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Complex system and future technologies in neuroscience

ABSTRACT BOOK

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КОМПЛЕКСНЫЕ СИСТЕМЫ И БУДУЩИЕ ТЕХНОЛОГИИ В НЕЙРОНАУКЕ

Сборник тезисов докладов

Выпуск 3

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Collection of abstracts

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В сборнике представлены тезисы докладов конференции CSFTN’26, посвященные будущим технологиям в нейробиологии для изучения мозга как сложной системы и разработки перспективных терапевтических стратегий лечения заболеваний головного мозга во время сна. В книге приведены тезисы приглашенных устных и стендовых докладов. Официальным языком конференции является английский.

Для студентов медицинских, биологических и биофизических специальностей, а также для ученых и врачей, работающих в области нейрофизиологии.

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The collection presents abstracts from the CSFTN'26 conference, dedicated to future technologies in neurobiology for studying the brain as a complex system and developing promising therapeutic strategies for treating brain diseases during sleep. The book contains abstracts of invited oral and poster presentations. The official language of the conference is English.

The collection is intended for students of medical, biological and biophysical fields of training, as well as for scientists and doctors involved in the field of neurophysiology.

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CSFTN'26 conference collection of abstracts are on the conference website
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Sleep disorders in neurodegenerative diseases

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Speaker: Lusine Brsikian works at the 5th Neurology Department with DNA Laboratory at Russian Center of Neurology and Neurosciences in Moscow. Her research interests include studying risk factors for dementia, particularly sleep disorders. She is currently conducting research as part of her PhD thesis to assess the role of sleep disturbances in Alzheimer's disease. She regularly participates in Russian and international conferences.

Abstract: Sleep disorders are increasingly recognized as integral components of the clinical and pathophysiological spectrum of neurodegenerative diseases rather than secondary manifestations of neuronal decline. Converging evidence from recent high-quality studies indicates a bidirectional relationship, whereby neurodegenerative processes disrupt central sleep-wake regulatory networks, while chronic sleep impairment may exacerbate disease progression through mechanisms including impaired glymphatic clearance, pathological protein aggregation, neuroinflammation, and synaptic dysfunction.

In Parkinson's disease and related synucleinopathies, sleep disturbances – encompassing insomnia, excessive daytime sleepiness, circadian rhythm disruption, obstructive sleep apnea, restless legs syndrome, and rapid eye movement sleep behaviour disorder (RBD) – are highly prevalent. Notably, isolated RD is now established as a strong prodromal marker of a-synucleinopathies. In Alzheimer's disease and other dementias, reduced slow-wave sleep, sleep fragmentation, and circadian dysregulation have been consistently associated with impaired clearance of amyloid-b and tau proteins, as well as accelerated cognitive decline.

Comprehensive sleep phenotyping, integrating clinical evaluation with polysomnography, actigraphy, circadian biomarkers, and emerging fluid or seeding assays, offers significant potential for early diagnosis and prognostic stratification. Therapeutic approaches should be individualized and multimodal, incorporating optimization of disease-specific pharmacotherapy, targeted treatment of sleep-disordered breathing, circadian rhythm interventions, and pharmacological or behavioral management of insomnia and RBD.

In conclusion, sleep disorders represent critical, potentially modifiable factors in neurodegenerative diseases, with growing relevance for early detection, risk stratification, and the development of disease-modifying therapeutic strategies.

Keywords: sleep disorders, neurodegenerative diseases.

Sleep and dreams in folk culture

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Speaker: Varvara Dobrovolskaya is a Russian folklorist, fairy-tale scholar, Ph.D. of Philology; a specialist in the study of folk mythological signs and beliefs; Head of folklore and ethnographic department of the Center of Russian Folklore; Associate Professor of the Department of General and Slavic Art Studies Institute of Slavic Culture of the Russian State University named by A. Kosygin; a member of the editorial board of the scientific almanac "Traditional Culture"; a member of the Ethnographic Commission of the Russian Geographical Society. He is the author of more than 250 works on folklore and traditional culture.

Abstract: Sleep and dreams occupy a special place in folklore. First of all, they appear in folklore texts: the heroes of fairy tales and epics fall asleep under the influence of magic and have prophetic dreams that help them meet danger or perform a feat. The motif of a prophetic dream or a kind of dream guidance on the border between sleep and reality is often found in folklore prose. The result of such a dream is the discovery of a place to build a city, the finding of a treasure, the search for lost livestock, etc. Sometimes, sleeping in a special place (at a spring, a roadside cross, an abandoned bathhouse, etc.) allows a person to come into contact with certain sacred forces. A special group consists of dreams in which deceased relatives act. In these dreams, they communicate with the living, give them some tasks, and help them find lost items. Divination, where the diviner must receive an answer to a question in a dream, is also extremely popular in Russian tradition. A significant group of texts is related to stories about fainting, visions that a person experiencing lethargic sleep sees. Of course, a special place is occupied by spells and non-verbal magic aimed at ensuring a good night's sleep for adults and children. Finally, there is a special group of dream interpretations that exist both in oral and written form.

Keywords: sleep, night dreams, folklore.

Behavioral and neurobiological analysis of rhythmic diaphragmatic breathing during falling asleep

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Speaker: Vladimir Dorokhov, Chief Researcher of the Laboratory of Sleep/Wake Neurobilogy of Institute of Higher Nervous Activity & Neurophysiology of the Russian Academy of Sciences. Moscow, Russia. He graduated from the Department of Higher Nervous Activity, Moscow State University, biological faculty, qualifying as a physiologist. Received a Doctor of Science degree in 2008. Member of dissertation committee of Institute of Higher Nervous Activity & Neurophysiology of the Russian Academy of Sciences (Physiology) and Higher School of Economics? Moscow, Russia. He is member of the European Sleep Research Society.
He is author more than 400 scientific papers in peer-reviewed journals, from them 200 publications in bases Web of Sciences and Scopus.

Abstract: Laboratory analysis of behavioral and physiological data on rhythmic deep diaphragmatic breathing (DB) upon presentation of sound 6 times/min. The experiments were conducted before and after training at home (the data from these workouts were not analyzed). The study involved 17 subjects (9 women). Registration of four experiments: 1) Background (20 min.) with spontaneous breathing and pressing the button + 5 minutes with DB (sound 6 times/min); 2) 5 minutes background with spontaneous breathing and pressing the button and 15 minutes with sound 6 times/min, DB when pressing the button, when pressing stops - breathing as in a dream; 3) 5 minutes background with a button and 30 minutes with a sound 6 times/min, DB and spontaneous breathing as in the previous experiment; 4) background (20 min.) with spontaneous breathing and pressing a button. In all experiments, pressing a button, 20 EEG channels, an electrocardiogram (ECG), and abdominal breathing were recorded. For experiments 2 and 3, statistical analysis was performed: the number of falls asleep according to the button analysis, EEG power in the alpha and delta ranges, ECG heart rate (HR) and heart rate variability (HRV).

In experiment 3, compared with experiment 2, a statistically significant increase in the duration and frequency of falling asleep was shown, the power of the alpha rhythm significantly decreased when falling asleep in experiments 2 and 3, the power of the delta rhythm significantly increased when falling asleep in experiments 2 and 3. HR significantly decreased in three conditions: background – DB – sleep, HRV increased insignificantly only in DB.

Keywords: diaphragmatic breathing, falling asleep, EEG, HR, HRV.

Functioning of the olfactory system during sleep: The effects of odors on sleep and sleep-related processes

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Speaker: Arianna Ever, a leading specialist at the Russian Presidential Academy of National Economy and Public Administration, specializes in cognitive psychology and ethology. Her interests include interspecies communication, olfactory perception, and learning. Her research focuses on developing methods for studying interspecies interactions in the context of olfactory learning (based on training scent detection dogs).

Abstract: The presentation addresses a research area in which olfaction is considered a sensory system that maintains functional communication with the sleeping brain. The focus is not on a single effect related to memory, dreaming, or clinical intervention, but on the layered organization of odor processing during sleep: from anatomical pathways and the activity of olfactory circuits to respiration, cortical rhythms, limbic responses, and plasticity.

The presentation will examine the processing chain of odors during sleep: the physicochemical properties of a substance — subjective odor perception — perception of the odor as familiar or unfamiliar — and the individually formed semantics of the odor, shaped by prior experience. These levels will be related to sleep physiology, emotional regulation, cognitive-mnestic processes during sleep, and the emotional tone and content of dreams. This approach shows that the effect of an odor during sleep is determined not only by the stimulus itself but also by prior experience: the same odor may differently affect sleep quality, respiration, arousal level, dream content, and subsequent recall.

This framework allows existing findings to be systematized, supports the consideration of controlled olfactory stimulation as an adjunctive method for disorders of the psychoemotional spectrum, and outlines directions for further research.

Keywords: sleep, olfactory system, physicochemical properties.

Transcranial magnetic stimulation for insomnia treatment: Placebo controlled trial

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Speaker: Andrey Golovatyuk work as a neurologist in University clinic of Sechenov University. In 2020 he graduated from the Sechenov First Moscow State Medical University and in the same year has attempt for international sleep research trainee program for 1 year in China, provided by World Sleep Society. In 2022 Andrey Golovatyuk had got the specialty in neurology. Now he conducts research in Sechenov University to get his PhD. In 2026 he has got the second specialty on functional diagnostic. Also he regularly participating in conferences provided by Russian society of Sleep Medicine.

Abstract: Chronic insomnia now is the most wide spread sleep disorders. Gold standard for insomnia treatment is cognitive-behavioral treatment (CBT-I), but this approach has disadvantages, here is some of them: a small number of specialists and, as a result, the unavailability of CBT-I; in addition, it is too expensive for most patients. The second line of therapy is pharmacotherapy, but due to side effects this approach is limited. Because of these facts it is necessary to investigate new type of treatment of insomnia.

The goal of the work was to assess the effectiveness of transcranial magnetic stimulation (TMS) for treatment of chronic insomnia.

Materials and methods. Inclusion criteria was age from 18 to 60 years old, absence of psychiatric and severe somatic diseases, diagnosis of chronic insomnia according to international classification of sleep disorders erd edition (ICSD-3). Exclusion criteria is age younger than 18 and older than 60 years old, presence of epileptic seizure at any age, presence of metallic implants in skull and/or artificial rhythm driver (with the exception of dental implants), presence of psychiatric and severe somatic diseases. Parameters that used for TMS was 80% of motor threshold, frequency 1 Gz, duration of one procedure 20 minutes, total number of procedures is 11 (7 days for every day than 4 weeks 1 procedure per week). Comparison was with control group, that was exposed by sham-TMS (the same duration of procedure but coil was rotated 180 degree). Effectiveness of treatment was assessed by using of sleep diary, 2 days actigraphy and scales (insomnia severity index, hospital anxiety and depression scale). All the parameters were fixed before and after treatment by TMS.

Results. Total amount of patients that was included in analyses was 22 in TMS group (mean age 34,7±7,1, 13 female) and 6 in control group (mean age 37,9±5,3, 3 female). Insomnia severity index in TMS group was 15,7±3,8 before treatment and 8,4±3,1 ($p<0,05$) after treatment, mean total sleep time was 379,5±52,2 minutes before treatment and 453,5±45,2 minutes after treatment ($p<0,05$). In comparison to control group the same parameters were 14,7±3,8 before treatment and

12,6±3,0 after treatment for Insomnia severity index and 378,0±46,7 minutes before treatment and 383,3±33,9 minutes after treatment for total sleep time.

Keywords: transcranial magnetic stimulation, chronic insomnia treatment.

Afferent therapy for restless legs syndrome

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Speaker: Nikita A. Gorbachev – MD, PhD, neurologist at the Sleep Medicine Department at Clinical Hospital No. 3 of I.M. Sechenov First Moscow State Medical University, Ministry of Health of the Russian Federation.
Provides outpatient care in the following areas:

- Sleep-related movement disorders (restless legs syndrome, bruxism);
- Insomnia;
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- Parasomnias (sleepwalking, night terrors, nightmares, etc.);
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Education:
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Author of 15 publications in medical journals.
Secretary of the Russian Society of Sleep Medicine.

Abstract: Restless legs syndrome (RLS) is a common condition seen by neurologists, movement disorders specialists, and somnologists. The pathophysiology of RLS is not fully understood, making treatment for this condition ineffective. Before initiating treatment, patients undergo laboratory testing for ferritin or transferrin saturation. If iron deficiency is detected (ferritin level < 75 μg/dL and transferrin saturation < 20%), patients are prescribed iron replacement therapy. Symptom relief medications are also prescribed. These include alpha-2-delta ligands (pregabalin, gabapentin) and dopamine receptor agonists. However, the therapeutic effect of drug therapy for at least one year remains insufficient. This is due to the natural progression of RLS and, in the case of long-term use of dopaminergic drugs, augmentation (a paradoxical increase in symptoms with increasing drug dose). Therefore, the search for additional treatment methods, including non-drug ones, is relevant.

Non-pharmacological treatments for RLS are discussed: pneumatic compression, direct current electrical stimulation of the spinal cord, transcranial magnetic stimulation, and deep brain stimulation. These methods influence the afferent pathways through which nerve impulses spread

from peripheral receptors to the central nervous system. The effectiveness of these methods was assessed using the International RLS study group severity scale. It has been demonstrated that in mild cases of the syndrome, these methods can significantly alleviate symptoms without drug therapy. However, in severe cases, non-pharmacological treatment can only be used as an adjunctive therapy, with drug therapy remaining the primary method of symptom management.

Keywords: restless legs syndrome, pathogenetic treatment, afferent therapy.

The effect of intermittent hypoxia during sleep on survival and the development of major non-communicable diseases in patients with sleep disorders

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Speaker: Alexander Kalinkin, MD, PhD, head of the Sleep Medicine Center (www.sleeplab.ru), leading researcher University Clinic of Lomonosov Moscow State University, Founder and Chairman of the Program Committee of the Sleep Forum (www.sleepforum.ru/en/), expert of the European Sleep Research Society (ESRS). Alexander Kalinkin stands as a distinguished alumnus of Sechenov University in Moscow. With a dual background in cardiology and sleep medicine from the esteemed Medical Centre of the Presidential Affairs Department, Dr. Kalinkin has established himself as a leading authority in the field of sleep medicine. His professional portfolio is further enriched by his roles as a board member of both the Russian Sleep Research Society and the Russian Neuro-Muscular Diseases Society, as well as his memberships in the American Academy of Sleep Medicine and the European Sleep Research Society (ESRS). Dr. Kalinkin holds the distinguished honor of being the first ESRS expert in Russia, a testament to his exceptional contributions to the global sleep research community.

Abstract: We conducted a prospective study (maximum follow-up period of 14.4 years, Me – 8.4 years) to assess the effect of intermittent hypoxia during sleep on survival and the development of major non-communicable diseases in patients with sleep disorders.

The cumulative incidence of the primary composite endpoint (death, myocardial infarction, stroke, TIA, cancer, and pacemaker insertion) was estimated using the Kaplan-Meier method. The risk of an event and the risk ratio were estimated using the Cox proportional hazards model.

It was found that intermittent hypoxia during sleep is an independent predictor of the development of major adverse cardiovascular events and cancer (MACC). When assessing the Q1-Q4 ID, the risks of adverse outcomes increased by 2.7 times in the 3rd quartile group and by 2.5 times in the 4th quartile group.

The data obtained indicate that intermittent hypoxia is an independent predictor of major adverse cardiovascular events and cancer. Its level can be used to stratify patients according to their risk. Individuals in the 3rd and 4th quartile groups require the most careful monitoring and potentially more aggressive preventive strategies.

Keywords: sleep, sleep disorders, hypoxia.

Cardiorespiratory monitoring in the practice of a somnologist: Problems and solutions

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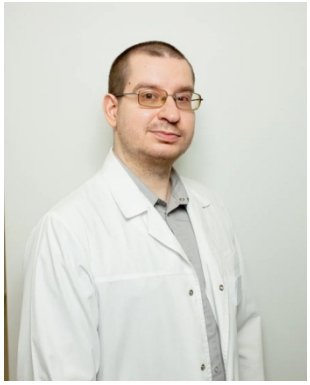

Speaker: Alexey Katyshev works as a neurologist and somnologist at the Invitro Clinic in Moscow. He graduated from Volgograd State Medical University in 2013. He has been diagnosing and treating sleep disorders since 2016. He is a member of the Russian Society of Somnologists. He maintains his own blog.

Abstract: Cardiorespiratory monitoring is a simple and convenient way to diagnose sleep-disordered breathing, performed at home. In practice, physicians often encounter technical limitations in the parameters recorded. This talk examines the most common errors made during cardiorespiratory monitoring and how to resolve them.

Keywords: sleep, polysomnography, cardiorespiratory monitoring.

