance for postmortem assessment of craniocerebral trauma. In: *Young science — practical healthcare:* Materials of the 92nd final scientific-practical conference of students, residents, postgraduates, young scientists (up to 35 years old) of E.A. Wagner Perm State Medical University, Perm, 15–16 April. Perm: Perm State Medical University named after Academician E.A. Wagner; 2019. P. 43–44. (In Russ.) EDN: FQOJYH

5. Zuev AL, Mishlanov VYu, Sudakov AI, Shakirov NV. Analysis of ionic, molecular and cellular mechanisms of electrical impedance formation in biological fluids and tissues. *Perm scientific center journal.* 2014;(2):69–78. EDN: SLQOVJ

6. Pikalyuk VS, Bessalova EY, Tkach VV, et al. *Liquor as humoral environment of the organism:* Monograph. Simferopol: Arial; 2010. 192 p. (In Russ.) EDN: GWTTCQ

7. Pozdeev AR. *Forensic medical evaluation of treatment defects in the premortem period:* Monograph. Nizhny Novgorod; 2004. 143 p. (In Russ.) EDN: QLKTZX

8. Dobrovolsky GF. *Topographic substantiation of the complex forensic-medical evaluation of the system of liquor circulation in traumatic brain injury* [dissertation abstract]: 14.00.24. Place of defence: Moscow State Medical and Dental University named after A.I. Evdokimov. Moscow; 2003. 39 p. (In Russ.)

9. Sarsenov TK. The forensic evaluation of traumatic brain injury. *Nauka i Zdravookhranenie.* 2013;(4):66–68. EDN: XIKOXL

10. Glantz S. *Medico-biological statistics.* Transl. from English Yu.A. Danilov, ed. by N.E. Buzikashvili, D.V. Samoilov. Moscow: Praktika; 1999. 459 p. (In Russ.)

11. Naumov ES. *Expert system of diagnostics of acute poisoning (for the purposes of forensic medical practice)* [dissertation abstract]: 14.00.24. Place of defence: Russian Centre of Forensic Medical Examination. Moscow; 2000. 24 p. (In Russ.)

12. Korotun VN, Lesnikov VV, Viter VI. Changes in synthesised ethanol during storage of cadaver blood under room temperature conditions. *Problemy ekspertizy v meditsine.* 2013;13(1):9–12. EDN: QZRSCV

13. Khalikov AA, Vavilov AYu. *Diagnostics of the age of mechanical trauma in forensic medicine by biophysical methods:* Monograph. Izhevsk; 2007. 159 p. (In Russ.) EDN: QLOUDP

14. Permyakov AV, Viter VI. *Pathomorphology and thanatogenesis of alcohol intoxication:* Monograph. Izhevsk: Ekspertiza; 2002. 91 p. (In Russ.) EDN: XVIWWD

СПИСОК ЛИТЕРАТУРЫ

1. Витер В.И., Сурков Ю.Г., Поздеев А.Р., и др. Оценка тяжести черепно-мозговой травмы по спектрам удельной электропроводности спинномозговой жидкости в раннем постмортальном периоде // Проблемы экспертизы в медицине. 2004. Т. 4, № 3. С. 12–14. EDN: OKGUTZ

2. Гайворонская В.И. Кристаллографический метод диагностики черепно-мозговой травмы и некоторых патологических состояний в судебно-медицинской практике: Автореф. дис. … д-ра мед. наук: 14.00.24. Место защиты: Российский центр судебно-медицинской экспертизы. Москва, 2001. 30 с.

3. Майновская О.А. Судебно-медицинская оценка черепно-мозговой травмы у живых лиц по кристаллографическим характеристикам спинномозговой жидкости: Автореф. дис. … канд. мед. наук: 14.00.24. Москва, 2001. 21 с. EDN: ZLCDDF

4. Чумутин А.Н. Исследование импеданса ликвора для постмортальной оценки давности черепно-мозговой травмы // Молодая наука — практическому здравоохранению: материалы 92-й итоговой научно-практической конференции студентов, ординаторов, аспирантов, молодых ученых (до 35 лет) ПГМУ имени академика Е.А. Вагнера, Пермь, 15–16 апреля. Пермь: Пермский государственный медицинский университет имени академика Е.А. Вагнера, 2019. С. 43–44. EDN: FQOJYH

5. Зуев А.Л., Мишланов В.Ю., Судаков А.И., Шакиров Н.В. Изучение ионных, молекулярных и клеточных механизмов формирования электрического импеданса в биологических жидкостях и тканях // Вестник Пермского научного центра УРО РАН. 2014. № 2. С. 69–78. EDN: SLQOVJ

6. Пикалюк В.С., Бессалова Е.Ю., Ткач В.В., и др. Ликвор как гуморальная среда организма: монография. Симферополь: Ариал, 2010. 192 с. EDN: GWTTCQ

7. Поздеев А.Р. Судебно-медицинская оценка дефектов лечения в премортальный период: монография. Нижний Новгород, 2004. 143 с. EDN: QLKTZX

8. Добровольский Г.Ф. Топографическое обоснование комплексной судебно-медицинской оценки системы ликворообращения при травматическом повреждении головного мозга: Автореф. дис. … докт. мед. наук: 14.00.24. Место защиты: Московский государственный медико-стоматологический университет имени А.И. Евдокимова. Москва, 2003. 39 с.

