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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.

GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.

ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ, რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

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CEREBROVASCULAR EVENTS AND NEUROCOGNITIVE IMPAIRMENTS WITH ALTERATIONS IN POLYSOMNOGRAPHIC INDICATORS FOLLOWING CARDIAC SURGERY

E. Tsitlidze, I. Rukhadze, I. Verulashvili, Derry Minyao NG.

Central University Clinic named after Academician N. Kipshidze, Tbilisi, Georgia, Vaja Pshavela Ave 29.

Abstract.

Introduction: Cardiac surgery involving cardiopulmonary bypass (CPB) is frequently associated with a spectrum of postoperative neurological complications, ranging from transient neurocognitive decline to permanent cerebrovascular damage. These events are often accompanied by significant disruptions in sleep architecture, which may further impede the brain's recovery process. Despite the prevalence of these issues, the correlation between postoperative sleep parameters and neurocognitive outcomes remains insufficiently explored.

Objective: The primary goal of this prospective study was to evaluate the relationship between postoperative cerebrovascular and cognitive dysfunctions and alterations in polysomnographic (PSG) parameters in patients undergoing cardiac surgery.

Methods: A total of 507 patients scheduled for cardiac surgery were screened, of whom 104 patients met the strict inclusion criteria and underwent comprehensive neurological and polysomnographic assessment. Patients were divided into two groups: Group I (n=52) received Citicoline as part of their perioperative management, while Group II (n=52) served as the control group. Cognitive function was assessed using the MMSE and MoCA scales. PSG parameters, including sleep latency, REM latency, and arousal index, were recorded preoperatively and postoperatively (at Day 10 and 1 month), while acute neurological evaluations were performed at Day 3.

Results: Pre-operative screening revealed internal carotid artery stenosis or occlusion in 28.8% (n=30) of the enrolled cohort. Acute postoperative neurological complications were documented in 35.6% (n=37) of the patients on Day 3. PSG data revealed profound alterations in sleep architecture, characterized by increased sleep latency and an elevated arousal index on Day 10, closely correlating with cognitive impairment. Notably, within the subgroup analysis of patients with POCD, Group I (Citicoline) demonstrated a significant recovery in MoCA scores and faster structural stabilization of sleep parameters compared to the control group by Day 30 ($p = 0.0016$).

Conclusion: The study demonstrates that polysomnography is a sensitive tool for detecting early neurocognitive dysfunction following cardiac surgery. The inclusion of Citicoline in the perioperative protocol significantly mitigates neurocognitive decline and facilitates the stabilization of sleep-wake cycles. PSG parameters may serve as reliable objective markers for predicting long-term neurological outcomes in cardiac surgery patients.

Key words. Cardiac surgery, neurocognitive impairment, polysomnography, citicoline, CPB, neuroprotection.

Introduction.

Open-heart surgery involving cardiopulmonary bypass (CPB) remains one of the most complex interventions in modern clinical medicine, frequently complicated by adverse cerebral outcomes [1-5]. While intraoperative macroembolic events have been significantly reduced through technological advancements, diffuse micro embolization and systemic inflammatory responses continue to pose a profound threat to central nervous system integrity [6-12]. Postoperative neurocognitive dysfunction (POCD) and transient ischemic events affect a substantial proportion of patients undergoing coronary artery bypass grafting or valvular procedures, severely impacting their long-term quality of life and rehabilitation.

Recent neurobiological insights indicate that the pathophysiology of POCD is multi factorial, involving acute endothelial cell necroptosis, micro vascular hypo perfusion, and a subsequent acute disruption of the blood-brain barrier (BBB) secondary to non-pulsatile perfusion dynamics [13]. Concurrently, contemporary sleep medicine has demonstrated that early postoperative sleep fragmentation significantly hinders cellular homeostasis and suppresses the brain's natural neuroprotective cascades. Complete or partial sleep deprivation impairs the functional integrity of the glymphatic system, which is crucial for clearing neurotoxic metabolic byproducts accumulated during ischemia and reperfusion phases [14-16].

Despite the established clinical relevance of both sleep disturbances and cognitive deficits in cardiac surgery patients, the precise interaction between perioperative sleep architecture alterations—such as sleep latency and arousal indices—and specific neurocognitive outcomes remains insufficiently quantified in standardized clinical settings. Furthermore, effective pharmacological strategies capable of mitigating this dual neurological burden require rigorous prospective evaluation.

Therefore, this prospective study aimed to investigate the direct correlation between postoperative cerebrovascular events, sleep-wake cycle disruptions quantified by polysomnography (PSG), and neurocognitive trajectory. Additionally, we evaluated the clinical efficacy of perioperative Citicoline administration as a potential neuroprotective agent to facilitate both cognitive recovery and the structural stabilization of sleep architecture.

Materials and Methods.

Study design and Patient Selection:

This prospective, controlled clinical study was conducted between 2011 and 2014. A total of 507 patients scheduled for cardiac surgery were initially screened. Following a rigorous selection process based on predefined inclusion and exclusion criteria, a finalized cohort of 104 patients was enrolled in the study.

To guarantee methodological rigor, strict selection criteria were applied. Inclusion criteria required patients to be: candidates for elective cardiac surgery involving cardiopulmonary bypass

(CPB), including isolated coronary artery bypass grafting (CABG) or valve replacement procedures; aged between 50 and 75 years; and capable of providing signed informed consent. Exclusion criteria comprised: pre-existing diagnosed dementia or severe cognitive impairment (baseline MMSE < 24); active major psychiatric or neurological disorders; a history of a major disabling ischemic or hemorrhagic stroke within the past six months; severe uncorrected hepatic or renal failure; and significant carotid artery stenosis (>70%) requiring simultaneous intervention. Based on these strict criteria, 403 patients were excluded during pre-operative screening, ensuring the validity of subsequent postoperative neurocognitive assessments.