The role of metabolites in the development of sleep-associated pathologies

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Speaker: Nataliya Kolotyeva, Doctor of Medical Sciences, Associate Professor.

Head of the Laboratory of Experimental and Translational Neurochemistry at the Brain Institute of the Russian Center of Neurology and Neurosciences; Professor of the Chair of Biological Chemistry at the Russian University of Medicine; Professor of the Chair of Biomedical Technical Systems at the Bauman Moscow State Technical University.

Her research interests focus on studying the cellular and molecular mechanisms of metabolic plasticity in the neurovascular unit in age-related neurodegenerative diseases, modeling neurodegeneration and neuroinflammation using primary brain cell cultures, as well as on investigating the role of redox homeostasis imbalance, aberrant lactate and NAD^+ metabolism in the pathogenesis of Alzheimer's and Parkinson's diseases. The research focuses particularly on developing optimized methods for the early diagnosis of neurodegenerative diseases based on the detection of proteins with aberrant conformation and on creating digital twins of cellular systems for microfluidic platforms.

She is the author and co-author of articles in peer-reviewed international journals in the fields of neurochemistry, molecular medicine, and biomedical technologies. She lectures and conducts practical sessions on biochemistry, molecular medicine, and regenerative medicine, serving as a research advisor to graduate students.

As a leader and executor, she participates in scientific projects aimed at studying the mechanisms of neurodegeneration, developing innovative diagnostic approaches, and implementing interdisciplinary solutions at the intersection of neuroscience, biochemistry, and engineering.

Abstract: Metabolic plasticity of the brain plays a fundamental role in regulating the sleep-wake cycle, and their dysregulation serves as a key mechanism in the development of neurodegenerative and somatic disorders associated with sleep disturbances. Lactate plays a central role in this system—it is not just the end product of glycolysis, but also a crucial signaling molecule and an energy substrate for brain cells. A number of studies have shown that extracellular lactate concentration in the cerebral cortex rapidly and consistently increases upon awakening and during rapid eye movement (REM) sleep, whereas a sustained decrease in lactate levels is observed during non-rapid eye movement (NREM) sleep.

Recent studies suggest that impaired NAD+ metabolism contributes to the pathogenesis of Parkinson's disease. A decrease in NAD+ levels in the brain's dopaminergic neurons is associated with impaired ATP production and the development of clinical symptoms. Pro-inflammatory signals induce cellular metabolic changes characterized by enhanced glycolysis in the presence of oxygen, similar to the Warburg effect. Previously, lactate was considered a byproduct of glucose

metabolism; however, current data indicate its key role in regulating gene expression, intracellular Ca2+ signaling, energy metabolism, channel and transporter activity, polarization, differentiation, and effector functions of cells, and myelination. Astrocytes have been shown to be the primary producers of lactate in brain tissue, ensuring neuron-astrocyte metabolic coupling and meeting the needs of neuronal cells. It has been shown that monocarboxylate transporters, which are localized on cerebral endothelial cells, perivascular astrocytes, and other cells, facilitate lactate transport and bind it to specialized GPR81 lactate receptors, whose function in the central nervous system remains poorly understood. In neurodegenerative diseases, a chronic disruption of lactate metabolism is observed. Abnormal lactate dynamics serve as an early marker of glial clearance dysfunction. During sleep deprivation or fragmented sleep, the efficiency of lactate and other toxic metabolite clearance, including β-amyloid and tau protein, is reduced.

The clinical significance lies in the potential to use lactate and related metabolites as biomarkers for the early diagnosis of sleep-related disorders and for assessing the effectiveness of treatment. Non-invasive methods, such as magnetic resonance spectroscopy, allow for real-time monitoring of metabolite dynamics in the human brain. A promising area of research is the development of strategies aimed at optimizing glymphatic clearance through sleep normalization, modulation of lactate metabolism, and reduction of neuroinflammation. The integration of metabolic profiling into clinical practice may be the key to personalized prevention and treatment of neurodegenerative diseases associated with sleep disorders.

Key words: metabolic plasticity, lactate, NAD+, brain, GPR81 receptor.

Frailty and sleep: An analysis of potential mechanisms of interaction

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Speaker: Yulia K. Komleva is a Professor of the Russian Academy of Sciences and a leading researcher in neuroinflammation, molecular neuroscience, and aging. She holds senior positions at the Brain Institute (Russian Center of Neurology and Neurosciences) and Bauman Moscow State Technical University. Her work, supported by grants, focuses on the understanding of molecular mechanisms of neuroinflammation and their role in cognitive impairment and neurodegeneration. The novel mechanisms involving inflammasomes in brain aging and developed an integrative, systems-level approach to studying age-related cognitive decline using experimental and translational models have been identified. The research has substantially contributed to elucidating the role of inflammatory and systemic metabolic dysregulation in both physiological and accelerated aging. Yulia Komleva is a recipient of several prestigious awards, including the Medal of the Russian Academy of Sciences for young scientists in biomedical sciences (2024), the Gerhard Domagk Award for Promising Young Scientists (Germany, 2023).

Abstract: Frailty is a multidimensional geriatric syndrome characterized by decreased physiological reserve, increased vulnerability to stressors, and a higher risk of adverse health outcomes. Accumulating evidence indicates that sleep disturbances are consistently associated with frailty in older adults. The scoping review linked to DOI 10.1186/s12877-024-05049-3 summarizes 39 publications on sleep and frailty and concludes that poor sleep quality, insomnia symptoms, and disturbed sleep are repeatedly associated with both frailty and pre-frailty, while the association with sleep duration appears less consistent than the association with sleep quality.

Available epidemiological data support a robust relationship between disturbed sleep and frailty. In the review literature, poor sleep quality is more consistently associated with frailty than sleep duration alone, and longitudinal findings suggest that sleep disturbances may precede frailty onset and progression. Recent systematic reviews also report that both short and long sleep duration are associated with higher frailty prevalence, although effect sizes vary across studies and measurement approaches.

Current evidence supports a bidirectional relationship between sleep and frailty. Poor sleep may accelerate frailty through inflammation, circadian disruption, muscle loss, and endocrine dysregulation; conversely, frailty itself may worsen sleep through multimorbidity, reduced physical activity, nocturnal symptoms, and impaired physiological adaptation. The strongest and most consistent clinical signal appears to come from sleep quality, especially insomnia symptoms and fragmented or non-restorative sleep, rather than from sleep duration alone.

Sleep disturbances should be considered not merely a comorbidity of aging, but a potentially modifiable component of frailty pathogenesis. The most plausible shared mechanisms include chronic inflammation, circadian rhythm disruption, sarcopenia-related muscle decline, and neuroendocrine imbalance. These findings support the idea that screening and improving sleep quality may become an important strategy for frailty prevention and management in older adults.

Keywords: frailty, sleep, insomnia, sleep quality, circadian rhythm, inflammation, sarcopenia, older adults.

Reference:

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The naked mole rat in the spotlight of modern science

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Abstract: Naked mole rats (*Heterocephalus glaber*) are among the most enigmatic land mammals. They live in large colonies, each of which has only one continuously reproducing female (the "queen") of enormous size, who is fertilized by one or more males. In other (worker) individuals, secondary sexual characteristics are reduced, and sex is determined only by genotyping. Mole rats do not get sick, do not age, have a very long lifespan, are resistant to hypoxia and hypercapnia, etc., and therefore attract the keen interest of representatives of a wide range of sciences. We have shown [*Kovalzon et al. // J. Evol. Biochem. Physiol., 2020, 56(5):451–458*] that workers are heterothermic mammals. They maintain a body temperature of 33–34°C during daily periods of rest, whereas during periods of activity, it drops almost to the ambient temperature. Apparently, in this way they manage to avoid overheating in the stuffy (8-15% O_2) underground labyrinths of the African Horn, where they live. The sleep structure of naked mole rats is quite original and resembles that characteristic of the early stages of ontogenesis of immature mammals [*Kovalzon et al. // Dokl. Biol. Sci., 2021, 496(1):25-29*], confirming the hypothesis that the main feature of the naked mole rats' organism is neoteny, i.e., the preservation of juvenile traits in adulthood [*Skulachev et al. // Physiol. Rev. 2017, 97:699–720*]. We further showed that enrichment of an artificial colony of naked mole rats with physical activity under conditions of relative hyperoxia (25% O_2) is a critical factor leading to the death of workers [*Adrianov. et al. // Eur. Phys. J. Spec. Top., 2025, doi:10.1140/epjs/s11734-025-02100-1*]. It was recently discovered [*Chen et al. // Science, 2025, 390(6769):eadp5056*] that the extraordinary lifespan of these animals and their resistance to cancer are associated with four C-terminal substitutions in the cGAS protein, which ensures efficient DNA repair.

Keywords: naked mole rats, heterothermia, sleep, hyperoxia, lifespan.

Sleep apnea and aging

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Abstract: ***Introduction:*** Recent studies have convincingly demonstrated the role of obstructive sleep apnea (OSA) in accelerating the aging process. These studies have also identified a new mechanism of action for proteins related to aging and age-related diseases. To further investigate this hypothesis, we evaluated the levels of the anti-aging protein klotho in patients with OSA and its relationship to sleep parameters. ***Materials and Methods:*** The study involved 29 male participants with a diagnosis of OSA of moderate severity at the Irkutsk Somnological Center. They formed the main group (OH) with a median age less than 45 years (38.5, 53). The control group (KG) included 20 healthy volunteers without OSA symptoms, matched for age (median 43.8, range 36-58). All participants provided informed consent to participate.. Standard polysomnography, enzyme immunoassay using a Chem Well device (USA) with a SEH757Hu commercial kit (Cloud-Clone Corp., USA) and statistical analysis were employed. All differences were considered significant at $p<0.05$ using the Mann-Whitney U-test. A Spirman correlation` coefficient was used for the correlation analysis. ***Results:*** The klotho protein level was 217 pg/ml (156-459) in exhaust gas and 272.5 pg/ml (210-459) in KG, with $p<0.012$. Correlation analysis demonstrated a positive linear relationship between klotho and sleep parameters such as deep sleep (3NREM) ($r=5980$, $p=0.001$) and REM sleep ($r=4281$, $p=0.21$), as well as a negative correlation with the severity of obstructive sleep apnea (OSA) as measured by the apnea-hypopnea index (AHI) and the desaturation index (DI) ($r=-0.7603$, $p=<0.000$; $r=-0.4601$, $p=0.12$). ***Conclusion:*** Our findings support the hypothesis that there is a decrease in klotho anti-aging levels in patients with OSA. This may contribute to premature aging.. The study revealed a positive correlation between the klotho protein and indicators of sleep patterns, as well as a negative relationship between this protein and the main trigger mechanism of intermittent hypoxia. This suggests that OSA can influence the processes of early and accelerated cellular aging.

Keywords: sleep, apnea, aging.

Clinically promising wearable and safe technologies for maintain active longevity

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Abstract: The 21st century has been heralded as a golden age in neuroscience. High-tech equipment has emerged for intravital imaging of brain structures and control of brain function using chips, light, and viruses. However, advances in pharmacological treatment of brain diseases are very limited due to difficulties in crossing the blood-brain barrier. Consequently, brain diseases still account for 30% of all known pathologies.

Photobiomodulation (PBM), which relies on non-invasive application of infrared light to targets such as the meningeal lymphatic vessels, offers promising new approaches to brain disease therapy. PBM technologies are safe, commercially viable, and portable.

Within Russian Science Foundation mega-grant 23-75-30001, the world's first medical light device (the AS-SGMO) was developed for stimulation of the brain and its meninges to lymphatic removal of toxins, such as beta-amyloid, from brain tissue and treat Alzheimer's disease. This technology was developed in accordance with modern medical requirements. Specifically, it is wearable and can be used both in the clinic for patient treatment and also at home, on airplanes, in the car, and in other comfortable settings to maintain brain function under conditions of intense work, emotional strain, stress, sleep deprivation, and age-related changes in the brain—i.e., in those at risk for dementia and other brain diseases.

This new field, called neurolymphotonics (doi:10.7150/thno.120374), reflects global changes in preventive medicine. Safe and wearable technologies are emerging that can be effectively used to maintain active brain function under conditions of chronic or excessive exposure to risk factors for neurodegenerative, metabolic, and age-related changes in the brain, with the goal of supporting active longevity.

An important continuation of mega-grant 23-75-3001 will be the development of a safe technology for the treatment of postnatal brain injury in newborns and infants, for whom

pharmacological therapy is limited not only by the presence of the blood-brain barrier but also by age.

Keywords: medical equipment, commercialization, applied and fundamental grants.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Narcolepsy as a natural experiment in disabling the orexin system in humans

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Abstract: Since Gelineau's description of narcolepsy's symptoms in 1880, this condition has become one of the most thoroughly studied sleep-wake disorders. The disease develops as a result of autoimmune inflammation of the hypothalamus-diencephalitis. Symptoms of narcolepsy, such as excessive daytime sleepiness and cataplexy attacks, become evident after the destruction of 90% of the neurons that produce the excitatory neurotransmitter orexin. The excess immune response occurs as a result of an infectious disease, vaccination, or without the evident cause. It most likely occurs in individuals having a specific histocompatibility antigen haplotype, HLA-DQB1*06:02. This trait alone does not fully explain the increased susceptibility to this disease. Other candidates include the human equivalent of the canarc-1 gene for canine narcolepsy and the hcrtr2 gene for the hypocretin/orexin receptor type 2.

Understanding the pathophysiology of narcolepsy leads to the creation of laboratory animals with knockout genes for the orexin receptors type 1 and type 2. They have the same behavioral features of the disease.

Selective destruction of orexin neurons is a unique opportunity to study the role of this neurotransmitter in cognitive, emotional, and behavioral processes in humans. Cognitive impairments un narcolepsy affect vigilance, selective attention, sustained attention, and alertness, as well as executive functions such as decision-making. Memory is also impaired. It has been shown that cognitive impairment is not related to the severity of sleepiness but represents a distinct process. Orexin is considered an «activator of activators» for systems involved in cognitive processing. For example, the attention network involves acetylcholine neurons in the basal forebrain ganglia, dopamine neurons in the ventrotegmental area, and noradrenergic neurons in the locus coeruleus. The absence of additional orexin stimulation leads to malfunctioning of these systems.

Cataplexy attacks in narcolepsy patients are known to be more often triggered by positive than negative emotions. The orexin system has been shown to be involved in modulating the

activity of dopaminergic ventrotegmental area. This explains the observed underactivation of the amygdala in patients with narcolepsy when presented with negative stimuli and overactivation in response to positive ones. The freezing response, a “false death” reaction that occurs in healthy individuals only to strong negative emotions, occurs in narcolepsy when presented with emotions of the opposite modality. Dysregulation of the dopamine system due to orexin deficiency also explains the phenomenon of narcolepsy patients' lack of dependence on dopaminergic psychostimulants.

Patients with narcolepsy exhibit difficulty making choices in ambiguous situations due to a dysfunction of the fronto-amygdalar reward system due to a lack of orexin stimulation. They do not experience difficulty making choices in risky situations depending from a different fronto-cortico-striatal system, which is less dependent on orexin.

Autonomic disturbances also reflect the orexin dysfunction in narcolepsy. Hypocretin hypothalamic neurons project to the nucleus of the solitary tract and the dorsal motor nucleus of the vagus nerve, the rostral ventrolateral medulla, and the lateral columns of the spinal cord.

A defect in orexin transmission leads to impaired sympathetic activation in response to stimuli of various modalities, resulting in insufficient heart rate reaction to stiluli and elevated blood pressure. Orexin dysfunction leads to metabolic disturbances. Weight gain in these patients develops due to decreased sympathetic stimulation of adipose tissue receptors, which mediate lipolytic processes.

Further advances in studying the role of the orexin system in the regulation of higher nervous functions are linked to the analysis of the brain neural networks in narcolepsy. For this purpose, approaches involving sleep microstaging (5-second epochs) and the use of AI engines that process large amounts of neurophysiological data in real time look promising.

Keywords: sleep, narcolepsy, orexin, cognitive functions.