9. Сарсенов Т.К. Судебно-медицинская оценка черепно-мозговой травмы в судебной медицине // Наука и здравоохранение. 2013. № 4. С. 66–68. EDN: XIKOXL

10. Гланц С. Медико-биологическая статистика / пер. с англ. Ю.А. Данилова, под ред. Н.Е. Бузикашвили, Д.В. Самойлова. Москва: Практика, 1999. 459 с.

11. Наумов Э.С. Экспертная система диагностики острого отравления (для целей судебно-медицинской практики): Автореф. дис… канд. мед. наук: 14.00.24. Место защиты: Российский центр судебно-медицинской экспертизы. Москва, 2000. 24 с.

12. Коротун В.Н., Лесников В.В., Витер В.И. Изменение синтезированного этанола при хранении трупной крови в условиях комнатной температуры // Проблемы экспертизы в медицине. 2013. Т. 13, № 1. С. 9–12. EDN: QZRSCV

13. Халиков А.А., Вавилов А.Ю. Диагностика давности механической травмы в судебной медицине биофизическими способами: монография. Ижевск, 2007. 159 с. EDN: QLOUDP

14. Пермяков А.В., Витер В.И. Патоморфология и танатогенез алкогольной интоксикации: монография. Ижевск: Экспертиза, 2002. 91 с. EDN: XVIWWD

AUTHORS' INFO

*** Vadim V. Agzamov;**
address: 3 Lenin st, Ufa, Russia, 450008;
ORCID: 0000-0001-9845-2280;
eLibrary SPIN: 2601-5385;
e-mail: expert.sudmed@yandex.ru

Alexey Yu. Vavilov, MD, Dr. Sci. (Medicine), Professor;
ORCID: 0000-0002-9472-7264;
eLibrary SPIN: 3275-3730;
e-mail: izhsudmed@hotmail.com

Alexey R. Pozdeev, MD, Dr. Sci. (Medicine), Assistant Professor;
ORCID: 0000-0002-6302-5219;
eLibrary SPIN: 2242-4828;
e-mail: apozdeev@bk.ru

Airat A. Khalikov, MD, Dr. Sci. (Medicine), Professor;
ORCID: 0000-0003-1045-5677;
eLibrary SPIN: 1895-7300;
e-mail: airat.expert@mail.ru

Sofia M. Bayandina;
ORCID: 0009-0005-9888-512X;
eLibrary SPIN: 8604-6691;
e-mail: bay_sofia@mail.ru

Maria A. Pozdeeva;
ORCID: 0009-0007-6403-9886;
eLibrary SPIN: 4731-6769;
e-mail: mashapozdeeva5@gmail.com

ОБ АВТОРАХ

*** Агзамов Вадим Валерьевич;**
адрес: Россия, 450008, Уфа, ул. Ленина, д. 3;
ORCID: 0000-0001-9845-2280;
eLibrary SPIN: 2601-5385;
e-mail: expert.sudmed@yandex.ru

Вавилов Алексей Юрьевич, д-р мед. наук, профессор;
ORCID: 0000-0002-9472-7264;
eLibrary SPIN: 3275-3730;
e-mail: izhsudmed@hotmail.com

Поздеев Алексей Родионович, д-р мед. наук, доцент;
ORCID: 0000-0002-6302-5219;
eLibrary SPIN: 2242-4828;
e-mail: apozdeev@bk.ru

Халиков Айрат Анварович, д-р мед. наук, профессор;
ORCID: 0000-0003-1045-5677;
eLibrary SPIN: 1895-7300;
e-mail: airat.expert@mail.ru

Баяндина София Михайловна;
ORCID: 0009-0005-9888-512X;
eLibrary SPIN: 8604-6691;
e-mail: bay_sofia@mail.ru

Поздеева Мария Алексеевна;
ORCID: 0009-0007-6403-9886;
eLibrary SPIN: 4731-6769;
e-mail: mashapozdeeva5@gmail.com

* Corresponding author / Автор, ответственный за переписку