Group Allocation and Intervention:

Group allocation was non-randomized, clinically driven, and adapted to the perioperative therapeutic protocols. The enrolled cohort of 104 patients was allocated into two distinct, equal groups to evaluate the efficacy of the neuroprotective intervention:

- **Group I (Intervention Group, n=52):** Patients received Citicoline according to a structured perioperative neuroprotective protocol: 1000 mg administered intravenously (IV) every 12 hours (totaling 2000 mg/day) starting 24 hours prior to surgery and continuing for the first 10 postoperative days. This acute phase was followed by a maintenance phase of 1000 mg administered intramuscularly (IM) once daily for the subsequent 20 days, completing a total therapeutic course of 30 days.
- **Group II (Control Group, n=52):** Patients received standard perioperative care and routine postoperative management without addition of specific neuroprotective pharmacological support.

Neurocognitive Assessment:

Neurocognitive function was evaluated using a comprehensive battery of internationally validated scales, administered preoperatively (baseline) and postoperatively at three specific clinical intervals: day 3, day 10, and one month (day 30). The assessment tools included:

- Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA) for objective global cognitive screening and identification of postoperative cognitive dysfunction (POCD).
- Clock Drawing Test (CDT) to specifically evaluate executive function, abstract thinking, and visuospatial abilities.
- Modified Rankin Scale (mRS) and Glasgow Coma Scale (GCS) to monitor functional independence, neurological deficit progression, and consciousness levels.

Polysomnographic (PSG) Protocol:

Objective sleep architecture and structure were analyzed via full-night polysomnography (PSG) in a standardized clinical laboratory environment. PSG recordings were performed preoperatively to establish baseline values and dynamically repeated during the postoperative recovery phase (day 10 and day 30). Key physiological parameters recorded and analyzed included:

- Sleep Latency (SL) and REM Latency (expressed in minutes).
- Arousal Index (AI): Defined as the number of neurophysiological arousals per hour of sleep, measuring the exact frequency of sleep fragmentations.
- Sleep Efficiency (%) and Stage Distribution: Specifically focusing on the percentages of REM sleep and slow-wave sleep (SWS, N3 stage).

Statistical Analysis:

Statistical processing was performed using SPSS Version 22.0. Continuous variables are presented as mean ± standard deviation (SD) with 95% confidence intervals (CI). Comparative analysis between Group I and Group II was conducted using Student's t-test for independent samples regarding continuous variables and Chi-square ($\chi 2$) tests for categorical data. Repeated measures ANOVA was utilized to track the longitudinal changes across the multiple postoperative timelines. A p-value of < 0.05 was considered statistically significant.

Results.

Neurological Outcomes and Cognitive Profile.

Study Population, Group Allocation, and Subgroup Specification:

Following cardiac surgery involving cardiopulmonary bypass, acute postoperative neurological complications and transient neurocognitive impairments were identified in 37 patients (35.6%) out of the total 104 enrolled participants during the initial evaluation on Day 3. Within this clinically complicated cohort, persistent postoperative cognitive dysfunction (POCD) was objectified in 35 patients based on standardized psychometric scoring on Day 10. Consequently, to ensure methodological rigor and track the longitudinal evolution of severe cognitive deterioration, a secondary subgroup analysis evaluating long-term neurocognitive and polysomnographic (PSG) parameters was performed specifically on these 35 affected individuals up to Day 30.

The longitudinal tracking strictly maintained the patients' original cohort allocation, demonstrating a clear neuroprotective

Table 1. *Baseline Clinical and Demographical Characteristics total cohort (N=104).*

Group I (Citicoline, n=52)	**Group II (Control, n=52)**	**p-value**		
Age (years, Mean ± SD)	64.2 ± 6.8	64.5 ± 6.5	63.9 ± 7.1	0.65
Gender (Male, n / %)	72 (69.2%)	35 (67.3%)	37 (71.2%)	0.67
— Isolated CABG (n / %)	68 (65.4%)	33 (63.5%)	35 (67.3%)	0.68
— Valve Replacement (n / %)	36 (34.6%)	19 (36.5%)	17 (32.7%)	0.68
Cardiopulmonary Bypass Time (min)	112.4 ± 24.6	110.8 ± 22.4	114.1 ± 26.7	0.49
Pre-operative Carotid Artery Stenosis (n / %)	30 (28.8%)	14 (26.9%)	16 (30.8%)	0.66
Acute Neurological Complications (Day 3)	37 (35.6%)	15 (28.8%)	22 (42.3%)	0.15

Table 2. *Postoperative Neurological Complications in the Cohort.*

Complication Type	Number of Cases (Total N=61*)	Percentage of Total Cohort (N=104)
Ischemic stroke	3	2.9%
Postoperative cognitive dysfunction (POCD)	35	33.7%
Severe sleep disturbances	19	18.3%
Epileptic seizures	3	2.9%
Polyneuropathic syndrome	1	1.0%

****Note:*** *The total number of recorded complications (n=61) exceeds the total number of affected patients (n=37) because several individuals manifested overlapping/combined neurological and cognitive symptoms postoperatively.*