Sleep apnea in adolescents: Sleep pattern and cognition

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Speaker: Liubov V. Rychkova, ScD, prof., RAS corresponding member, is a Director of the "Scientific Center for Family Health and Human Reproduction Problems" (SC FHHRP), Irkutsk, Russia; Professor of the Basic Department of Medical Psychology of the SC FHHRP and the Irkutsk State University, Secretary of the Commission of the Scientific Council for Pediatrics of the Section of Clinical Medicine of the Department of Medical Sciences of the Russian Academy of Sciences, President of the Irkutsk Regional Branch of the Union of Pediatricians of Russia, Head of the Irkutsk Scientific Center of the Russian Academy of Education, Member of the Association of Medical and Pharmaceutical Workers of the Irkutsk Region, Chairman of the Commission on Science and Education of the Irkutsk Region Public Chamber of the VIII convocation, Member of the Board of the Public Council under the Ministry of Health of the Irkutsk Region, Member of the Coordinating Council of the Russian Academy of Sciences and the Russian Academy of Education "Health and Education of Children, Adolescents, and Youth", Member of the Expert Council on Demographic Development in the Irkutsk Region under the Legislative Assembly of the Irkutsk Region. Rychkova L.V. is a Deputy Editor-in-Chief of journal "Acta Biomedica Scientifica" (Scopus). She obtained her Ph.D. (1997) and D.Sc. (2004) in pediatrics and pathophysiology. The main focus of her research interests is the study of fundamental mechanisms of childhood disease development as a basis for the development of new diagnostic, treatment, and rehabilitation technologies. Rychkova L.V. is scientific supervision of 11 scientific theses. She is author more than 670 scientific papers in peer-reviewed journals, from them 396 publications in bases Web of Sciences and Scopus, 15 monographs, 7 methodical recommendations, and 39 protected intellectual property rights.

Abstract: Sleep apnea (SA) can negatively affect adolescents' cognitive functioning. There are main pathogenetic mechanisms of SA such as hypoxic burden and altered sleep homeostasis that could initiate brain damage. It is known that obesity aggravates cognitive changes in SA. Thus, it is of particular interest to evaluate the cognitive functions and their associations with polysomnographic (PSG) variables in SA adolescents. Fifty-five SA male adolescents aged 15-17 years (35 obese and 20 normal weights, NW) and 20 matched controls were included in the study. Wechsler intelligence test (WISC-IV) was used to evaluate the participants' cognition. Spearman rank correlation analysis was performed to investigate the relationships between cognitive abilities against PSG variables. The PSG data showed that apnea/hypopnea index, desaturation index, arousal index, 1-2 stages, fragmentation index scores were significantly higher, while slow wave sleep and rapid eye movements time were significantly lower in adolescents with SA compared with controls. There was a tendency to higher SA severity in boys with obesity. Full-scale cognitive

ability quotient (FSCAQ), visual-spatial index, fluid reasoning index, working memory index, and processing speed index (PSI) scores were significantly lower for SA obese boys. NW SA adolescents had significantly lower FSCAQ and PSI scores compared with those in controls. Significant correlations were found between verbal/nonverbal indexes and PSG variables in obese boys only. The study demonstrates that the cognitive status in adolescents with SA decreases with a predominant deterioration of nonverbal abilities. This trend is most clearly manifested with obesity, which aggravates both hypoxia and sleep fragmentation severities.

Keywords: sleep apnea, adolescents, sleep pattern, cognition.

Mechanisms of plasticity and brain metabolism in sleep

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Abstract: Brain plasticity is a phenomenon of brain adaptation to the permanently changing environment. Physiological – developmental or adaptive - neuroplasticity is based on numerous mechanisms like synaptic turnover, synaptic transmission, neurogenesis, metabolic plasticity, cerebral angiogenesis, etc. Aberrant brain plasticity is linked to the development of central nervous system disorders and brain aging. The major manifestations of plasticity alterations are various neurological deficits, including learning and memory impairments.

Mitochondrial activity and dynamics underly plasticity of brain cells either in physiological or pathological conditions. Particularly, changes in the number and quality of mitochondria affect the ability of neurons, glia and cerebral endothelial cells to respond properly to stimuli inducing plastic events. Energy requirements of cells within the neurovascular unit are quite different and depend on the prevalence of glycolytic activity or mitochondrial oxidative phosphorylation. In general, neuroplasticity is associated with the metabolic reprogramming of brain cells, e.g. switch

from mitochondrial energy production to excessive glycolysis in activated microglia, or lactate-supported enhancement of oxidative phosphorylation in neurons within the active neuronal circuits. In adult brain neurogenic niches, changes in the energy production correspond to the intensity of neurogenesis: quiescence of neural stem cells requires extensive glycolysis and fatty acids oxidation whereas recruitment, proliferation and differentiation of neural stem cells depend on the contribution of mitochondria to the energy production.

Sleep is known as a powerful regulator of brain plasticity. In general, sleep supports mitochondrial quality control, repair of dsDNA breaks caused by the neuronal activity in the day time, as well as enhanced neurogenesis and memory consolidation. Recent data suggest that all these events might be controlled by mitochondrial activity and dynamics in sleep-regulating neurons and result in the restoration of mitochondria mass and quality in brain cells for the next day activity. Thus, sleep deprivation associates with significant changes in mitochondrial respiration, electron leakage in the electron transport chain, mitochondrial dysfunction, and release of mitochondrial DAMPs into the extracellular space. As a result, brain plasticity is affected due to progression of cellular senescence, disruption of the blood-brain barrier, and development of neuroinflammation.

Deciphering the key mechanisms of aberrant metabolism and blood-brain barrier alterations in sleep deprivation conditions provide novel prospective targets for the pharmacological correction of altered brain plasticity in brain aging and neurodegeneration.

Keywords: brain plasticity, metabolism, mitochondria, blood-brain barrier, neuroinflammation, sleep.

Photobiostimulation of the brain of patients with Alzheimer's disease

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Speaker: Vladislav Sursaev works as a MD at the Department of Nervous Diseases at Sechenov University in Moscow. In 2021 he graduated from the Medical University by I.M. Sechenov, then specialized in neurology. He is currently conducting research as part of his PhD thesis on 'The impact of sleep disturbances on cognitive function in Alzheimer's disease: a clinical and neurophysiological study'. He is the author and co-author of articles in journals such as the "S.S. Korsakov Journal of Neurology and Psychiatry" and "Effective Pharmacotherapy".

Abstract: A prospective randomized study of photobiostimulation of the brain of patients with Alzheimer's disease is being conducted on the basis of the Sechenov University Clinic of Nervous Diseases. During the study, patients are given PET\CT with 18F-FDG at the outpatient stage, followed by neurocognitive testing, EEG on the first day of hospitalization. For 10 days, patients receive photostimulation therapy for 30 minutes a day in a preset mode. After the therapy, the neurocognitive status, EEG, and PET are re-evaluated.\CT scan with 18F-FDG. According to preliminary data, patients showed a statistically significant improvement during neurocognitive tests, an increase in the amplitudes of EEG activity in the temporal and parietal lobes, and an increase in glucose metabolism during repeated PET\CT scan with 18F-FDG.

Keywords: photobiostimulation, Alzheimer's disease, cognitive functions.

Classification of insomnia forms based on analysis of brain electrical activity and sleep structure – impact on clinical outcomes

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Speaker: Mikhail Tardov is a professor in the Department of General Medical Practice at Peoples' Friendship University of Russia, where he teaches neurology and the fundamentals of somnology, supervises dissertation research (he has supervised nine dissertations), and also works clinically as a neurologist and somnologist. He graduated from the N.A. Semashko Medical Institute in 1986, defended his PhD dissertation in 1998 (on the diagnosis of brain death), and defended his doctoral dissertation in 2009 (on cerebral blood flow in gestosis). He regularly publishes issues on neurological and sleep disorders in the "S.S. Korsakov Journal of Neurology and Psychiatry", "Effective Pharmacotherapy" and other. Author of more than 120 publications in Russian and foreign journals, 1 monograph in Russian, co-author of 6 monographs.

Abstract: Insomnia is one of the most common medical problems in modern humanity, significantly impairing quality of life. Its prevalence, according to some estimates, reaches 45%. Cognitive behavioral therapy, although not universally available, and medications are successfully used for treatment, which in turn create a number of problems, including the development of dependence or tolerance to sleeping pills. Several hypotheses for the development of insomnia have been proposed, the most significant of which is the hyperactivation model, associated with increased nervous system tone both during wakefulness and sleep. Increased brain activity during sleep can be recorded using electroencephalography, either as a standalone technique or as part of polysomnography. In cases of insomnia with hyperactivation, the EEG records a number of electrophysiological phenomena characteristic of wakefulness, not sleep. Identifying such signs can form the basis for a treatment approach that does not target GABA or histamine receptors, but rather directly affects orexin receptors.

Keywords: insomnia, cognitive function, polysomnography.

Changes in visual perception in healthy volunteers after transcranial photobiomodulation

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Speaker: Alex O. Trofimov is an Associate Professor at the Department of Neurological Diseases of Privolzhsky Research Medical University in Nizhny Novgorod, Russia. He received his MD and PhD degrees in neurosurgery and neurology from the Nizhny Novgorod Medical State Academy in 1998 and 2006, respectively. At various times, he completed fellowships at Johns Hopkins University in Baltimore, the Catholic University of Leuven, King's College London, the University of California, Los Angeles, Sklifosovsky's Emergency Care Institute of Moscow, and etc.. His current research interests include brain physics, intracranial pressure, cerebral microcirculation, transcranial photobiomodulation, and electrical stimulation. He has published more than 100 journal articles and 5 book chapters. He is a member of ISOTT, AANS, and EANS.

Abstract: Low-level near-infrared light-induced transcranial photobiomodulation (NIR-TPBM) is a promising technology for improving cerebral blood flow and metabolism. However, the effects of NIR-TPBM on the visual pathway's function remain poorly understood. The aim was to assess the visual pathway's function changes in response to NIR-TPBM in young, healthy volunteers. Our results on the increase in eye movement coupling after NIR-TPBM, with a high probability, indicate a positive effect on the functional connectivity of neural networks, which opens up broad prospects for its use in various neurological and mental disorders. Finally, although this study demonstrated the effectiveness of NIR-TPBM on visual pathways function, the single application certainly limits the generalizability of these results to clinical settings.

Keywords: photobiomodulation, volunteers, eye tracking.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 24-45-00010).

Stress whirlwind: Arterial hypertension, insomnia and lymphatic drainage

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Qualification:

- awarded the degree of PhD 2007;
- by the decision of the Presidium of the Higher Attestation Commission of the Republic of Belarus, he was awarded the academic title of Associate Professor in 2011;
- by the decision of the Presidium of the Higher Attestation Commission of the Republic of Belarus, the degree of Doctor of Medical Sciences was awarded in 2020,he was awarded the academic title of professor in 2021.

I had been the leader or scientific performer of several funded research projects: "Develop and implement a method for the treatment of coronary heart disease and osteoporosis by influencing the general mechanisms of their development", (2011–2013).

"To develop and implement a new method of secondary prevention and treatment of lesions of the cardiovascular system in case of deficiency /vitamin D deficiency in people with arterial hypertension" (2013-2015). "Identification of risk groups for D-vitamin deficiency", (2013–2015).

"Research on the impact of palm oil on the health of the population of the Republic of Belarus and the establishment of acceptable medical and biological levels of palm oil consumption" (2017–2018). Grant of the President of the Republic of Belarus (2019) for the development and implementation in general medical practice of recommendations for identifying risk factors, diagnosing and correcting D-hypovitaminosis, the use of which will help increase the primary prevention of vitamin D-associated diseases among residents of the Republic of Belarus.

"To develop new types of chocolate products enriched with protein, calcium and vitamin D, providing an increase in the balance of nutrition of preschool and school children" (2016–2020).

Research work on the project of cross-border cooperation No. RVI 1/0326/16 "Model of the medical program to combat osteoporosis in the Polish-Belarusian border area" (2018–2021).

"Develop and implement a method for assessing the risk of development and progression of atrial fibrillation in patients with arterial hypertension" (2021–2024).

Abstract: Chronic stress plays a significant role in the development of arterial hypertension (AH), being a significant modifiable cardiovascular risk factor and a target for intervention. Chronic stress, in turn, often causes sleep disturbances. Psychoemotional disturbances in the early stages of AH may reflect not only vascular damage to the brain but also be a manifestation of stress-related neuroinflammatory processes in the hippocampus. Impaired glymphatic clearance is a key link between stress, inflammation, and brain dysfunction. The modern model of metabolite removal

from the central nervous system or the “lymphatic drainage system of the brain” is represented by the functionally interconnected glymphatic system and meningeal lymphatic vessels. Despite a clear understanding of the general anatomy, the role of the "lymphatic drainage system of the brain" in the context of cerebroprotection remains poorly understood.

The purpose of my presentation is to provide an overview of the accumulated research findings on the relationship between chronic stress, hypertension, sleep disorders, and the role of glymphatic dysfunction as a key factor in the development of these diseases.

The report will examine the main mechanisms of impaired glymphatic clearance: neuroendocrine (hypercortisolemia and astrocyte atrophy), vascular (endothelial dysfunction, reduction of arterial pulsation and increased arterial stiffening), and inflammatory (microglial activation and release of pro-inflammatory cytokines). Special attention is paid to the formation of three self-perpetuating vicious cycles: «stress → impaired glymphatic clearance → hippocampal damage → increased stress»; «AH → reduction of arterial pulsation → glymphatic dysfunction → AH progresses»; and «insomnia → toxin accumulation → locus coeruleus damage → aggravation of sleep disorders».

Photobiomodulation, a non-invasive treatment using red and infrared light, is considered a promising therapeutic approach. Results from pilot clinical trials have now been published, confirming the positive impact of this therapy on cognitive function, emotional status, and sleep quality. Accumulated research data indicates the potential and innovative nature of photobiomodulation in the comprehensive treatment of a number of conditions and may be useful in the treatment of sleep disorders, AH and chronic stress.

Keywords: stress, arterial hypertension, insomnia, lymphatic drainage.

Introduction for advanced biomedical imaging facility

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Speaker: Dan Zhu is Distinguished Professor of Huazhong University of Science and Technology, SPIE/OPTICA Fellow, Director of Advanced Biomedical Imaging Facility, Vice-director of Wuhan National Laboratory for Optoelectronics. She has been developing tissue optical clearing methods from in vitro to in vivo. She has owned more than 200 peer-review papers in Science Advances、Nature Communications、Light: Science & Applications et al, and 100 plenary or invited talk on international conferences, including SPIE Bios Hot Topic. She is an Associate editor of Journal of Biomedical Optics, except executive Editor-in-Chief of Frontier of Optoelectronics：Biomedical Photonics, Editorial Member or Guest Editor of Biomedical Optics Express, Scientific Reports, Journal of Innovative Optical Health Sciences, and Frontier of Optoelectronics etc.

Abstract: Advanced Biomedical Imaging Facility (ABIF), co-founded by Hubei Province and the Ministry of Education, is located in Wuhan, China with a total investment exceeding 1.1 billion RMB and a 30,000 m² dedicated imaging building. It is co-constructed by Huazhong University of Science and Technology (HUST) and the Innovation Academy for Precision Measurement Science and Technology, CAS. ABIF has assembled a team of nearly 100 R&D and technical support personnel, focusing on optical imaging, 4D-EM, MRI, PET, and image fusion & intelligent diagnosis. The newly built laboratories provide an excellent venue for life science research, drug development, and clinical research. The ABIF is expected to be completed and open to the public in then of 2026.

Keywords: optical imaging techniques, optical clearing.

High-throughput volumetric mapping of synaptic transmission and microcirculations in the brain *in vivo*

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Speaker: Wei Chen is a Professor at Huazhong University of Science and Technology and a core member of the Advanced Biomedical Imaging Facility. His research focuses on the development of high-performance optical imaging technologies for neuroscience, with particular emphasis on in vivo, high-resolution, and high-sensitivity imaging of brain structure and function at subcellular details. Prof. Chen's work integrates optical engineering, computational imaging, and machine learning to overcome key challenges in deep-tissue imaging, such as optical aberration and low signal-to-noise ratio. Prof. Chen has published over 40 peer-reviewed papers in leading journals such as Nature Methods, Nature Neuroscience, Nature Communications, and Cell Metabolism, and has served as a reviewer for top-tier journals including Nature Photonics, Nature Communications, and Optica. He is a recipient of the National Natural Science Foundation of China Excellent Young Scientists Fund. His research aims to advance next-generation neuroimaging tools for uncovering the spatiotemporal organization of neural circuits and their roles in brain function and behavior.

Abstract: Volumetric imaging of synaptic transmission and microcirculations in the brain in vivo requires high spatial and high temporal resolution. Shaping the wavefront of two-photon fluorescence excitation light, we developed Bessel-droplet foci for high-contrast and high-resolution volumetric imaging of synapses. Applying our method to imaging glutamate release, we demonstrated high-throughput mapping of excitatory inputs at > 1,000 synapses per volume and > 500 dendritic spines per neuron in vivo and unveiled novel features of functional synaptic organization in the mouse primary visual cortex. We also achieved high-resolution volumetric imaging of lymphatic microcirculations in mouse brain in vivo.

Keywords: high-resolution volumetric imaging, brain and lymphatic microcirculations.

PET instrument for freely behaving animals

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Speaker: Dr. Peng Xiao is a professor at Huazhong University of science and technology (HUST). He obtained his PhD degree from the National University of Singapore (NUS). After working two years in the R&D Department STMicroelectronics Asia, Dr. Xiao joined HUST to pursue his academic career in 2006.
He has been actively working in innovative reconstruction algorithms and instrumentation development for Positron Emission Tomography, as well as its applications in biology and medicine. He has owned more than 70 papers in journals including Physics in Medicine and Biology, IEEE Transactions on Radiation and Plasma Medical Sciences, and Computer Methods and Programs in Biomedicine. He is also a co-founder of RaySolution Medical Imaging Technology Co., Ltd., which commercializes the "all-digital PET" technology.

Abstract: Brain science is currently a highly challenging research hotspot, and in vivo brain function observation in living animals is critical to its advancement. As a non-invasive functional imaging modality, positron emission tomography (PET) offers unique advantages in such applications. However, conventional animal PET imaging requires the subject to be anesthetized or restrained, resulting in a non-awake or non-free-moving state; the observed outcomes therefore do not reflect the normal state of brain function. Meanwhile, brain function is dynamically changing, and existing animal PET systems cannot simultaneously achieve satisfactory temporal resolution and image quality, making it difficult to meet the demands of dynamic brain function observation. We have developed a "Bi-Dynamic" PET instrument capable of dynamic imaging in awake and freely moving animals, enabling high-temporal-resolution and high-spatial-resolution dynamic imaging of the rat brain.

Keywords: positron emission tomography, freely behaving animals.

From detecting to imaging: Computing architecture based on plug-n-image

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Speaker: Professor, School of Software Engineering, Huazhong University of Science and Technology, PhD in Computer Application.

Her research interests lie in rendering and imaging algorithms, as well as software engineering. She is dedicated to build the Plug-n-Image technology system to support the rapid development and innovative applications of detection and imaging systems. She is the author of The Art of Functional Programming and has published more than 40 academic papers.

Abstract: The information flow in PET spans six main levels: gamma photons, scintillation photons, scintillation pulses, single events, coincidence events, and images. The essence of PET digitalization lies in advancing the computation origin, leading to characteristics of full decoupling, full digitalization, and full data accessibility. These features bring both opportunities and challenges to PET imaging computation. Based on her academic and research experience, the speaker will explore the topic of a Plug-n-Image-Based Computing Architecture, illustrating how top-level design can decouple the entire workflow from particle detection to imaging, integrate diverse heterogeneous computing resources to meet different computational requirements, and build an innovative, modular platform. This platform enables researchers to flexibly assemble intelligent detection and imaging systems, perform intelligent full-process data analysis, and rapidly conduct clinical and preclinical studies.

Keywords: positron emission tomography, intelligent full-process data analysis, imaging systems.

Tissue optical clearing for deep imaging in neuroscience

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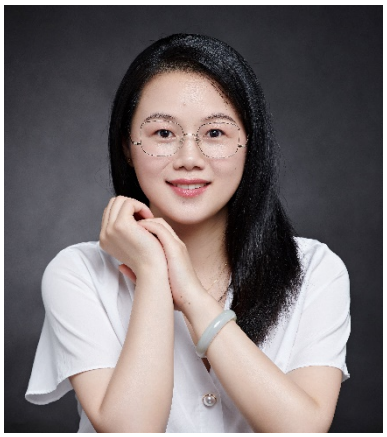

Speaker: Tingting Yu is an Associate Professor of Huazhong University of Science and Technology. She is mainly engaged in research on tissue optical clearing methods and applications, focusing on the development of optical imaging techniques based on tissue clearing for obtaining and reconstructing three-dimensional structure information of the central nervous system, peripheral nervous system, and other biological tissues. She has published over 30 SCI papers in journals such as Science Advances, Nature Communications, and Theranostics, and has contributed to the compilation of four Chinese and English monographs, with eight authorized patents. She has led projects including the General Project, Young Scientists Fund from NSFC, International Cooperation and Exchanges Projects from NSFC, and Hubei Province's Key R&D Program, as well as participating in Key R&D projects of the Ministry of Science and Technology and the Key International Cooperation Research Projects of NSFC. She is a Young Committee Member and the deputy secretary-general of the Biomedical Optics Professional Committee of the Chinese Optical Society.

Abstract: Acquiring the three-dimensional (3D) structure of biological tissues is essential for research in life sciences. Modern optical imaging techniques and fluorescent labeling technologies have provided vital tools for obtaining high-resolution information on the 3D structures of biological tissues. However, the turbid nature of biological tissues limits the depth of light penetration, leading to restricted applications for large tissues or whole organs. Tissue optical clearing technology takes a different approach by making the tissues transparent using various physical and chemical strategies to reduce the attenuation of light in tissues, and providing a new approach for the 3D imaging of deep tissues. Here, we will introduce the principle of tissue optical clearing, as well as the progress of in this field, covering the fluorescence labeling, tissue clearing, and imaging of various tissues, as well as the applications in neuroscience.

Keywords: optical imaging techniques, mechanisms of tissue optical clearing.

All-digital brain PET system: Design and performance evaluation

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Speaker: Mr. Lei Fang is a PhD student at Huazhong University of Science and Technology (HUST). He has been dedicated to the research and development of all-digital PET systems for over 17 years.
He led the development of the world's first clinical all-digital PET system, recognized as a National Innovative Medical Device, and the first brain-dedicated all-digital PET system with independent intellectual property rights. He has overseen the approval of nine Class III medical device registration certificates and built a high-performance product portfolio. His work has been recognized among China's Top 10 Sci-Tech News Events and Major Medical Advances in 2019. He has filed over 70 patents and published more than 10 high-impact papers.

Abstract: We present the design and performance evaluation of an all-digital brain PET system optimized for high-resolution and dynamic neuroimaging. The system features a transaxial and axial field-of-view of 320 mm and 255 mm, respectively, and comprises a 6 × 6 array of detector modules. Each module integrates 3.9 mm × 3.9 mm × 20 mm lutetium-yttrium oxyorthosilicate (LYSO) crystals coupled one-to-one with silicon photomultipliers (SiPM). Detector signals are individually digitized using a multi-voltage threshold (MVT) scheme, enabling precise signal sampling and high count-rate performance. The system achieves an average sensitivity of 22.1 cps/kBq and a peak noise equivalent count rate (NECR) of 150.9 kcps. Phantom studies demonstrate a spatial resolution of 2.0 mm. In human brain imaging, the system provides high image quality and supports dynamic acquisition with temporal resolution as short as 2 s per frame, enabling visualization of regional tracer uptake and vascular dynamics.

Keywords: all-digital brain PET system, high-resolution and dynamic neuroimaging.

All-digital brain PET: A new paradigm in neuroimaging

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Speaker: Mr. Bo Zhang is a PhD student at Huazhong University of Science and Technology (HUST). In 2014, he founded RAYSOLUTION to advance the industrialization of all-digital PET technology. Under his leadership, the company has become a leading high-end medical device enterprise and is recognized as one of China's Top 500 "Invisible Unicorn" companies. He contributed to the formulation of China's digital PET standards and to revising registration guidelines at the Center for Medical Device. He received the First Prize of the "Huang Jiasi Biomedical Engineering Technology Invention Award" in 2019 and was named "National Upward Good Youth" in 2020. He has filed 36 patents, published over 10 papers, and serves on committees of the China Instrument and Control Society and the Chinese Nuclear Society.

Abstract: Deciphering the functional and molecular complexities of the human brain requires highly precise imaging tools. The DigitMI i30 is an all-digital brain-dedicated PET system designed to provide high sensitivity and optimized performance for neurological imaging without the need for CT, thereby reducing radiation exposure. The system achieves a time-of-flight (TOF) resolution of 249 ps and a sensitivity of 22.1 cps/kBq, supporting high-quality and efficient brain imaging. This presentation describes the system design and its key clinical applications. CT-free attenuation correction approaches are presented, demonstrating robust quantitative performance. The advantages of brain-dedicated PET in epilepsy imaging are highlighted, particularly for accurate localization of epileptogenic foci. High-resolution visualization of small deep brain nuclei is demonstrated, enabled by the system's dedicated geometry and enhanced sensitivity. In addition, ultra-fast dynamic imaging with temporal resolution down to 2 s per frame facilitates improved characterization of tracer kinetics and cerebral perfusion. Together, these results support a new paradigm for brain PET, enabling more accurate, low-dose, and quantitative neuroimaging.

Keywords: all-digital brain PET, optimization of neurological imaging.

High-speed hemodynamic imaging with low fluence photoacoustic microscopy

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Speaker: Fenghe Zhong works as a postdoctoral research fellow at the Huazhong University of Science and Technology. He received his bachelor's degree from the Huazhong University of Science and Technology, his MS degree from the University of Rochester, and his PhD from the Washington University in St. Louis. His research focuses on functional photoacoustic microscopy and fluorescence microscopy to advance the understanding of brain metabolism.

Abstract: High-speed multi-parameter photoacoustic microscopy (PAM) holds immense value in biomedical research, yet its imaging quality is often compromised by noise stemming from limited pulse energy and low average power. This report outlines innovative hardware and algorithmic strategies to enhance imaging quality and throughput in PAM. Firstly, recognizing the constraints imposed by traditional piezoelectric ultrasonic transducers on sensitivity, field-of-view and detection bandwidth due to their size and performance, we adopted a polymer-based micro-ring resonator. This enabled high-speed functional PAM imaging of the living mouse cerebral cortex, facilitating precise tracking and localization of individual red blood cells. Furthermore, we performed a side-by-side comparison with two-photon microscopy to validate the localization accuracy and achieved super-resolution monitoring of ischemic stroke in the cortical region. Secondly, leveraging the oversampling and continuity of axial signals in 3D PAM, we employed a self-supervised single volume denoising algorithm. This approach significantly reduced the required pulse energy for imaging while maintaining the functional imaging ability (sO_2 and blood flow). We achieved high quality imaging with 1/10 of the original pulse energy, thereby mitigating potential thermal damage caused by high excitation power and expanding the application potential of high-speed multi-parameter PAM. The development and integration of these innovative methods will serve as a robust toolset for advancing biomedical imaging.

Keywords: high-speed hemodynamic imaging, low fluence photoacoustic microscopy.

Ultrafast photothermal PCR for POCT

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Speaker: ZHAO Xiangwei is a professor of State Key Laboratory of Digital Medical Engineering, Southeast University. He has successively served as a visiting scholar at the Institute of Laser Engineering, Osaka University, Japan; the Department of Biomedical Engineering, University of Michigan, USA; the Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, USA; and Harvard Medical School. Currently, his research focused on bio-barcode technology. The research themes include spatial omics, brain organoids, POCT, etc. He was PI of more than 10 projects, such as the National Natural Science Foundation of China grant, the National Key R & D Program projects, and the Science and Technology Support Program of Jiangsu Province. He has published more than 100 SCI papers and transferred 9 invention patents. He has won the First Prize of the Natural Science Award from the Ministry of Education, the Second Prize of the Technological Invention Award of the "Huang Jiasi Biomedical Engineering Award" by the Chinese Society of Biomedical Engineering, and the Gold Medal at the Geneva International Invention Exhibition. He has been selected as an Excellent Talent in the New Century by the Ministry of Education, a Middle-aged and Young Academic Leader in the Qinglan Project of Jiangsu Province, a High-level Talent in the "Six Talent Peaks" Project of Jiangsu Province, and a "Zijin Young Scholar" and a "Huaying Scholar" at Southeast University.

Abstract: Plasmonics is a branch of optics that primarily utilizes surface plasmons (SPs) to confine, conduct, and manipulate external electromagnetic fields at the nanoscale, enabling the exploration of interactions between light and matter. Plasmonic nanomaterials, owing to their excellent near-field enhancement, photothermal effect, and optical force effect, hold broad application prospects in fields such as energy, catalysis, optics, and biomedicine. In this study, leveraging the efficient photothermal effect of surface plasmons, we designed and fabricated a photothermal fiber with broadband light absorption capability, achieving ultrafast photothermal PCR based on a white LED. Our results show that this photothermal fiber material can reduce the PCR detection time to within 10 minutes while enabling fluorescence or colorimetric detection of the amplification products. More importantly, the photothermal fiber-based PCR also allows the integration of bacterial photothermal lysis and PCR amplification in a single step. These findings demonstrate the great potential of photothermal fibers in applications such as infectious disease diagnosis, food safety, and environmental monitoring.

Keywords: plasmonic nanomaterials, photothermal effect.

Research on flexible conductive hydrogel semi-dry electrodes for non-invasive brain-computer interfaces

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Speaker: Quanguo He is a professor at the School of Biological Sciences and Medical Engineering, Hunan University of Technology, China. He was born in 1973. He obtained his MSc degree in Organic Chemistry from Xiangtan University in 2000, and his PhD degree in Biomedical Engineering from Southeast University in 2003, China. Then he entered the South China University of Technology as a postdoctoral researcher in 2005 and has become a professor at Hunan University of Technology since 2008. He has been selected on the candidates list of "Hunan Provincial 121 Talents Program" since 2010. Currently, he serves as the Dean of the School of Biological and Medical Engineering at Hunan University of Technology. His research interest covers biosensors, Brain-Computer-Inferface(BCI), and relevant applications. He recently focuses his research on the methodology of ultrasensitive biochemical detection and devices, as well as BCI elctrodes in the long form. He has published more than 200 papers in international journals.

Abstract: Flexible conductive hydrogel semi-dry electrodes represent a pivotal advance in non-invasive brain-computer interfaces, bridging high signal fidelity and long-term wearability. Core formulations integrate hydrophilic polymer matrices (gelatin, polyvinyl alcohol, polyacrylamide), conductive components (Fe^{3+} ionic crosslinkers, PEDOT:PSS, carbon nanotubes), and functional additives (glycerol for moisture retention, chitosan derivatives for antibacterial activity). A benchmark Fe^{3+}-doped gelatin/poly(acrylate-co-acrylamide) hydrogel achieves 534% fracture strain and a stable electrode-scalp impedance of 17.8 ± 3.69 kΩ at 10 Hz, enabling EEG signal acquisition with >0.9 correlation to gold-standard wet electrodes.

Scalable fabrication strategies include one-pot room-temperature polymerization for double-network hydrogels, 3D printing for personalized electrode architectures, and phase separation to construct hydrophobic conductive skeletons embedded with ionic hydrogel electrolytes. These processes balance mechanical compliance, long-term conductivity, and biocompatibility, accelerating the translation of hydrogel semi-dry electrodes to clinical and consumer applications.

Keywords: conductive hydrogel, semi-dry electrode, brain-computer interface, ionic conductivity, flexible electronics.

Ultrawideband photoacoustic cerebrovascular imaging of rodents: From scanning angiography to real-time tomography

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Speaker: Pavel V. Subochev, PhD, is Head of the Laboratory of Ultrasonic and Optoacoustic Diagnostics at the A.V. Gaponov-Grekhov Institute of Applied Physics of the Russian Academy of Sciences and Director of BARI-NN Ltd., a company developing custom piezopolymer ultrasound detectors for optoacoustic imaging. He graduated from Lobachevsky State University of Nizhni Novgorod in 2006 and received his PhD in acoustics from the Institute of Applied Physics in 2010.

His research is centered on a practical question: how can light-based contrast be converted into reliable ultrasound images of living tissues? Since 2012, he has developed instrumentation for optoacoustic imaging, including ultrawideband PVDF-, PVDF-ITO-, and PVDF-TrFE-based detectors, multimodal optoacoustic and laser-ultrasound systems, image reconstruction methods, and translational vascular imaging approaches.

As principal investigator of Russian Science Foundation projects, he has led work on clinical optoacoustic microscopy, detector arrays for brain imaging, and multimodal microscopy for neurovascular-coupling studies. His recent work includes transcranial rodent cerebrovascular imaging, post-thrombotic syndrome angiography, breast-cancer therapy-response imaging, and real-time spherical-array optoacoustic micro-angiography.

He is a co-author of papers in Light: Science & Applications, Advanced Science, Laser & Photonics Reviews, and other peer-reviewed journals. He has also worked as a visiting researcher at the Tohoku University in Japan (2019), University of Bern (2014, 2016), and ETH Zurich (2019) in Switzerland.

Abstract: Photoacoustic imaging can be described very simply: we shine short pulses of light into tissue and then listen to the ultrasound waves that are born where the light is absorbed. For brain research, this is especially attractive because blood vessels are natural optical absorbers, and their signals can reveal vascular architecture and hemodynamic changes without the need for external contrast agents. The difficult part is that the brain is hidden behind the skull, and the acoustic signals are extremely broad in frequency and direction-dependent.

This talk will show how custom ultrawideband piezopolymer ultrasound detectors help us hear these signals more clearly. I will begin with scanning optoacoustic angiography of the rodent brain, where modeling and in vivo experiments helped identify illumination conditions for visualizing cerebral vessels several millimeters below the surface. I will then discuss miniature PVDF-TrFE hydrophones and ring-segment detectors for optical-resolution photoacoustic microscopy, including hybrid optical and acoustic neuroimaging geometries.