Table 3. *Dynamics of Polysomnographic Parameters Across Subgroups (Mean ± SD).*

Parameter & Affected Subgroups	Preoperative Baseline	Postoperative (Day 10)	1 Month Post-Surgery (Day 30)	Normal Reference Range
Montreal Cognitive Assessment (MoCA)				≥ 26 points
— Subgroup I (Citicoline, n=13)	26.3 ± 1.2	24.2 ± 1.1	26.4 ± 1.2	
— Subgroup II (Control, n=22)	26.1 ± 1.4	21.8 ± 1.4	23.1 ± 1.8	(p = 0.0016)
Sleep Latency (minutes)				20–30 min
— Subgroup I (Citicoline, n=13)	28.4 ± 4.2	64.8 ± 12.4	32.1 ± 5.6	
— Subgroup II (Control, n=22)	28.1 ± 4.5	66.2 ± 13.1	48.4 ± 7.9	(p < 0.01)
Arousal Index (events / hour)				< 15 events/hr
— Subgroup I (Citicoline, n=13)	12.3 ± 3.1	38.7 ± 8.4	16.2 ± 4.3	
— Subgroup II (Control, n=22)	12.5 ± 2.9	39.4 ± 9.1	26.8 ± 5.7	(p < 0.01)
Sleep Efficiency (%)				> 85%
— Subgroup I (Citicoline, n=13)	88.2 ± 5.4	54.1 ± 10.2	82.6 ± 6.7%	
— Subgroup II (Control, n=22)	87.9 ± 5.1	52.8 ± 10.8	68.4 ± 7.1%	(p < 0.01)

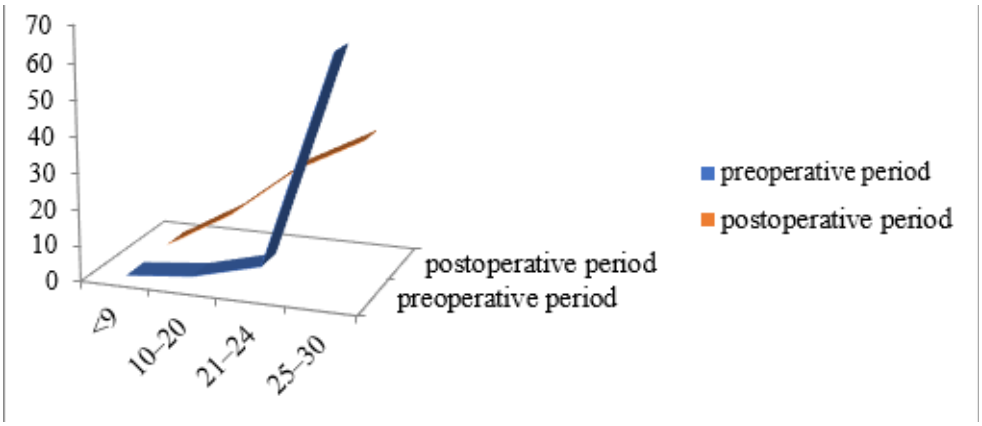

Figure 1. *Flowchart of study design, patient screening, and longitudinal subgroup allocation.*

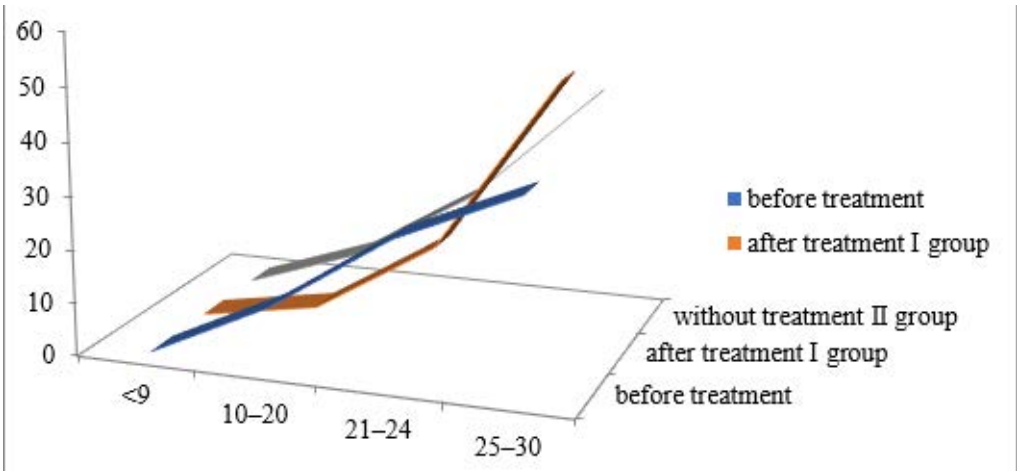

Figure 2. *Neurocognitive dysfunctions demonstrate a significant decrease following targeted therapy, highlighting a distinct variance between Group I and Group II patients.*