The final part will move from slow scanning to real-time volumetric tomography using high-density polymer-based spherical arrays. These arrays are designed to combine sensitivity, bandwidth, and wide angular coverage, so that vascular morphology and oxygenation can be followed dynamically in small animals. The central message is that better photoacoustic brain imaging is not only a question of stronger lasers or faster algorithms; it also depends on building better acoustic ears for listening to light.

Keywords: photoacoustic imaging; optoacoustic angiography; neurovascular coupling; ultrawideband ultrasound detection; piezopolymer detectors; cerebral microangiography

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 25-45-02127, “Multimodal optical microscope for cortex-wide neurovascular coupling study”, Russia-China grant).

Complex system and future technologies in neuroscience – CSFTN'26

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Multimodal imaging devices work together with nano- and microstructure materials for biomedical applications

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Speaker: Prof. Dmitry Gorin, Full Professor at the Center of Photonic Science and Engineering at Skolkovo Institute of Science and Technology. Dmitry Gorin received his Diploma of Engineer-Physicist in 1997 and CSc and DSc degrees in Physical Chemistry in 2001 and 2011, respectively, from Saratov State University. From 2005 to 2009, he visited the Max-Planck Institute of Colloids and Interfaces (the group of Dr. G.B. Sukhorukov), before becoming a postdoc there from 2009 to 2010 in the group of Prof. Dr.H. Moehwald. He was then appointed professor at the Department of Nano- and Biomedical Technologies at Saratov State University from 2011 till 2017, after which he joined Skoltech as a Full Professor (http://biophotonicsskoltech.ru/). He was the supervisor and co-supervisor of 20 PhD theses and consultant of 2 DSc theses. His research interests are biophysics, biophotonics, and physics of colloids and interfaces. As a visiting scientist, he collaborated with the University of Arkansas for Medical Sciences (Little Rock), Charité University Hospital (Berlin), Queen Mary University of London, Ankara and Ghent Universities, Tomsk Polytechnic University, Bilkent University. He is co-founder of Tetraquant and Hyperspectrus companies.

Abstract: A trend in the development of modern medical imaging is the introduction of devices that combine multiple modalities into clinical practice. For example, four imaging systems combining optoacoustics and ultrasound, have already been approved for clinical use in the United States, China, and Japan. An endoscopic system has been developed that combines modalities such as OCT and optoacoustics. The possibility of combining diffuse reflectance spectroscopy and optoacoustics has been demonstrated. For such systems, it is necessary to develop calibration test systems, biological tissue phantoms, and multimodal contrast agents that support several modalities, such as ultrasound, MRI, and optoacoustics. Methods for obtaining contrast agents include the Layer by Layer assembly method, the Freezing Induced Loading method, and their combination. Promising components providing contrast in MRI are iron oxide nanoparticles, indocyanine green and its aggregates provide fluorescent and optoacoustic contrast. The use of a gas or liquid core provides ultrasound contrast. Maghemite nanoparticles measuring 3.2±0.7 nm were found to have T1-enhancing properties comparable to those of a commercially available contrast agent. Maghemite nanoparticles were synthesized using a TetraQuant CR-1 automated reactor. It should be noted that iron oxide nanoparticle-based preparations have already been approved by the FDA for clinical use in the treatment of anemia (Feraheme) and for MRI contrast of glioblastomas (Ferabright). Modern

technologies make it possible to create multicomponent nanocomposite particles that provide not only multimodal contrast but also a therapeutic function controlled by external influences.

Keywords: multimodal imaging devices, nano- and microstructure materials, biomedical applications.

Sleep deficiency exacerbates age-related decline in brain drainage and clearance in mice

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Meningeal lymphatic vessels (MLV) drainage of the brain plays a key role in maintaining homeostasis and removing toxic metabolites. With age, the function of the MLV naturally deteriorates, which contributes to the accumulation of metabolic products in brain tissues. However, in real life, aging rarely occurs in isolation — it is often accompanied by additional negative factors, among which one of the leading places is occupied by chronic sleep disorders. It is known that sleep is a natural time for activating brain drainage. It is logical to assume that such two processes as age-related sleep disorders and decreased brain drainage are interrelated, which, however, remains poorly understood.

The aim of the research was to study the effects of acute and chronic sleep deficiency on brain drainage in mice of different ages.

The studies were conducted on male C57BL/6 mice (aged 3, 12, and 24 months). To simulate sleep deficiency, the "What is it?" reflex method was used by providing a new object to the cage every 3 hours, which caused arousal in mice and activation of research activities. For acute sleep deficiency, the method was used for 24 hours, for chronic - for 10 days, where sleep was excluded every day from 17:00 to 20:00, which is associated with the preference of mice to sleep at this time of day. EEG recordings were used to assess sleep and wakefulness. To study the effect of sleep deficiency on brain drainage, confocal ex vivo analysis of the distribution of fluorescein isothiocyanate carboxymethyl dextran (FITCD, 70 kDa, Sigma, 5 µl, intraventricular injection at a rate of 0.1 µl/min) in the dorsal and ventral parts of the brain was performed. To analyze the effects of sleep deficiency on the excretion of metabolites from the brain, the ELISA method was used to quantify the metabolites of neurons in brain structures.

The results revealed an expected age-related decrease in brain drainage. Indeed, the intensity of the FITCD signal in 24-month-old mice compared with 3- and 12-month-old mice was 2.2 times ($p<0.001$) and 2.7 times ($p<0.001$) lower in the ventral part of the brain and 1.7 times ($p<0.01$) and 0.6 times ($p<0.01$) is lower in the dorsal parts of the brain. Chronic but not acute sleep deficiency was accompanied by a decrease in brain drainage, and it was more pronounced in old mice than in young and middle-aged animals. Thus, after chronic sleep deprivation, compared with control, the intensity of the FITCD signal in the ventral and dorsal parts was lower in 24-month-old mice by 7.8 times ($p<0.01$) and 5.6 times ($p<0.01$), in 12-month-old mice by 3.5 times ($p<0.001$) and 2.2 times three times ($p<0.001$), 1.7 times ($p<0.001$) and 1.7 times ($p<0.001$) in 3-month-old mice.

Decreased brain drainage caused by chronic sleep deficiency led to the accumulation of neuronal metabolites such as beta-amyloid and tau protein in mice of all ages. However, these changes were statistically significant only in older mice. Thus, the level of beta-amyloid in the brain

of 24-month-old mice was 18.30 ± 2.26 pg/g of protein versus 11.65 ± 1.25 pg/g of protein; 123.35 ± 2.26 pg/g of protein versus 92.40 ± 3.41 pg/g of protein.

Overall, the results revealed that chronic sleep deficiency worsens the age-related decline in brain drainage and the excretion of toxic metabolites from mouse brain tissues. These findings suggest that maintaining adequate sleep in old age is important for maintaining the drainage function of the brain and preventing accelerated aging of neurons.

Keywords: drainage, chronic sleep deprivation, meningeal lymphatic vessels.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 25-15-00174).

Technology of optical in vivo visualization of the functions of cervical lymphatic vessels in real time

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The cervical lymphatic system, which includes pathways in the form of lymph vessels and an anatomical station as deep cervical lymph nodes, is closely anatomically and morphologically connected to the meningeal lymphatic network, playing an important role in the drainage and clearance of the brain. The contractility of lymphatic vessels is an important manifestation of their function, ensuring the movement of lymph through the lymphatic network in order to remove unnecessary compounds, metabolites and toxins from tissues. In this aspect, the contractility of the cervical lymphatic vessels is a key mechanism in the processes of drainage and clearance of the brain. However, despite the understanding of the important role of cervical lymph vessel contractility in maintaining brain homeostasis, methods for studying this function in real time in living animals are limited, which requires the development of new and accessible approaches.

The purpose of this study was to develop a technology for multiphoton imaging of the cervical lymphatic vessel using a non-immersion (dry) lens in male mice. Mature male BALB/c mice were used as the object of the study. The study used a Nikon A1R MP microscope, a 10x lens.

During the study, a surgical protocol for detecting a lymphatic cervical vessel was developed. The peculiarity of surgical intervention, in this case, is the proximity of the carotid artery to the area of surgical interest. It is important to detect the lymph vessel without affecting the carotid artery, because otherwise, it is possible to induce the development of baroreflex, which will cause bradycardia and a decrease in lymph flow rate, which, in turn, will affect the reliability of the study.

In the course of the study, a technology was developed to maintain physiological temperature not only in the area of the animal's entire body, but also in the neck area, taking into account its bend (in the form of a "scarf"). This allows you to increase the duration of the optical examination to 8 hours, while other similar studies are carried out within 3–5 minutes.

The proposed protocol for imaging cervical lymphatic vessels ensures compatibility with other types of two-photon microscopes with different lens ranges. The developed technique makes it possible to conduct long-term studies of the contractility of blood vessels using FBM (up to 8 hours), taking into account the environmental characteristics (temperature/humidity) and the working distance from the lens while maintaining high-quality images up to 500 microns deep.

Keywords: multiphoton microscopy, cervical lymphatic vessel, contractility of lymphatic vessels.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 25-15-00174).

Transcranial laser treatment of rat brain glioblastoma without photosensitizers

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Glioblastoma (GBM) is the most lethal form of brain cancer, which remains incurable despite advances in neuroscience. Phototherapy with photosensitizers (PS) is considered as a promising, non-pharmacological and safe method of treating GBM. However, this method has side effects due to PS, which can cause allergies, photophobia, and even disruption of the blood-brain barrier. This study investigated the effect of transcranial phototherapy of GBM in rats without PS using a 1267 nm laser, which stimulates the formation of singlet oxygen directly in the GBM cells. For the assessment of effectiveness of a 30-day course of phototherapy in rats with GBM, tumor progression, animal survival, and cellular mechanisms of apoptosis were evaluated.

To optimize parameters of phototherapy, the experiments were conducted to select an effective and safe of laser radiation. This included temperature monitoring using an A-K3 type thermocouple (Ellab, Hillerød, Denmark) on the skull surface and brain cortex, as well as survival analysis (using the Kaplan-Meier method) of male Wistar rats (age 6 months, weight 350-380 g) and tumor volume assessment (using the magnetic resonance imaging, MRI) at different laser doses (8.7, 12.6, and 16.3 kJ/cm²).

The results revealed that a course of phototherapy with a power of 100 mW, providing a total dose of 12.6 kJ/cm², is optimal as it does not cause critical heating of brain tissue and shows the best therapeutic outcomes.

After establishing the effective dose, experiments were conducted to study the effect of phototherapy on the GBM growth. The MRI and histological analysis results showed that a course of phototherapy (12.6 kJ/cm²) led to significant suppression of tumor growth (the GBM volume decreased 1.5 times compared to the control group); to the changes in the nature of tumor growth (after phototherapy the diffuse GBM growth transformed into tumor encapsulation). A key result was the increase in animal survival from 34% in the control group to 64% after the therapy course, i.e., resistance to GBM progression doubled following a course of phototherapy.

In sum, the obtained data indicate that a course of phototherapy with a wavelength of 1267 nm and a total dose of 12.6 kJ/cm² effectively suppresses glioblastoma growth in the rat brain, induces apoptosis, and reduces the proliferation of tumor cells, which critically increases rat survival.

Keywords: glioblastoma, phototherapy, 1267 nm laser, lymphatic system.

Acknowledgements: The research was supported by the Russian Science Foundation (project No. 25-45-20004).

Effect of photobiomodulation during sleep and wakefulness on glioma growth and cerebral drainage in rats

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Impaired lymphatic drainage of the brain is one of the factors contributing to glioma progression. It is known that photobiomodulation (PBM) can stimulate the functions of the meningeal lymphatic vessels (MLVs), while deep sleep is accompanied by natural activation of brain clearance processes. In this regard, it is logical to assume that performing PBM during sleep may enhance its therapeutic effect against brain tumors. This study investigated how a course of PBM (1050 nm, pulsed mode) during sleep or wakefulness affects glioma progression and brain drainage function.

Experimental evidence indicates that a course of PBM during sleep exerts a more pronounced suppressive effect on glioma growth compared to PBM during wakefulness. Tumor volume was reduced 1.3 times more strongly when PBM was performed during sleep than during wakefulness. At the same time, no significant differences in animal lifespan were observed between the groups.

Next, the effect of PBM on brain drainage was assessed by administering the fluorescent tracer FITC-dextran and measuring its accumulation in the deep cervical lymph nodes (dcLNs). In rats with glioma without PBM, tracer distribution in brain tissues and its clearance to the dcLNs were significantly reduced compared to the control group. The fluorescence intensity in the ventral and dorsal parts of the brain and in the dcLNs was 7.5, 9.3, and 5.1 times higher in healthy animals than in rats with glioma, respectively.

Both PBM courses — during sleep and during wakefulness — significantly improved tracer distribution in brain tissues and its subsequent accumulation in the deep cervical lymph nodes. However, the stimulating effects of PBM on brain drainage were greater in rats receiving the PBM course during sleep compared to awake animals. Thus, glioma-induced suppression of brain drainage can be corrected by a course of PBM, with more pronounced effects achieved when PBM is performed during sleep rather than during wakefulness.

These findings open a new strategy for non-invasive glioma therapy during sleep as a natural state that enhances the therapeutic effects of PBM.

Keywords: glioma, photobiomodulation, brain drainage.

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Differences in brain drainage and cognitive function between BALB/c and C57Bl/6 mice

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C57BL/6 and BALB/c mouse strains are widely used in preclinical research; however, they exhibit significant differences in brain anatomy and function, including the cerebrospinal fluid circulation and drainage system. It has previously been shown that brain drainage efficiency may affect cognitive abilities, but the direct link between drainage function and learning performance across different mouse strains remained unexplored. This study tested the hypothesis that differences in ventricular size and brain drainage intensity between C57BL/6 and BALB/c mice are associated with differences in the rate of conditioned reflex formation. Understanding these inter-strain differences is essential for informed strain selection when designing experiments involving traumatic brain injury (TBI), ischemic stroke, and other brain pathologies, as baseline differences in the drainage system may significantly affect the recovery of cognitive function.

Experiments were performed on 6-month-old male C57BL/6 and BALB/c mice (n=10 per group). To assess brain drainage, the fluorescent tracer FITC-dextran (5 µL, 0.1 µL/min) was injected into the right lateral ventricle. After 1.5 hours, ex vivo optical imaging of tracer distribution was performed in the dorsal and ventral parts of the brain as well as in the deep cervical lymph nodes (dCLNs) using a confocal microscope. Ventricular morphometry was carried out on brain sections in three planes. Cognitive function after TBI was assessed by the rate of formation of a stable Pavlovian "light-food" conditioned reflex (number of sessions to reach criterion and number of head entries into the food trough during the final session).

The results showed that in C57BL/6 mice, all ventricles were significantly larger than in BALB/c mice: lateral ventricles – 2.5-fold (0.28 ± 0.02 mm² vs. 0.11 ± 0.01 mm², $p < 0.001$); third ventricle – 5.8-fold (0.53 ± 0.01 mm² vs. 0.09 ± 0.005 mm², $p < 0.001$); fourth ventricle – 5.3-fold (0.75 ± 0.03 mm² vs. 0.14 ± 0.01 mm², $p < 0.001$). The fluorescence intensity of FITC-dextran, reflecting drainage efficiency, was higher in C57BL/6 mice: in the ventral brain – 4-fold (1.89 ± 0.06 vs. 0.47 ± 0.05, $p = 0.003112$); in the dorsal brain – 3.5-fold (0.78 ± 0.03 vs. 0.22 ± 0.03, $p = 0.001572$); in the deep cervical lymph nodes – 6.7-fold (14.19 ± 0.25 vs. 2.12 ± 0.22, $p = 0.0014228$). Conditioned reflex formation after TBI proceeded faster in C57BL/6 mice: the number of sessions was 1.7-fold lower (12.00 ± 0.15 vs. 21.00 ± 0.17, $p = 0.0011134$), and the number of reinforcements in the final session was 1.5-fold higher (21.00 ± 0.10 vs. 14.00 ± 0.12, $p = 0.0012572$).

The results show differences in ventricle size and tracer distribution in the brain and lymph nodes of control mice. C57BL/6 mice exhibit more intense accumulation of FITC-dextran in the

ventral and dorsal brain regions, as well as more pronounced clearance into the dCLNs, indicating higher drainage capacity compared to BALB/c mice. In cognitive testing, the C57BL/6 strain demonstrated more stable conditioned reflex formation than BALB/c.

Thus, for the first time, a direct relationship has been demonstrated between ventricular system size, brain drainage efficiency, and learning rate. C57BL/6 mice, possessing larger ventricles and more intense drainage, form a conditioned reflex significantly faster than BALB/c mice. These findings are important for planning studies on recovery after TBI, ischemic stroke, and other brain pathologies involving meningeal lymphatic vessels and the cerebrospinal fluid system, taking inter-strain differences into account.

Keywords: brain drainage, brain ventricles, TBI, C57BL/6, BALB/c.

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Cerebrospinal fluid circulation and cerebral waste management

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The presentation explores the integrated systems responsible for maintaining the brain's delicate chemical balance: Cerebrospinal Fluid (CSF) circulation and the recently identified meningeal lymphatic system. Historically viewed as a static cushion, CSF is now understood as the primary medium for a dynamic "biological rinse" known as the glymphatic system.

The report will detail how CSF enters the brain parenchyma via perivascular spaces, facilitated by astrocytic channels, to flush out interstitial metabolic byproducts such as amyloid-beta and tau proteins. We will emphasize the critical role of meningeal lymphatic vessels, located within the dura mater, which act as the primary drainage "exhaust" for the central nervous system. These vessels bridge the gap between the brain and the peripheral immune system, transporting waste-laden fluid to the deep cervical lymph nodes.

Crucially, we will discuss how this entire clearance network is highly dependent on circadian rhythms, with peak activity occurring during deep sleep.

Finally, we will discuss non-invasive photobiomodulation of meningeal lymphatic vessels as a way to address clinical problems associated with impaired "brain blood outflow system", where impaired drainage contributes to aging and the progression of neurodegenerative diseases such as Alzheimer's disease.

Keywords: cerebrospinal fluid, perivascular space, meningeal lymphatics, brain clearance, transcranial photobiomodulation.

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Study of blood flow velocity in blood vessels using laser scanning microscopy

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The accurate assessment of hemodynamic parameters, particularly blood flow velocity in micro- and macro-vessels, remains a critical challenge in modern cardiovascular and neurovascular research. Despite significant advances in medical imaging, conventional methods often lack the spatiotemporal resolution required for real-time monitoring or require invasive procedures that limit their clinical applicability. Consequently, vascular pathologies continue to account for a substantial proportion of global morbidity and mortality.

Laser scanning microscopy (LSM), particularly when combined with optical contrast techniques, offers a high-resolution, dynamic approach to visualize and quantify blood flow velocity in living tissues. LSM-based technologies are safe, highly reproducible, and adaptable to both research and clinical environments.

To solve this problem, laser scanning microscopy technologies using fluorescence are used, which makes it possible to noninvasively obtain information about blood flow velocity by analyzing changes in the number of fluorophores on the scans.

To date, there are several modern methods for measuring blood flow velocity

Spatiotemporal correlation image spectroscopy (STICS) makes it possible to map flow vectors along curved and branched vessels by analyzing the temporal autocorrelation of fluorescence fluctuations. Scanning Laser Image Correlation (SLIC) measures the velocity of movement of suspended particles (e.g., red blood cells) in a liquid by spatial cross-correlation of consecutive line scans; Linear scan correlation analysis, widely used in two-photon LSM, calculates the velocity of red blood cells as $v=\Delta x/\Delta t$ along diagonal bands on xt cymograms with accuracy confirmed for vessel diameters from 5 to 100 microns;

An important continuation of these studies will be the integration of adaptive optics and machine learning to automate speed assessment, improve assessment accuracy, and use other fluorophores to assess lymph flow.

Keywords: laser scanning microscopy, blood flow velocity, hemodynamics, microcirculation, vascular imaging, medical diagnostics.

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Age differences in the effectiveness of phototherapy of glioblastoma

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Glioblastoma is an incurable and aggressive oncological disease of the brain. Recent studies have shown that transcranial non-invasive photobiomodulation is a promising new alternative method for suppression of glioblastoma growth. The lymphatic endothelium of the meningeal lymphatic vessels is an important target for the therapeutic effects of photobiomodulation. However, the functions of the meningeal lymphatic vessels decline with age. Therefore, it remains unknown whether photobiomodulation can be effective in adults and the elderly. The aim of this study is to study the role of meningeal lymphatic vessels and brain drainage in age-related differences in glioblastoma resistance.

The studies were performed on 6- and 24-month-old rats using a model of fluorescent glioblastoma. Photobiomodulation was performed for 14 days for phototherapy of glioblastoma or once to study photo effects on the brain's drainage. Brain drainage was studied by optical imaging of the lymphatic excretion of dye from the brain to the deep cervical lymph nodes, as well as by assessing the water content in brain tissues and the intracranial pressure. Histological and immunohistochemical methods were used to study apoptosis, proliferation and migration of CD8+ cells from the peripheral lymphatic system to glioblastoma.

The results of the study showed that the network of the meningeal lymphatic vessels and brain drainage reduced in 24-month-old rats vs. 6-month-old animals, which is accompanied by a decrease in resistance to the development of glioblastoma. Photobiomodulation significantly increases survival in 6-month-old, but not in 24-month-old rats via an improvement of the functions of the meningeal lymphatic vessels, including a facilitating the traffic of protective CD8+ cells to glioblastoma, reducing intracranial pressure and brain edema. The blockade of lymphatic communication between the peripheral and meningeal lymphatic systems completely suppresses the therapeutic effects of photobiomodulation in 6-month-old rats.

Thus, photobiomodulation is an effective method of stimulation of brain drainage and immunity increasing resistance to glioblastoma progression in early but not in late ontogenesis due to the age-related decline in the functions of the meningeal lymphatic vessels.

Keywords: glioblastoma, photobiomodulation, aging, meningeal lymphatic vessels, brain's drainage.

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Technology of photobiomodulation of the mouse brain and its meninges during sleep

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Photobiomodulation (PBM) is a perspective noninvasive treatment of Alzheimer's disease (AD). One of the therapeutic mechanisms of PBM is photostimulation of brain clearance of metabolities, including amyloid-beta (Aβ). It is known that brain drainage is activated during deep sleep, which suggests that PBM during sleep may have more pronounced effects on this process. Therefore, here we tested the hypothesis that PBM during deep sleep vs. wakefulness stronger stimulates lymphatic clearance of (Aβ) from the brain in male AD mice.

The 7-day PBM course (LED 1050 nm, 30 J/cm^2) during wakefulness or deep sleep under EEG-control (17 min - irradiation, 5 min -pause; 61 min total time of PBM) was used in male mice with the injected AD model. FAβ was injected into the right lateral ventricle (coordinates: AP-1 mm; ML-1.4 mm; DV-3.5 mm) in a volume of 5 µl. Lymphatic clearance of fluorescent Aβ (fAβ 1 mL, 200 mM,AnaSpec Inc., Fremont, CA, USA) was studied by the confocal analysis (Nikon, Japan, Tokyo) of the intensity of its spreading in brain tissues and accumulation in the deep cervical lymph nodes after its administration into the right lateral ventricle.

The results of the studies revealed that PBM during sleep, compared with wakefulness, significantly more strongly stimulates the distribution of fAβ in both the ventral and dorsal parts of the brain, and also promotes more intensive accumulation of fAβ in the deep cervical lymph nodes.

These findings suggest that the effects of PBM on lymphatic clearance of Aβ from the brain of AD mice are significantly more pronounced during sleep than during wakefulness. These results expand our understanding of the mechanisms underlying the therapeutic effects of FBM and open new strategies for phototherapy of AD during sleep.

Keywords: photobiomodulation, electroencephalography, meningeal lymphatic system, Alzheimer's disease, brain drainage.

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Photobiomodulation of the mouse brain under EEG-control

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In recent decades, photobiomodulation (PBM) has been used as a non-pharmacological treatment of neurodegenerative diseases associated with amyloidosis. The PBM-mediated stimulation of brain drainage and clearance is a crucial mechanism of therapeutic effects of PBM. It is important to note that the effectiveness of PBM during sleep is significantly increased due to natural activation of elimination of metabolites from the brain. However, there are currently no commercial devices for PBM sleep monitoring. Therefore, the goal of this study was the development of novel technology of PBM under EEG-control of sleep.

This study presents a new portable technology of transcranial photobiomodulation (tPBM) under electroencephalographic (EEG) control of sleep designed to photo-stimulate removal of toxins (e.g. soluble amyloid beta (Aβ)) from the brain of aged BALB/c mice with the ability to compare the therapeutic effectiveness of different optical resources. The technology can be used in natural condition of a home cage without anesthesia maintaining motor activity of mice. These data open up new prospects for the development of non-invasive and clinically promising photo-technologies for correction of age-related changes in brain drainage and for the effective cleansing of brain tissues from metabolites and toxins. This technology is intended both for preclinical studies of the functions of the sleeping brain and for the development of clinically relevant treatments for sleep-related brain diseases.

Keywords: PBM (photobiomodulation), EEG (electroencephalography), MLS (meningeal lymphatic system), AD (Alzheimer's disease).

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New strategies in stimulation of brain drainage clearance

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Pharmacological treatment of brain diseases is hampered by the blood-brain barrier, which prevents the vast majority of drugs from reaching the brain. For this reason, the pharmaceutical industry is reluctant to invest in the development of new neurotropic drugs. In this context, neurolymphaphotonics, which is based on the development of promising non-pharmacological modulation of the meningeal lymphatic vessels (MLVs), has gained increasing attention. MLVs play a crucial role in the removal of toxins and metabolites from the brain, as well as in the regulation of brain homeostasis and immunity. Since MLVs are located on the brain's surface, light penetrating the skull easily reaches the MLVs and affects their function. Thus, MLVs are an ideal target for photobiomodulation (PBM). Pioneering research has shown that PBM of MLVs is a promising technology for treating a wide range of neuropathological disorders, including Alzheimer's disease, age-related brain diseases, tumors, intracranial hemorrhages, and diabetes-related brain damage. Notably, the greatest benefit of PBM-mediated stimulation of MLVs is observed during sleep. Given that PBM application is non-invasive and safe, and has commercially viable potential (portability and low cost), neurolymphaphotonics offers promising strategies of the development of advanced technologies for effective non-invasive treatment of brain diseases.

Keywords: neurolymphaphotonics, brain drainage and clearance, meningeal lymphatics.

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Voxel-based approach in the modeling of parenchymal flows and molecular transport

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The neuroglial-vascular unit (NGVU) is considered a minimal functionally sufficient structure capable of supplying neurons, removing metabolites, responding to stimuli, generating systemic signals such as sleep induction, and much more. The pathways of neurovascular communication are relatively well studied, and numerous models have been constructed. However, NGVUs do not have clear boundaries; a single astrocyte contacts several neurons, and substances diffuse freely in the intercellular space. Furthermore, NGVUs and their components vary greatly, which, coupled with the complex geometry of the vessels, presents a significant challenge in assessing the efficiency of removing harmful metabolites.

Modern imaging techniques, particularly MRI, have a spatial resolution of approximately 1 mm. This means we cannot access processes at the level of individual vessels and neurons. This and the above motivate the development of a mathematical model that would describe brain drainage in a fixed spatial domain, namely, a cube (voxel) with sides of 1 mm. In this context, we can use terms such as perfusion, incoming cerebrospinal fluid flow, and outgoing cerebrospinal fluid flow containing metabolites.

The main result of this study is the demonstration of the effect of "antiphase modulation of outflow", which contributes to the effectiveness of arterial pulsations and is due to the specific location of the drainage channels: they are often paravascular, located near blood vessels. Specifically, arteriole distension due to the pulse wave compresses the drainage channel and significantly enhances fluid penetration into the intercellular space, accelerating the removal of harmful metabolites during return flow phase .

Keywords: mathematical model, brain drainage, neuro-glia-vascular complex.

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An Arduino-based device for grip strength measurement in mice to assess phototherapy of traumatic brain injury

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Traumatic brain injury (TBI) is a major cause of long-term neuromotor impairment. Photobiomodulation (PBM) is considered as a promising therapeutic approach for post-traumatic recovery. A reliable, quantitative, and affordable instrument is therefore required to track motor function longitudinally in the same animal before injury, after injury, and across the course of therapy.

A compact grip strength meter has been developed around an Arduino microcontroller and a tensometric force sensor with ADC, the elastic bending deflection of which is converted into an output force value expressed in newtons. The animal interacts with the instrument through a 3D-printed holder terminated by a horizontal tubular bar that the mouse instinctively grasps with its forepaws; during a standardized steady-speed pull the device continuously records the applied force as the animal is gently retracted from the bar. Raw samples are streamed in real time to a host PC over a USB interface, and custom software reconstructs the full force-versus-time curve of each trial. From this curve a rich set of parameters is extracted — peak grip force, grip hold duration, latency to release and the integrated impulse (area under the force–time curve) — which together provide a markedly more informative description of forelimb motor performance than the single peak-force value reported by conventional grip meters.

The instrument has been integrated into an experimental paradigm in which repetitive mild TBI is induced in mice using a weight-drop model: a striker is accelerated onto the skull by an electromagnetically driven rod, delivering a controlled and reproducible impact. Animals then receive a course of transcranial photobiomodulation at a wavelength of 1050 nm. Using the developed device, grip strength is assessed at three critical stages of the experimental timeline — at baseline before injury, during the early post-injury period, and after completion of the PBM treatment course — yielding for every individual animal a longitudinal quantitative profile of motor impairment and subsequent recovery.

The key novelty of the proposed solution is the adaptation of an open, low-cost, force-and-time recording architecture specifically to the requirements of preclinical TBI and PBM neurorehabilitation research. By replacing the standard single-value peak-force measurement with continuous force–time recording, the device enables a fine-grained analysis of the dynamics of motor impairment and of the therapeutic response to photobiomodulation within the same animal, thereby improving the sensitivity and the translational value of behavioural outcome assessment in experimental brain injury studies.

Keywords: grip strength, traumatic brain injury, photobiomodulation, Arduino, load cell, mouse model, neuromotor assessment.

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Using a dual system of dual immunohistochemical staining to identify Lyve-1-positive structures in the human brain

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The lymphatic system of the meninges was discovered just eight years ago in independent studies conducted by American and Finnish scientists. This discovery was an important step in the development of neuroscience and significantly changed the understanding of drainage processes and immune responses in the central nervous system (CNS). Our research team in Russia has done groundbreaking work on detecting lymphatic vessels directly in brain tissue. We also laid the foundation for the development of digital and interactive methods for studying the functions of cerebral and meningeal lymphatic vessels during life. We have developed an algorithm for double staining of paraffin sections with brown and red visualization. At the same time, the Lyve-1 marker was always colored red using AEC chromogenic visualization. This allowed us to assess the location of Lyve-1-positive structures in the human brain and distinguish them from blood vessels (CD31) and macrophages (CD68) that turn brown. The proposed method of double staining of Lyve-1-positive structures in the human brain suggested that the lymphatic system of the human central nervous system consists of narrow and thin tubes located in the perivascular space. Sometimes macrophages can be seen in the lumen of these tubes.

This technique can be used for further detailed study of the lymphatic system of the brain and meningeal membranes, as well as for evaluating the effect of photobiomodulation on lymphatic vessels in experimental studies.

Keywords: photobiomodulation, brain diseases, lymphatic system, brain.

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Photo-therapy of Alzheimer's disease during sleep under EEG control

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Alzheimer's disease remains one of the major biomedical challenges, underscoring the need for novel non-invasive approaches aimed at enhancing the brain's drainage. This study presents a hardware-software system for automated photobiomodulation of the brain in small laboratory animals, primarily mice, under EEG monitoring with real-time detection of deep sleep. The developed device comprises a biopotential recording module, a microcontroller-based control board, a wireless data transmission system, an LED mounting unit, and a software interface for EEG signal visualization and spectral analysis. The key feature of the system is a closed-loop control scheme: upon detection of delta activity characteristic of deep sleep, photobiomodulation is automatically initiated. This approach makes it possible to synchronize stimulation with the functional state of the brain and to use photobiomodulation as a tool for enhancing brain drainage processes during the most physiologically relevant period, thereby improving experimental reproducibility and reducing operator dependence.

The practical significance of the study lies in the creation of an experimental platform for the preclinical optimization of photobiomodulation protocols in mice in Alzheimer's disease models. The proposed system can be used to identify optimal stimulation regimens aimed at enhancing brain drainage function during deep sleep.

Keywords: photobiomodulation, brain drainage, electroencephalography, deep sleep.

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Automated computer vision technologies for quantitative analysis of sperm motility

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The development of computer vision and artificial intelligence technologies has significantly expanded possibilities for automated biomedical image analysis. Modern microscopy produces large volumes of video data requiring objective and reproducible quantitative evaluation. One of the most important applications is the analysis of sperm motility, which remains a key parameter in reproductive medicine and fertility diagnostics.

Traditional manual assessment of sperm movement is subjective, time-consuming, and strongly dependent on operator experience. Therefore, automated tracking systems capable of following individual cells and calculating their motion characteristics are critically needed.