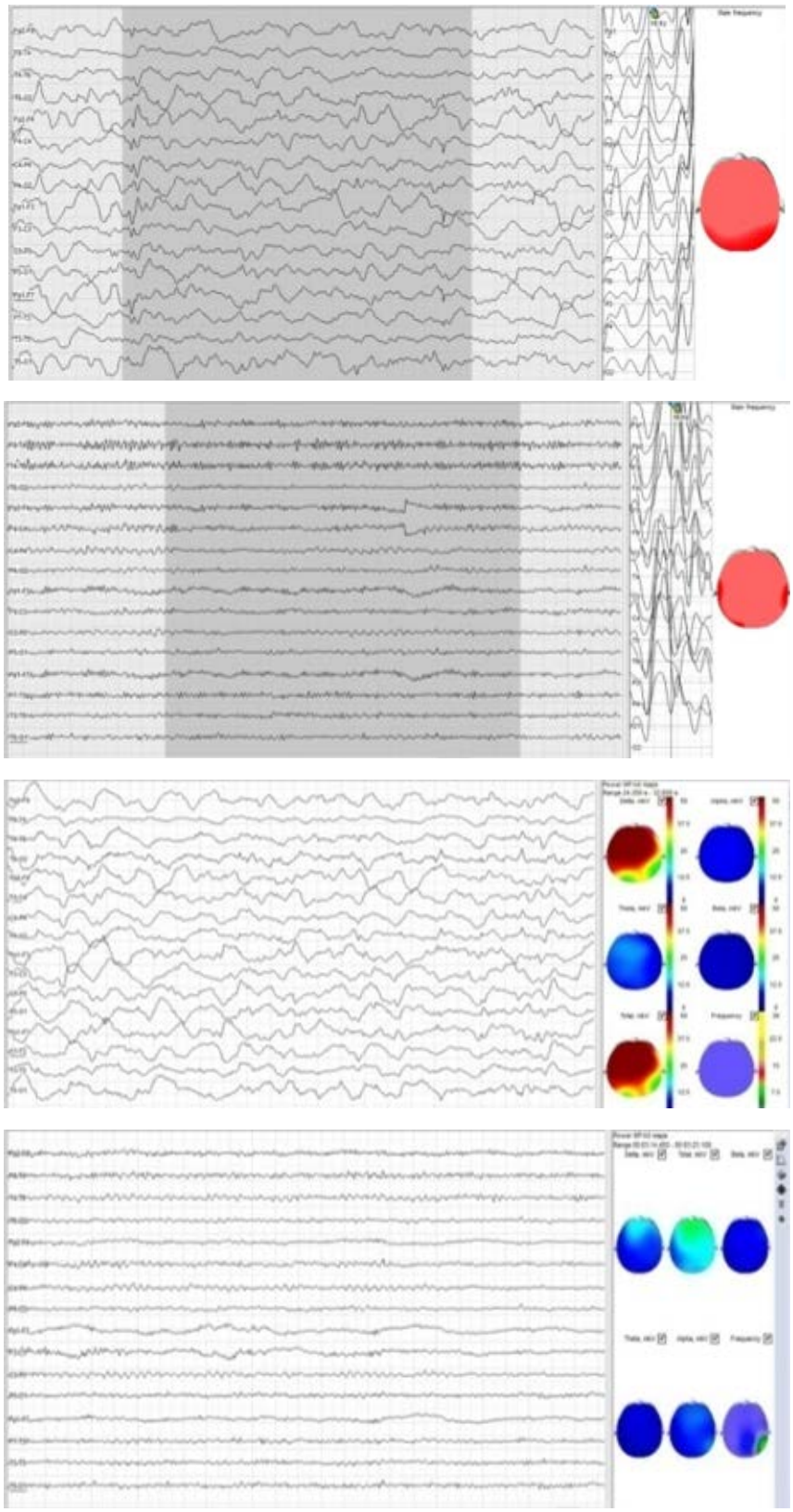

Figure 3. *Shows electroencephalographic (EEG) recordings mapping cerebral bioelectrical activity variations.*

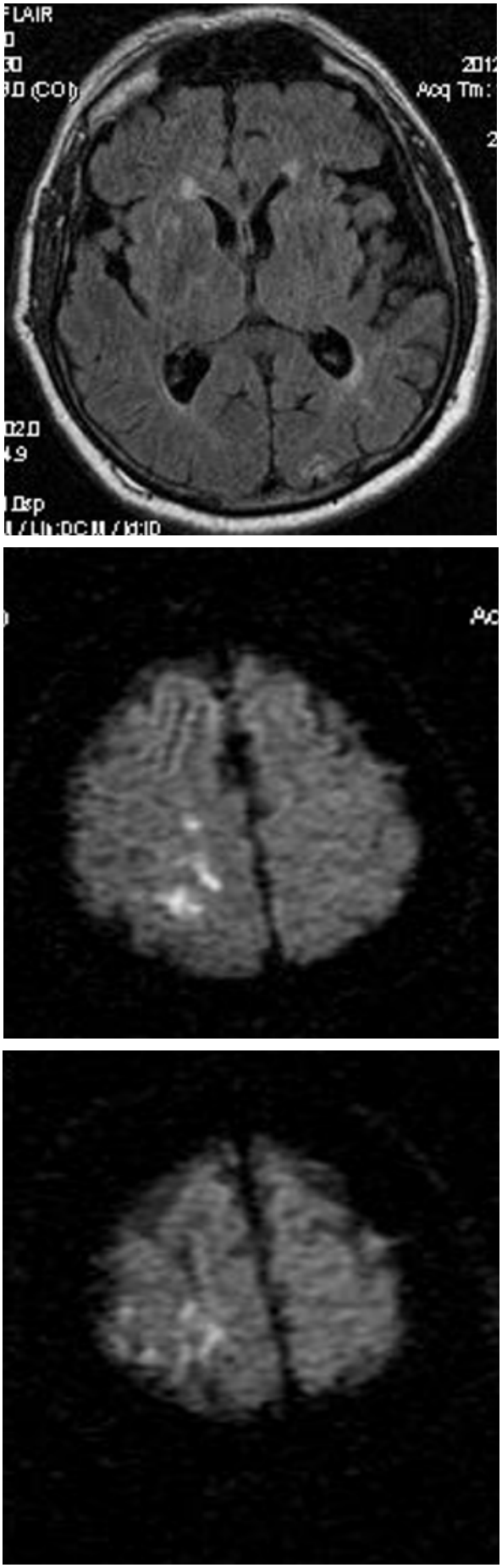

Figure 4. *Postoperative structural neuroimaging and electrophysiological dynamics. Axial T2-FLAIR and DWI sequences demonstrating subclinical, silent microischemic foci within the periventricular white matter and hippocampal regions post-cardiopulmonary bypass.*