In this work, a computer vision algorithm was developed for tracking manually selected objects in microscopy videos and calculating kinematic parameters of motion. The proposed approach allows the user to select sperm cells interactively, after which the algorithm automatically follows the selected object throughout the video sequence. Object tracking is performed using visual feature analysis and adaptive motion prediction, ensuring stable tracking without loss of the object even under noisy imaging conditions.

The developed software continuously visualizes the tracked trajectory using a persistent marker and computes quantitative motion parameters, including instantaneous velocity, trajectory length, and displacement dynamics. This enables objective estimation of sperm motility characteristics directly from experimental recordings.

The presented technology represents a step toward accessible and reproducible tools for biomedical video analysis. Such systems can be integrated into laboratory practice for assisted reproductive technologies, biological research, and clinical diagnostics, providing standardized quantitative evaluation while reducing human bias.

Future development will focus on multi-object tracking, automated sperm detection, trajectory classification, and integration with machine learning methods for assessment of fertility-related parameters.

Keywords: computer vision, sperm motility, object tracking, microscopy video analysis, biomedical image processing.

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Immunofluorescence identification of Lyve-1/Prox-1 expressing lymphatic elements in the unaffected and affected human brain

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The existence of lymphatic vessels in the human brain parenchyma remains controversial. Using dual immunofluorescence staining for Lyve-1 and Prox-1, we examined post-mortem brain samples from 8 healthy controls and 34 patients with intraventricular hemorrhage (IVH). For the first time, we demonstrate lumenized Lyve-1/Prox-1-positive vessels with a single endothelial layer, valves, and wavy distal regions (precollectors). Lymphatic vessels were found in 3 out of 8 control brains and in 5 out of 34 IVH brains. Additionally, Lyve-1/Prox-1-positive lymphatic elements were identified within enlarged perivascular spaces (PVS). Median PVS size and the number of lymphatic elements per mm² were significantly higher in the IVH group (12.4 µm and 4.2 vs. 5.1 µm and 1.1 in controls; $p < 0.05$). These findings provide evidence for the existence of cerebral lymphatic vessels and suggest their involvement in IVH pathology, opening new avenues for therapies targeting brain lymphatic clearance.

Keywords: Lyve-1/Prox-1; lymphatic elements; human brain; intraventricular hemorrhage; perivascular spaces.

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Targeting meningeal lymphatic vessels: Novel strategies for enhancing brain clearance in Alzheimer's disease

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Alzheimer's disease (AD) remains a critical global health challenge, characterized by progressive cognitive decline and the pathological accumulation of amyloid-beta (Aβ) and tau proteins. Conventional therapeutic strategies primarily target plaque reduction but demonstrate limited clinical efficacy and fail to halt disease progression. Recent neurobiological advances have identified the meningeal lymphatic vessels (MLVs) as a pivotal component of the brain's drainage and clearance system, positioning them as a promising therapeutic target. This study synthesizes emerging pharmacological and non-pharmacological strategies aimed at augmenting the MLV function to mitigate AD pathology. Pharmacologically, the combination of anti-Aβ immunotherapy with vascular endothelial growth factor-C (VEGF-C) demonstrates enhanced Aβ clearance by promoting lymphangiogenesis, although the blood-brain barrier penetration remains a logistical challenge. Non-invasive approaches show particular clinical promise, with transcranial photobiomodulation (PBM) utilizing near-infrared wavelengths (e.g., 1065–1267 nm) effectively stimulating singlet oxygen production, enhancing lymphatic contractility, and accelerating metabolite clearance. Notably, administering PBM during sleep significantly amplifies its therapeutic efficacy in aged models by synchronizing with natural clearance rhythms. Furthermore, lifestyle interventions, including structured physical exercise and optimized sleep architecture, naturally upregulate glymphatic and meningeal lymphatic drainage. Adjunctive techniques such as acoustic stimulation at 40 Hz and targeted acupuncture further support lymphatic outflow. Collectively, these findings underscore a paradigm shift from direct amyloid neutralization toward enhancing endogenous brain clearance mechanisms. The ongoing development of portable, FDA-recognized PBM devices highlights the high translational potential of lymphatic-targeted therapies. Future clinical trials will be essential to validate safety profiles, optimize dosing parameters, and establish standardized protocols for integrating MLV stimulation into comprehensive, patient-centered AD management strategies.

Keywords: Alzheimer's disease, meningeal lymphatic vessels (MLVs), brain drainage and clearance, photobiomodulation (PBM).

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NO-ergic mechanisms of age-related changes in the sensitivity of lymphatic vessels to photobiomodulation

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Photobiomodulation (PBM) is a promising noninvasive therapy for brain diseases. One of the therapeutic mechanisms is the stimulation of brain drainage and clearance by enhancing the function of the lymphatic vessels involved in these processes. However, sensitivity to PBM is known to decrease with age. The mechanisms behind this phenomenon remain poorly understood. PBM exerts its therapeutic effects largely by stimulating nitric oxide (NO) production in the endothelium of blood vessels and neurons. Based on this fact, it has been hypothesized that PBM's stimulating effects on lymphatic vessel function are also associated with PBM-mediated increases in NO production in the lymphatic endothelium and that this process slows with age, which may explain the decreased sensitivity to PBM in older individuals.The aim of this study was to investigate age-related differences in the NO-ergic mechanisms of PBM effects on the contractility of afferent (drainage function) and efferent (filtration function) cervical lymphatic vessels (cLVs) and their relationship to brain clearance.

The study was performed on male BALB/c mice aged 3, 12, and 24 months. PBM (1050 nm LED, 10 J/cm²) was applied. cLV contractility was assessed in vivo using two-photon microscopy and optical coherence tomography (OCT). NO production was measured in primary cultures of lymphatic endothelial cells (LECs) in vitro. The NO synthase inhibitor L-NAME was used for NO blockade. Lymphatic clearance of amyloid-beta (Aβ) from the brain to deep cervical lymph nodes (dcLNs) was evaluated by confocal microscopy, and cLV morphology was also analyzed.

The results showed that PBM significantly increased the contractility of both afferent and efferent cLVs as well as NO production in LECs in 3- and 12-month-old mice, and these effects were suppressed by L-NAME. In contrast, 24-month-old mice exhibited reduced basal cLV contractility, no significant increase in cLV contractility or NO production after PBM, insensitivity to NO blockade, reduced lymphatic clearance of Aβ from the brain, and lymphatic hyperplasia (increased LYVE-1 signal) in dcLNs.

Thus, aging leads to lymphatic endothelial dysfunction characterized by reduced basal NO production, impaired cLV contractility, and morphological changes, which together cause resistance to PBM. The NO-ergic pathway is essential for PBM-induced stimulation of brain lymphatic drainage in young and middle-aged mice but is compromised in aged animals. These findings suggest that combined therapy including PBM and NO enhancement may improve the effectiveness of treatment for brain diseases in the elderly.

Keywords: photobiomodulation, aging, nitric oxide, lymphatic drainage, cervical lymphatic vessels, brain clearance, Alzheimer's disease.

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Non-invasive phototherapy of glioblastoma in rats

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Non-invasive laser therapy (LT) at 1267 nm generates singlet oxygen via endogenous photosensitizers, offering a novel approach for glioblastoma (GB) treatment. This study investigated the pathomorphosis of transplanted C6 glioma in rats after LT at 12.6 kJ/cm² (daily for three weeks). Survival in the GB+LT group was 64%, 1.8-fold higher than in untreated GB (34%). LT significantly reduced tumor volume (152±11 mm³ vs. 225±7 mm³ in controls, $p<0.001$), suppressed proliferation (Ki-67), activated the mitochondrial apoptosis pathway (Bax and p53), and decreased autophagolysosome formation (LC3b, clathrin, caveolin). Moreover, LT restored meningeal lymphatic function, improving brain clearance. Thus, 1267 nm laser irradiation induces pronounced GB pathomorphosis, slows tumor growth, and increases animal survival, representing a promising non-invasive therapeutic strategy for glioblastoma.

Keywords: glioblastoma, laser therapy, 1267 nm laser, apoptosis, autophagy, lymphatic drainage.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 25-45-20004).

Non-invasive monitoring of hemodynamic response to photobiomodulation of the brain and its meninges

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Among non-pharmacological methods, transcranial photobiomodulation (PBM) is regarded as the most promising approach for the treatment of neurodegenerative diseases. Hypothetically, this method may facilitate the modulation of local vascular tone regulation, manifesting as vasospasm reduction or vasodilation, thereby contributing to a more stable microcirculatory flow. However, significant challenges remain in achieving non-invasive real-time monitoring of such responses during and after exposure to PBM. The complexity of the underlying hemodynamic systems limits current research capabilities and necessitates the development of novel investigational tools.

To address this, a non-invasive approach based on laser Doppler flowmetry (LDF) has been proposed for assessing microcirculatory parameters in the skin and superficial cerebral vessels.

This study emphasizes the analysis of the myogenic response of microvessels. Therapeutic interventions aimed at enhancing or restoring myogenic reactivity may play a crucial role in preventing disease progression in neurodegenerative conditions and improving cognitive functions.

The application of LDF with a portable device, as utilized in this research, enables continuous monitoring of microcirculatory dynamics, serving as an indirect index of regulatory mechanism activity.

For the assessment of the frequency-temporal structure of microvascular oscillations, continuous wavelet transform (CWT) with an optimized frequency-time resolution ratio was employed.

Asynchronous behavior was observed in the power distribution of wavelet coefficients from signals obtained by spatially proximal detectors. This phenomenon is hypothesized to reflect individual-specific characteristics of the regulatory mechanisms' function and warrants further investigation with a larger cohort.

Significant alterations in the wavelet power spectra were detected within ranges corresponding to myogenic regulatory activity. The observed increase in myogenic microhemodynamic activity may indicate a favorable response to therapy; however, ongoing monitoring is essential to prevent hypertonus and ischemic events.

This research represents a meaningful step toward identifying reliable bio-physical markers of human physiological states in therapeutic settings, with implications for personalized medicine and neurovascular research.

Keywords: neurotechnology, cardiovascular system, wavelet analysis, biophysics.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 25-15-00174).

Development of controlled brain concussion technology in laboratory animals

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Traumatic brain injury (TBI) remains one of the most common neurological disorders and a significant public health concern. Currently, TBI is considered not only as an acute condition but also as a chronic process associated with long-term consequences, including an increased risk of neurodegenerative diseases. Mouse models of TBI offer several advantages: cost-effectiveness, ease of maintenance, and the possibility of using genetically modified lines.

Various approaches are used to reproduce TBI in experimental settings, ranging from direct trauma to concussion or contusion. The controlled brain blunt injury (CBBI) technology, due to its reproducibility and controllability of injury parameters, has become widely adopted. The classic design is based on a pneumatic piston, while a modern alternative — a linear actuator with an electromagnetic piston — is more portable and does not require a compressed gas cylinder.

Compared to other models (e.g., weight drop or fluid percussion), the proposed CBBI technology provides higher precision and controllability, making it possible to model injuries close to clinical observations in humans.

This paper describes the CBBI technology developed in our laboratory, which enables the study of both short-term and long-term consequences of TBI, including neuronal death, memory impairment, and brain edema, as well as the evaluation of promising treatment methods.

Keywords: traumatic brain injury, mice, electromagnet, pneumatics, controlled brain injury.

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Histological changes and brain drainage in a mouse model of obstructive sleep apnea

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Obstructive sleep apnea (OSA) is a common disorder characterized by recurrent episodes of upper airway collapse during sleep, leading to chronic intermittent hypoxia and sleep fragmentation. OSA is an independent risk factor for cognitive impairment and neurodegenerative diseases; however, the underlying mechanisms remain incompletely understood. Histological changes in brain tissue and dysfunction of its clearance systems — the glymphatic system and the meningeal lymphatic vessels — may play an important role in the pathogenesis of OSA. Mouse models of OSA are an indispensable tool for studying these processes, as they allow controlled investigation of cause-and-effect relationships and the molecular mechanisms underlying cerebral complications of the disease

The aim of this study was to evaluate brain drainage and histological changes in internal organs in a mouse model of OSA.

The studies were conducted on male C57BL/6 mice, including the following groups: 1 – sham group (injection of 100 µl of saline solution into the tongue and soft palate), 2 – OSA model (injection of 100 µl of polytetrafluoroethylene diluted in a glycerol solution into the base of tongue and soft palate to increase volume). N=4 in each group. To study the drainage system of the brain, the distribution of FITC-dextran in the dorsal and ventral parts of the brain after injection into the magna cistern was investigated. A routine histological protocol was used to assess the condition of the internal organs.

The results showed that OSA in animals has impaired blood circulation, in the form of increased fullness of the heart and other organs. Hyperplasia of the olfactory epithelium and increased exfoliation of the epithelium into the nasal lumen were recorded in the nasal passages. Brain drainage in the OSA group was significantly reduced compared to the sham group.

Thus, the mouse model of OSA reproduces key systemic and cerebral pathologies. These findings suggest that dysfunction of the cerebral clearance systems is a critical component of OSA pathogenesis, potentially explaining the link between OSA and cognitive decline or neurodegenerative diseases.

Keywords: obstructive sleep apnea, meningeal lymphatic vessels, mouse model.

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Photobiomodulation preserves motor function and attenuates neuronal and muscular injury in ALS mice

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Amyotrophic lateral sclerosis (ALS) is a fatal neurodegenerative disease characterized primarily by motor dysfunction and neuromuscular degeneration. Its pathogenesis is complex and remains incompletely understood, which has limited the development of effective therapeutic strategies. Effective disease-modifying therapies remain urgently needed for ALS, while delaying disease progression, improving quality of life, and prolonging survival continue to be important clinical goals. Photobiomodulation (PBM), a noninvasive neuroprotective approach, has demonstrated therapeutic potential in studies of Alzheimer's disease, peripheral nerve injury, pain relief, and wound healing; however, its therapeutic efficacy in ALS remains to be further clarified.

In this study, female SOD1-G93A transgenic mice were used as an ALS model and received 1275 nm near-infrared PBM treatment. Behavioral tests, motor neuron labeling, and skeletal muscle imaging analysis were performed to evaluate the effects of PBM in ALS mice. PBM partially delayed the decline in balance and grip strength, increased spontaneous locomotor activity, and showed preliminary improvement in several gait parameters. Preliminary observations indicated that the total number of hindlimb-innervating motor neurons was slightly higher in the PBM-treated group than in the untreated ALS group. In skeletal muscle, PBM treatment was associated with trends toward increased extensor digitorum longus muscle volume and total neuromuscular junction (NMJ) number, reduced NMJ denervation, and better preservation of some fine structures.

These preliminary findings suggest that PBM may partially alleviate motor decline and neuromuscular injury in ALS mice, providing preliminary experimental support for its potential as an intervention strategy for ALS.

Keywords: ALS, photobiomodulation, motor neuron, skeletal muscle.

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Multidirectional interstitial flow promotes microvascular network formation: Insights from a square chip-based platform

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Microvascular network formation is governed by a variety of factors, with interstitial flow (IF) playing a pivotal role. However, the impact of multidirectional IF (MDIF) on microvascular network development remains insufficiently explored. In this study, we developed a platform consisting of a Square chip capable of generating MDIF and a deep learning-based Vasculature-on-a-Chip Analysis Tool (VoCAT) for high-efficient analysis of vascular morphology on the chip. Using this platform, we demonstrated that microvascular networks formed on the Square chip exhibited intricate structural features with enhanced functionality. We also demonstrated its utility in modeling a tumor microenvironment with complex microvascular networks and observed enhanced tumor cell migration. This study provides the first evidence that MDIF promotes microvascular network formation, offering new perspectives for advanced *in vitro* vascular and disease research.

Key words: interstitial flow, microvascular network, microvascular organ-on-a-chip, deep learning.

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Full-waveform inversion for transcranial sound speed reconstruction based on optimal transport distance

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Ultrasound Computed Tomography (USCT) has emerged as a promising medical imaging technology in recent years, demonstrating considerable potential for clinical applications, particularly in breast cancer detection and musculoskeletal assessment. Within this field, high-resolution sound speed imaging by full-waveform inversion (FWI) represents a key research focus. While this technique achieves resolution comparable to magnetic resonance imaging in soft tissues and structurally simple bone regions — such as the breast and limbs—accurate reconstruction in transcranial imaging remains challenging due to the complex structural composition of the skull and intracranial tissues. From a mathematical perspective, FWI constitutes an optimization problem constrained by partial differential equations. It falls under the category of strongly ill-posed inverse scattering problems, which are non-convex and nonlinear. In transcranial imaging, the high acoustic impedance contrast and strong attenuation of the imaging object further complicate the solution, introducing more local optima within the solution space.

In this study, we introduce a novel measurement function based on optimal transport distance to quantify the discrepancy between synthetic and observed seismic signals in FWI. Compared to conventional L2-norm least-squares misfits, the optimal transport distance places greater emphasis on low-frequency kinematic differences between waveforms, thereby penalizing such discrepancies more strongly while remaining less sensitive to high-frequency variations in amplitude, phase, and waveform details. The resulting loss function exhibits enhanced local convexity, which helps alleviate the ill-posedness of the inverse problem, reduces susceptibility to local minima, and improves the robustness of model reconstruction.

Transcranial numerical simulations demonstrate that the proposed method effectively removes image artifacts and surpasses several representative imaging techniques. Notably, it significantly reduces low-frequency linear artifacts within intracranial soft tissues. This approach enables high-resolution reconstruction of sound speed distribution in the brain and shows potential for application in focused ultrasound neuromodulation, where it may improve beam focusing accuracy and achieve precise modulation inside the cranial cavity.

Keywords: ultrasound computed tomography, full-waveform inversion, sound speed imaging, transcranial imaging.

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CSFTN-26-27

Non-invasive deep brain ultrasonic neuromodulation for brain function exploration: A 7.5-cm transcranial focusing solution using Fresnel lenses

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The exploration of deep brain function and the development of non-invasive regulatory technologies are critical for advancing neuroscience research, yet the heterogeneous structure of the skull poses a major barrier to precise transcranial focused ultrasound (tFUS) focusing, limiting the clinical application of tFUS in deep brain neuromodulation. Impaired ultrasound wavefront caused by skull heterogeneity leads to inaccurate energy delivery to target deep brain regions, which not only reduces the efficacy of neuromodulation but also increases the risk of damage to surrounding normal brain tissues. Therefore, developing a precise tFUS focusing solution that can effectively compensate for skull-induced distortion is of great significance for promoting non-invasive deep brain function exploration and the development of related neuroscience technologies.

In this study, we utilized skull and brain magnetic resonance imaging (MRI) or computed tomography (CT) data to conduct acoustic simulations, aiming to estimate the intracranial sound field and provide a theoretical basis for the structural design of Fresnel acoustic lenses. We designed a flat and thin Fresnel acoustic lens, which modulates the ultrasound wavefront through the constructive interference of its concentric zones, thereby overcoming the wavefront distortion caused by skull heterogeneity and achieving precise transcranial focusing. Experimental results showed that the tFUS modulated by the Fresnel lens achieved a focusing depth of 7.5 cm, with a focal spot size of approximately 3×8 mm, and could stably and safely deliver acoustic energy to target deep brain regions without damaging surrounding tissues.

These findings demonstrate the efficacy and feasibility of the Fresnel lens-based tFUS focusing solution in non-invasive deep brain neuromodulation. Due to its non-invasive nature, precise focusing performance, and compatibility with clinical imaging data, this approach provides a reliable technical support for the accurate positioning and precision control of tFUS, and holds significant promise for advancing deep brain function exploration and the development of future neuroscience technologies.

Keywords: transcranial focused ultrasound, Deep brain neuromodulation, Fresnel lens.

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CSFTN-26-28

Rapid quantitative assessment of brain glucose metabolism in small animals using 18F-FDG PET/CT

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Background Small-animal positron emission tomography (PET) provides a crucial non-invasive approach for assessing *in vivo* brain metabolism. While 18F-FDG PET is widely utilized to measure cerebral glucose uptake, brain signals in rodents are highly sensitive to imaging protocols, particularly the physiological conditions during the tracer uptake phase. This study aims to establish a rapid quantitative PET/CT workflow and evaluate the impact of conscious versus anesthetized uptake states on regional brain metabolism.

Methods Healthy rodents were injected with 18F-FDG under two distinct uptake conditions: awake (freely moving) and anesthetized (continuous isoflurane). Following a standardized uptake period, *in vivo* static PET/CT imaging was performed. Reconstructed PET images were co-registered with CT images for anatomical reference. Brain regions were segmented using template-guided regions of interest (ROIs). Regional mean standardized uptake values (SUVmean), standard uptake value ratios (SUVR), and left-right asymmetry indices were calculated across major anatomical structures.

Results Representative PET/CT fused images provided clear visualization of cerebral 18F-FDG distribution. Preliminary quantitative analysis demonstrated measurable differences in both whole-brain and regional glucose metabolism between the distinct uptake states. ROI-based analysis successfully differentiated metabolic signals across the cortex, striatum, hippocampus, and cerebellum, capturing protocol-dependent metabolic variations. The established workflow generated highly reproducible regional metrics and verified metabolic left-right symmetry in healthy subjects.

Conclusion This preliminary study establishes a rapid and reliable PET/CT-based workflow for the quantitative assessment of small-animal brain glucose metabolism. The findings highlight the significant influence of tracer uptake conditions on regional metabolic readouts, emphasizing the necessity of standardized protocols. This framework validates the imaging platform's analytical capabilities and provides a solid methodological foundation for future preclinical neuroscience research involving disease models or neuromodulation.

Key words: small-animal PET, cerebral glucose uptake, quantitative neuroimaging.

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CSFTN-26-29

A novel quantitative method for meningeal lymphatic drainage via coincidence event detection in all-digital brain PET

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Preclinical studies have demonstrated that meningeal lymphatic drainage dysfunction may represent a potential causal or contributing factor in various neurodegenerative diseases. However, direct in vivo evidence in humans using high-temporal-resolution dynamic functional imaging is still lacking to validate findings from animal models. Low-molecular-weight radiotracers can enter and exit meningeal lymphatic vessels via perivascular drainage and other pathways, yet no studies to date have established PET-based quantitative methods for meningeal lymphatic vessels. Accordingly, there is a critical need for a dynamic PET imaging strategy that permits quantitative characterization of meningeal lymphatic drainage in humans, in order to elucidate the contribution of impaired meningeal lymphatic drainage to the pathogenesis of neurological disorders.

In this study, we propose a high-precision quantitative approach based on fine-tuning of brain PET coincidence count data. Through spatial encoding of sub-second coincidence events, this method accurately captures the time point at which tracer first enters the brain, thereby establishing the precise starting point of the dynamic time–activity curve (TAC). Absolute quantitative evaluation of meningeal lymphatic drainage function is then performed using metrics including time-to-peak (TTP), drainage rate, and clearance rate. Human imaging results demonstrate that the dynamic images reconstructed using this method clearly visualize the tracer influx process in the brain and accurately delineate the dynamic curves of drainage.

Together, these findings demonstrate that the proposed method enables accurate quantitative evaluation of meningeal lymphatic drainage function and is compatible with postprocessing workflows adopted in previous studies. Furthermore, this approach is not only applicable to the extraction of meningeal lymphatic drainage curves, but can also be employed in any scenario involving rapid kinetic changes of radiotracers, underscoring its considerable potential for clinical translation and practical applications.

Keywords: meningeal lymphatic drainage, coincidence event detection, brain PET, quantitative method.

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CSFTN-26-30

High-throughput and standardized tissue processing: The integrated automated platform for tissue optical clearing

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Tissue optical clearing (TOC) is a crucial technique for enabling three-dimensional, high-resolution biomedical imaging. However, conventional manual clearing procedures are labor-intensive, suffer from poor reproducibility, and lack standardized real-time monitoring. These limitations significantly hinder the scalability of TOC in large-scale biological studies.

To address these challenges, we have developed a fully automated tissue processing instrument built upon a novel dual-framework architecture: a comprehensive "Hardware Map" and an "Edge-Side Program Generation Model". The Hardware Map provides a standardized engineering foundation, abstracting and coordinating fluidic, mechanical, and environmental control mechanisms for precise physical execution. Operating at the edge, the program generation model functions as a critical bridge. It automatically translates structured experimental clearing protocols into machine-executable programs. This seamless conversion from abstract protocols to precise hardware commands ensures strict execution without requiring manual coding or human intervention.

By precisely regulating the physicochemical environment during clearing, this integrated hardware platform effectively eliminates human error and drastically improves processing efficiency. Experimental validations demonstrate that the automated system yields consistent clearing outcomes across various biological samples. Ultimately, this instrument provides a robust and standardized hardware foundation, facilitating high-throughput tissue processing for advanced 3D imaging applications.

Keywords: tissue optical clearing, automated instrument, protocol translation, standardized processing, 3D biomedical imaging.

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Modeling stroke recovery as a complex system: PET-guided cross-modal conditional learning via latent variables

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Stroke recovery exhibits substantial inter-subject variability that cannot be fully explained by structural damage alone, indicating the presence of hidden functional dynamics underlying the recovery process. From a complex systems perspective, post-stroke recovery can be viewed as an emergent outcome driven by interactions among multiple biological and clinical factors.

In this work, we reformulate stroke outcome prediction as a latent-variable-driven cross-modal conditional modeling problem, where an unobserved latent factor—referred to as metabolic reserve—captures the functional capacity of brain tissue. Within this framework, multimodal inputs are not treated as independent sources, but as interacting components of a system.

A key aspect of our approach is the role of high-resolution PET imaging. Rather than introducing PET as an additional modality, we treat it as a conditioning variable that governs cross-modal interactions, providing access to latent functional states that cannot be inferred from structural imaging alone. This makes PET particularly suitable for modeling system-level dynamics in neurological recovery.

To operationalize this idea, we propose a cross-modal conditional learning framework, in which metabolic representations derived from PET are used to dynamically modulate structural representations from MRI through feature-wise transformations. This mechanism explicitly captures asymmetric conditional dependencies across modalities, shifting multimodal learning from conventional feature fusion toward interaction-driven modeling with a structured inductive bias.

We further design a hypothesis-driven experimental protocol with progressive model variants to evaluate the contribution of conditional interactions over standard fusion-based approaches. Beyond stroke outcome prediction, the proposed framework provides a general paradigm for modeling latent dynamics in complex multimodal systems, with potential applications in broader neuroscience contexts.

Keywords: complex systems, multimodal learning, cross-modal conditional modeling, latent variable modeling, positron emission tomography (PET), stroke outcome prediction.

Photobiostimulation of motor activity of macrophages: New strategies for therapy of brain tumor

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The efficacy of glioblastoma therapy is limited by the blood–brain barrier (BBB) and the immunosuppressive tumor microenvironment dominated by pro-tumor M2 macrophages. This study investigated the effect of laser photobiomodulation (1268 nm, 35.7 J/cm²) on BBB function and macrophage activity in an in vitro model (rat BBB co-culture with C6 glioma cells and macrophages). Irradiation decreased the expression of tight junction proteins (CLDN5, ZO-1) and transendothelial electrical resistance, thereby increasing BBB permeability. Concurrently, laser treatment shifted macrophages towards an M1-like phenotype (increased CD38 and HIF-1α without upregulation of VEGF and CD11b), elevated lactate concentration in the microenvironment, and enhanced directional migration of activated macrophages towards a lactate gradient. Thus, 1268 nm photobiomodulation reversibly increases BBB permeability and promotes macrophage infiltration and anti-tumor activation, offering a novel non-invasive strategy for glioblastoma immunotherapy.

Keywords: blood-brain barrier; glioma; macrophages; photobiomodulation; 1268 nm laser; lactate; migration; tight junctions.

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Science news on the media resources of Saratov University and in other media outlets (based on the research supported by RSF grants)

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Saratov University actively promotes the scientific activities of its staff, including conducting research, participating in grant programmes, conferences, and forums. There are successful four world-class laboratories at the university – Metamaterials, Remotely Controlled Systems for Theranostics, Biomedical Photoacoustics, and Smart Sleep. The results of the research conducted in these laboratories are regularly covered by media.

Every year, the scientists from Saratov University win Russian Science Foundation (RSF) competitions. In 2025, the Russian Science Foundation supported 57 grants.

The Department of Media Communications actively promotes the scientific achievements of SSU researchers. The materials are published on the universityís news feed, in SSUís social media accounts ó VKontakte, Telegram, Zen, Odnoklassniki, and Rutube ó in the *Saratov University* newspaper, and in the *Sweet Milk* student media project. The *Science City* section features digests with the materials presented in regional and federal media.

The university successfully promotes scientific topics on external platforms. Science news appears in such media outlets as *Kommersant*, *RIA Novosti*, *TASS*, *Gazeta.Ru*, as well as on the platforms of the RSF and the Ministry of Higher Education and Science.

For example, in February 2026, the universityís website published a piece about a method to improve the effectiveness of radiation therapy without increasing the radiation dose. The study was carried out by the researchers from the Laboratory of Inorganic Chemistry as part of an RSF grant. The news article provides more details about the platform designed to enhance radiation damage to tumour cells. The press release about the study was also posted on the Ministry of Education and Scienceís website, published in Kommersant newspaper, and covered by a number of other federal media outlets.

At the request of Kommersant journalists, the researchers from the *Smart Sleep* laboratory commented on a technology for treating Alzheimerís disease, which was developed as part of an RSF grant. The news story about replacing neural networks with oscillators with delayed feedback received 17,000 views on the *RIA Science* website.

The SSU media resources regularly inform young researchers about RSF competitions.

In autumn 2025 and spring 2026, SSU hosted the All-Russian Lecture Series of the RSF. The leading scientists — the RSF grantees — explained how scientific ideas turn into applied technologies. The event was widely covered by the SSU media resources. For instance, you can read about the opening of the lecture series and lectures by researchers from the Institute of Chemistry in the news *RSF Science Lecture Series: Schoolchildren Learned about Quantum Dots and Polymers for Agriculture*.

Saratov University is traditionally ranked among the leaders in the integral rating of communication effectiveness for universities, which is compiled by the international media group *Russia Today* and *Brand Analytics*. One section of the rating includes data on the universityís visibility in popular-science public publications. According to the 2025 ratings, the Russian Ministry of Higher Education and Science also recognises SSU as one of the top 10 universities considering the media publications about science and the scientific developments of Saratov researchers.

Key words: media resources, science, journalism.

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Intracranial ultrasonic detectors for photoacoustic microscopy: Modeling and ex vivo validation

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Brain disorders such as stroke and neurodegeneration are closely linked to changes in cortical blood vessels and neurovascular coupling. Photoacoustic microscopy is attractive for this field because it combines optical absorption contrast with ultrasonic readout and can map vascular structures without exogenous labels. However, the mouse skull remains a serious acoustic barrier: it attenuates, refracts, and distorts broadband photoacoustic waves, which limits the sensitivity and reproducibility of transcranial measurements.

This poster describes a strategy for improving photoacoustic detection from the mouse cerebral cortex using two customized transcranial ultrasonic transducers. Optical access is provided by a conventional cranial window. A focused laser beam is scanned through this window and excites photoacoustic signals in cortical vessels, while the acoustic response is detected by miniature transducers positioned outside the skull or, in later configurations, partially implanted through small skull openings. The long-term goal is to develop implantable ultrasonic detectors that can remain mechanically stable with respect to the skull and improve the signal-to-noise ratio of longitudinal brain imaging experiments.

At the present stage, the work is focused on physical modeling and phantom validation rather than on a completed in vivo protocol. We simulate propagation of broadband photoacoustic waves through the mouse skull and analyze how skull thickness, detector position, and the presence of drilled openings influence the detected signal. In parallel, we perform phantom experiments with excised mouse skull bones. The laser is scanned through an artificial cranial window, and the generated ultrasound is recorded either through intact skull regions or through prepared openings using customized hydrophones and compact transducers. These experiments are expected to define the acoustic penalty introduced by the skull, identify detector geometries suitable for transcranial listening, and guide the next stage of the project: implantation-compatible ultrasonic detectors for more sensitive photoacoustic monitoring of cortical vasculature.

Keywords: biophotonics, photoacoustics, ultrasound, brain.

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Optoacoustic imaging of mouse cortical vessels using skull-implanted miniature ultrasound hydrophones

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Sleep deprivation and its effects on youth

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Poor sleep is a growing health concern among young people. During adolescence and early adulthood, natural changes in sleep regulation make individuals more vulnerable to insufficient rest.

This review examines how sleep deprivation affects stress, daily functioning, and social adjustment in youth. Lack of sleep increases perceived stress and reduces a person's ability to maintain productivity and positive social interactions. Young people with chronic sleep loss often struggle with emotional regulation and cognitive performance.

Adolescents are at higher risk for mood disorders and self-harm. Rapid biological and psychosocial changes during this life stage, combined with insufficient sleep, may contribute to these risks. Sleep deprivation can be both a cause and a consequence of mental health problems, creating a difficult cycle.

Excessive social media use has worsened these issues. Late-night screen time, exposure to blue light, and constant notifications disrupt natural sleep cycles. Many young people prioritize online activities over rest, leading to shorter sleep duration and poorer sleep quality.

Improving sleep hygiene and teaching stress management strategies should be priorities for schools and universities. Future research should develop intervention programs that help young people protect their sleep quality and build resilience against stress.

Keywords: sleep deficeincy, adolescents, stress.

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