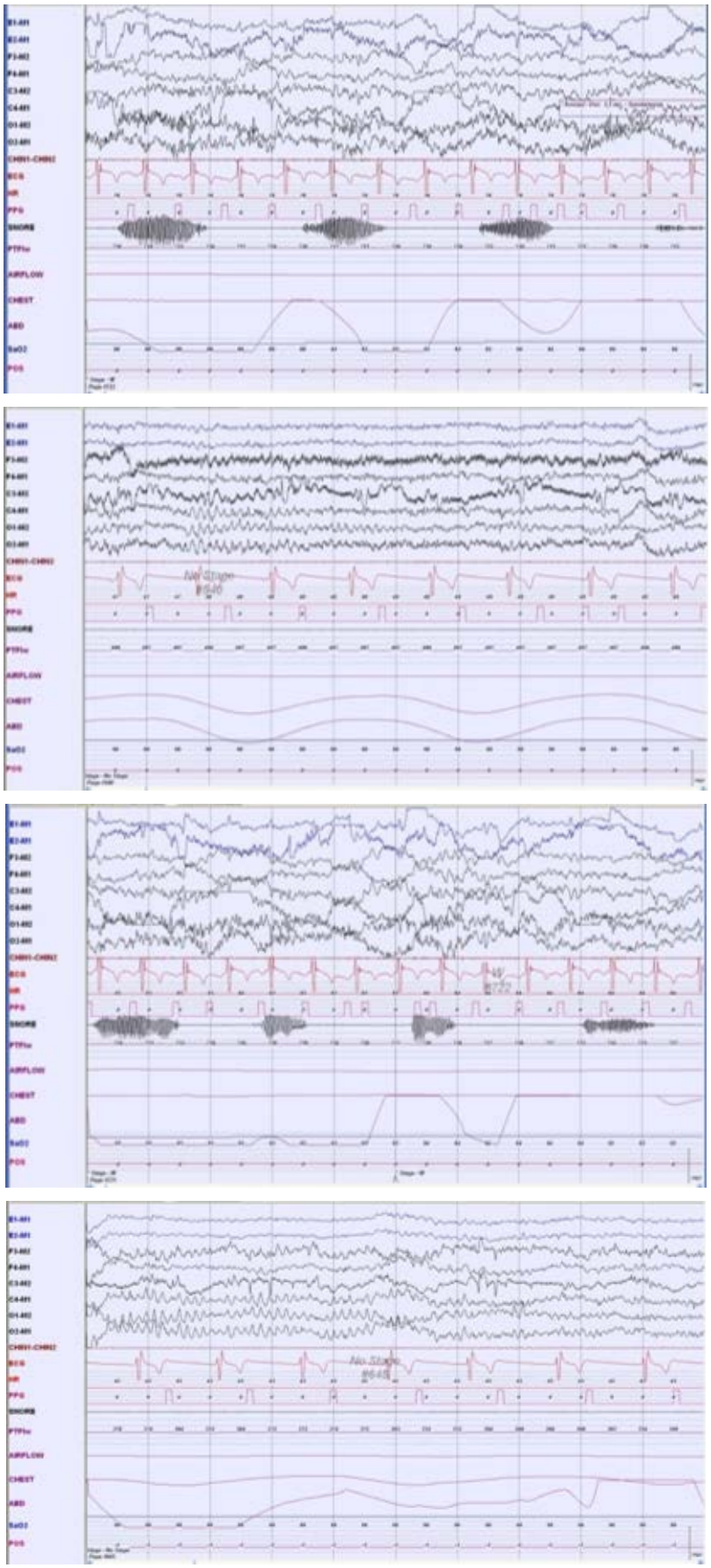

Figure 5. *Shows PSG in dynamics.*

therapeutic effect. The remaining neurocognitive deficit was distributed as follows: Subgroup I (n=13, representing the persistent POCD patients from the original Citicoline intervention arm, indicating an accelerated recovery rate), and Subgroup II (n=22, representing the persistent POCD patients from the original non-treated Control arm, highlighting a sustained cognitive decline). This statistical distribution confirmed a significantly lower incidence of persistent POCD in the neuroprotective treatment arm compared to the control group.

On postoperative Day 3, a total of 37 patients (35.6%) within the entire cohort (N=104) exhibited acute, transient or sustained neurological and cognitive symptoms, ranging from focal deficits to global encephalopathy. To comprehensively evaluate the nature of these perioperative challenges, all recorded clinical adverse events were categorized based on specific neuro-functional manifestations.

As detailed in Table 2, while severe macro-embolic events like ischemic stroke remained minimal due to advanced arterial filtration, micro-fragmented complications such as acute sleep architecture disruptions and early-onset cognitive fluctuations were highly prevalent, often co-occurring within the same individuals.

Neurocognitive Therapy and PSG Outcomes.

Out of the initially enrolled 104 patients (Group I, n=52 Citicoline; Group II, n=52 Control), acute postoperative neurological complications occurred in 37 patients (35.6%). Within this complicated cohort, persistent postoperative cognitive dysfunction (POCD) developed in 35 patients by Day 10. Consequently, the secondary subgroup analysis evaluating long-term neurocognitive and polysomnographic (PSG) outcomes was performed specifically on these 35 affected individuals up to Day 30, strictly maintaining their original cohort allocation to demonstrate therapeutic variance.

The subgroup distribution clearly objectified the neuroprotective efficacy of the intervention, structured as follows: Subgroup I (n=13, representing the persistent POCD patients from the original Citicoline arm, indicating a high recovery rate) and Subgroup II (n=22, representing the persistent POCD patients from the original non-treated Control arm, highlighting sustained cognitive impairment). All patients underwent standardized pre- and postoperative neuro-psychological assessments to dynamically evaluate their global cognitive functions. The following section outlines the Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA) performance results.

Baseline psychometric evaluation demonstrated that both groups possessed comparable cognitive and neuropsychological status prior to surgery. The mean Mini-Mental State Examination (MMSE) score was 27.4 ± 1.1 in Group I (Citicoline) and 27.2 ± 1.3 in Group II (Control), while the baseline Montreal Cognitive Assessment (MoCA) scores were 26.3 ± 1.2 and 26.1 ± 1.4, respectively. On postoperative Day 3, an acute, uniform decline in cognitive performance was documented across the entire complicated cohort (n=35), with mean MoCA scores dropping significantly to 21.4 ± 1.5 in Subgroup I and 21.2 ± 1.7 in Subgroup II, reflecting early perioperative neurocognitive fluctuations and metabolic impact.

However, longitudinal tracking revealed divergent recovery trajectories between the two arms. By Day 10, Subgroup I (Citicoline) demonstrated accelerated cognitive stabilization, with mean MMSE scores improving to 25.1 ± 1.2 (95% CI: 24.4–25.8) and MoCA scores rising to 24.2 ± 1.1 (95% CI: 23.5–24.9). In contrast, Subgroup II (Control) exhibited prolonged cognitive deficit, with their MoCA scores stagnating at 21.8 ± 1.4 (95% CI: 21.1–22.5).

This therapeutic divergence became definitive by Day 30 (1 month postoperatively). Subgroup I achieved near-baseline neurocognitive restoration, with a finalized mean MMSE score of 27.1 ± 0.9 and a MoCA score of 26.4 ± 1.2 (95% CI: 25.9–26.9). Conversely, the untreated Control subgroup (Subgroup II) continued to manifest persistent postoperative cognitive dysfunction (POCD), with a mean MoCA score remaining significantly depressed at 23.1 ± 1.8 (95% CI: 22.4–23.8), establishing a statistically significant long-term therapeutic advantage for the Citicoline intervention arm ($p = 0.0016$).

Figure 1 Flowchart of study design, patient screening, and longitudinal subgroup allocation. Out of 507 screened patients, 104 met strict inclusion criteria and were split into Group I (Citicoline, n=52) and Group II (Control, n=52). Secondary longitudinal subgroup analysis track the 35 patients who developed persistent postoperative cognitive dysfunction (POCD) by Day 10 up to Day 30.

According to the diagram below (Figure 2), neurocognitive dysfunctions demonstrate a significant decrease following targeted therapy, highlighting a distinct variance between Group I and Group II patients.

Polysomnographic and Neurophysiological Indicators.

The analysis of cerebral bioelectrical activity and sleep architecture demonstrated profound alterations in patients with neurocognitive impairment following cardiopulmonary bypass (CPB). Quantitative electroencephalographic (EEG) monitoring pre- and postoperatively tracked the evolution of functional encephalopathy. Early postoperative phases were characterized by diffuse background slowing with a shift toward theta and delta power frequencies, indicating perioperative metabolic and ischemic impact. Subsequent longitudinal tracking documented a systematic restoration of the posterior dominant alpha rhythm and stabilization of spectral power distribution, which correlated with clinical recovery.

Similarly, polysomnography (PSG) objectified severe structural sleep disruptions. Table 3 summarizes the dynamic changes in key PSG parameters from the preoperative baseline to one-month post-surgery, stratified by subgroup to demonstrate therapeutic variance. The baseline sleep-wake architecture was heavily fragmented postoperatively, manifesting as prolonged sleep latency and a marked elevation of the arousal index, driven by micro-arousals during non-REM stages.

Impact of Neuroprotective Therapy.

Longitudinal objective monitoring revealed that patients who received Citicoline (Subgroup I) demonstrated a highly superior neurophysiological recovery profile. By the end of the first postoperative month (Day 30), the mean MoCA score in Subgroup I had returned to near-baseline levels (26.4 ± 1.2), whereas the untreated Control cohort (Subgroup II) continued

to exhibit severe deficits in executive function and delayed recall (23.1 ± 1.8, p = 0.0016).

Furthermore, quantitative EEG and PSG dynamic tracking confirmed that the stabilization of both the Arousal Index and Sleep Latency occurred significantly faster and more systematically in the Citicoline arm. By Day 30, Subgroup I achieved near-complete normalization of sleep efficiency (82.6 ± 6.7%), while Subgroup II demonstrated persistent sleep fragmentation, prolonged REM latency, and unstable sleep stage architecture ($p < 0.01$).

Following Figure 3 shows electroencephalographic (EEG) recordings mapping cerebral bioelectrical activity variations. The early postoperative phase illustrates a functional metabolic encephalopathy with diffuse background slowing and an increase in low-frequency theta and delta spectral power. Subsequent traces demonstrate a progressive, therapeutic restoration of the posterior dominant alpha rhythm and synchronization of cortical voltage distribution.

Neuroimaging via structural magnetic resonance imaging (MRI) postoperatively correlated with these functional recovery patterns. Patients adhering to the neuroprotective protocol demonstrated a lower incidence of silent microischemic foci within the periventricular white matter and hippocampal regions. In patients manifesting persistent cognitive fluctuations, postoperative structural MRI sequences revealed subclinical, silent microischemic alterations prior to any overt clinical neurological manifestations, as illustrated in Figure 4.

Figure 5 Representative multi-channel overnight polysomnography (PSG) tracings demonstrating early postoperative structural sleep disruptions and subsequent therapeutic stabilization. The raw PSG epochs illustrate continuous electrophysiological monitoring across standardized clinical channels, including electrooculography (EOG: E1–M1, E2–M1) for REM detection, multi-channel electroencephalography (EEG: F3–M2, C3–M2, O1–M2) for sleep architecture staging and micro-arousal quantification, and submental electromyography (EMG) for muscle tone assessment. Concurrently integrated cardiorespiratory dynamics track multi-lead electrocardiography (ECG), photoplethysmography (PPG), nasal airflow, thoracic-abdominal respiratory effort, and continuous oxygen saturation (SaO2).

Early postoperative recordings in untreated controls are characterized by profound architectural disintegration, manifesting as severe fragmentation of non-REM slow-wave sleep, prolonged sleep onset latency, and a pathologically elevated Arousal Index driven by recurrent micro-arousals and transient electroencephalographic shifts. Dynamic tracking demonstrates that perioperative Citicoline pharmacotherapy facilitates accelerated homeostatic stabilization, characterized by the progressive restoration of organized sleep spindles, K-complexes, stable REM sleep synchronization, and a significant reduction in micro-arousal frequency by Day 30.

Discussion.

The results of our study underscore the critical and intricate interplay between cardiac surgery, postoperative sleep architecture disruptions, and neurocognitive integrity. The clinical incidence of early neurological complications and neurocognitive fluctuations (35.6%) objectified in our cohort aligns with contemporary international findings. These studies identify cardiopulmonary bypass (CPB) and non-pulsatile perfusion dynamics as major systemic triggers for acute microembolization and generalized neuroinflammatory response patterns, both of which are heavily detrimental to higher cerebral functions.

While modern technological advancements over the past two decades—such as the systematic implementation of mini-CPB circuits, leukocyte-depleting arterial line filters, and biocompatible thromboresistant coatings—have successfully minimized the risk of gross embolic cortical strokes, microembolic showers and systemic inflammatory response syndrome (SIRS) remain pervasive intraoperative challenges. Recent international literature confirms that the blood-brain barrier (BBB) maintains an extreme vulnerability to CPB-induced endothelial cell mechanical injury and subsequent necroptosis. This cellular cascade directly triggers microglial activation, acute neuroinflammation, and subsequent structural sleep-wake cycle disturbances within regulatory hypothalamic centers.

The Diagnostic Value of Polysomnography (PSG) and Pathophysiological Correlations.

Our dynamic neurophysiological findings highlight a profound, multidimensional disruption in sleep-wake cycles following CPB. The significant, acute increase in sleep latency and the arousal index (detailed in Table 3) directly suggests that major cardiac surgery induces a transient state of "cerebral instability" or metabolic encephalopathy. Crucially, we observed that patients presenting with the most severe neurocognitive decline (measured by longitudinal MMSE and MoCA scoring) also exhibited the most fragmented sleep architecture. This strong clinical interplay underscores that postoperative PSG is not merely a diagnostic tool for sleep disturbances, but functions as a highly sensitive, objective biomarker for early postoperative encephalopathy.

Furthermore, contemporary sleep medicine underscores that severe postoperative REM sleep fragmentation and slow-wave sleep deprivation directly impair the functional integrity of cerebral glymphatic clearance mechanisms. This metabolic pathway explains why the significantly elevated Arousal Index and prolonged sleep latency documented in our non-treated control cohort (Subgroup II) directly correlated with severe, sustained verbal learning deficits, executive dysfunctions, and memory retention delays postoperatively. The persistent reduction in REM sleep stages and the pathological persistence of sleep fragmentation documented via electrophysiological tracing (Figure 5) and quantified in Table 3 reflect a homeostatic failure in the brain's glymphatic clearance and neuroplastic recovery pathways, thereby compounding cognitive deficits over time.

The strong positive correlation established between the chronological normalization of REM latency and global cognitive scores at the one-month mark ($r = 0.68$, $p < 0.01$) strongly indicates that the structural restoration of sleep architecture is a pathophysiological prerequisite for sustained neurocognitive recovery following extracorporeal circulation.

In this clinical framework, the Arousal Index proved to be an exceptionally sensitive marker; its pathological persistence in the control arm directly correlated with long-term, unmitigated postoperative cognitive dysfunction (POCD). Conversely, its rapid, systematic decline in the intervention arm served as a reliable early indicator of a favorable long-term neurological prognosis.

Mechanisms of Citicoline's Neuroprotective Efficacy.

The distinct therapeutic efficacy of Citicoline observed in our intervention arm (Subgroup I) dynamically aligns with modern molecular evidence regarding central neuroprotection and neurorestoration. Citicoline acts as an essential rate-limiting intermediate via the Kennedy pathway, directly preserving structural neuronal membrane phospholipids, mitigating blood-brain barrier endothelial permeability, and accelerating acetylcholine synthesis within the reticular activating system.

Our quantitative data demonstrates that Citicoline-treated individuals achieved a significantly faster, structural stabilization of both the arousal index and overall sleep efficiency compared to the control group (Table 3). By firmly preserving endothelial and neuronal membrane integrity, perioperative Citicoline pharmacotherapy appears to prevent the functional "leakage" of the BBB and suppress the acute neuroinflammatory cytokine cascade. This facilitates an accelerated, synchronized restoration of both physiological sleep patterns and cognitive performance scores.

By functionally stabilizing these critical central cholinergic pathways, Citicoline facilitates the accelerated restoration of physiological slow-wave and REM sleep architecture. This structural sleep stabilization is vital for the timely activation of the glymphatic clearance system, which is responsible for effectively flushing neurotoxic metabolic byproducts from hippocampal formations following cardiopulmonary bypass hypoperfusion. This dual synergistic mechanism fully accounts for the significantly accelerated MoCA and MMSE score recovery profiles objectified in our treatment cohort by Day 30. It also correlates with neuroimaging outcomes (Figure 4), which demonstrate a reduced incidence and faster stabilization of subclinical microischemic foci within the periventricular white matter and hippocampal formations among patients adhering to the neuroprotective protocol.

Clinical Implications.

Given the definitive lack of a current global "gold standard" protocol for perioperative neuroprotection in open-heart surgery, our study suggests that a synchronized combination of objective postoperative PSG monitoring and structured perioperative Citicoline therapy could significantly optimize long-term clinical outcomes. Incorporating full-night PSG screening or objective electrophysiological monitoring in the early postoperative phase may allow clinicians to objectively identify "at-risk," neurocognitively vulnerable patients well before permanent, irreversible neurological and ischemic damage occurs.

Conclusion.

In conclusion, the findings of this prospective clinical study demonstrate that postoperative neurocognitive impairment in cardiac surgery patients undergoing cardiopulmonary bypass is intimately and mechanistically linked to profound structural disruptions in sleep architecture. Polysomnography (PSG) serves as a critical, highly sensitive neurophysiological tool, providing objective, non-invasive biomarkers—specifically the Arousal Index and REM latency—that reliably predict the trajectory of long-term neurocognitive recovery.

Furthermore, the perioperative administration of Citicoline proved to be a highly effective neuroprotective strategy, significantly accelerating the homeostatic stabilization of both psychometric cognitive scores and physiological sleep parameters by Day 30. Ultimately, these insights strongly advocate for a paradigm shift toward an integrated, multimodal approach in perioperative neurological care, systematically combining objective sleep architecture monitoring with targeted pharmacological neuroprotection to optimize long-term clinical and functional outcomes in cardiac surgery patients.

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Цереброваскулярные события и нейрокогнитивные нарушения с изменениями полисомнографических показателей после кардиохирургических операций

Э. Цитлидзе, И. Рухадзе, И. Верулашвили, Дерри Миньяо Нг

Центральная университетская клиника им. академика Н. Кипшидзе, Тбилиси, Грузия.

Резюме.

Введение: Кардиохирургические вмешательства в условиях искусственного кровообращения (ИК) сопряжены с высоким риском развития постперифузионных неврологических осложнений и нарушений архитектуры сна. Однако взаимосвязь между объективными параметрами сна и траекторией нейрокогнитивного восстановления остается недостаточно изученной.

Цель исследования: Оценить взаимосвязь между послеоперационными цереброваскулярными/ когнитивными нарушениями и динамикой показателей полисомнографии (ПСГ) у пациентов после кардиохирургических операций, а также определить эффективность периоперационной нейропротекции цитиколином.

Материал и методы: В проспективное контролируемое исследование были включены **104 пациента**, перенесших плановые операции в условиях ИК (коронарное шунтирование или протезирование клапанов). Пациенты были разделены на две равные группы: Группа I (n=52, основная) получала цитиколин по ступенчатой схеме (2000 мг/сут внутривенно в течение 10 дней, затем 1000 мг/сут внутримышечно в течение 20 дней); Группа II (n=52, контрольная) получала стандартную терапию. Нейропсихологический статус оценивали с помощью шкал MMSE и MoCA. ПСГ-мониторинг выполнялся исходно, на 10-е и 30-е сутки после операции.

Результаты: Дооперационный скрининг выявил гемодинамически значимый стеноз или окклюзию внутренней сонной артерии у **30 пациентов (28.8%)**. В раннем послеоперационном периоде (на 3-и сутки) острые неврологические нарушения разной степени выраженности были зафиксированы у **37 пациентов (35.6%)**. К 10-м суткам у 35 пациентов сформировался стойкий послеоперационный когнитивный дефицит (ПОКД), сопровождавшийся тяжелой дезорганизацией сна (повышение индекса микропробуждений до 38.7 ± 8.4 в час, удлинение латентности REM-сна).

В ходе продольного наблюдения была доказана высокая терапевтическая эффективность цитиколина: в подгруппе I (пациенты с ПОКД, получавшие цитиколин, n=13) к 30-м суткам отмечалось значительное восстановление когнитивных функций (балл по MoCA достиг 26.4 ±1.2, p = 0.0016) и нормализация структуры сна (эффективность сна 82.6 ± 6.7). В подгруппе II (контроль, n=22) сохранялся выраженный нейрокогнитивный дефицит (балл MoCA 23.1 ±1.8) и персистирующая фрагментация сна ($p < 0.01$).

Заключение: Посткардиотомные когнитивные нарушения тесно сопряжены с деструкцией фаз сна. Периоперационное применение цитиколина эффективно минимизирует выраженность когнитивного дефицита и ускоряет стабилизацию циклов сон-бодрствование. Параметры полисомнографии (индекс микропробуждений и латентность REM-фазы) могут служить надежными объективными биомаркерами для прогнозирования неврологического исхода.

Ключевые слова: Кардиохирургия, нейрокогнитивные нарушения, полисомнография, цитиколин, искусственное кровообращение.