

ANNOTATION

Kastey Rauan Meiramuly's dissertation on "Ways to Improve Specialized Care for Patients with Acute Cerebrovascular Accidents," submitted for the degree of Doctor of Philosophy (PhD) in the specialty 6D110200 "Public Health"

Relevance of the research topic

Cardiovascular diseases (CVDs) remain the leading cause of mortality worldwide and represent a serious medical and social problem. According to WHO data, in 2022, 19.8 million people died from CVDs, of which 85% were due to heart attacks and strokes. More than 75% of these deaths occur in low- and middle-income countries, where access to healthcare and prevention is limited [1-3]. Stroke is one of the most severe manifestations of CVD and is a leading cause of mortality and disability among adults. It is an acute disturbance of cerebral circulation causing brain tissue damage due to ischemia or hemorrhage. According to WHO, stroke is defined as a neurological deficit of vascular origin lasting more than 24 hours or leading to death within this period. Two main types are distinguished: ischemic (about 85% of cases) and hemorrhagic (about 15%) [4].

From 1990 to 2021, global stroke incidence increased by 70%, and mortality by 44%, reaching 7.25 million cases annually [5]. By 2050, deaths may rise to 9.7 million, with up to 89% occurring in low- and middle-income countries. Population aging is a key factor, but strokes are increasingly occurring in younger individuals.

Among young adults, prognosis is generally more favorable than in older people; however, incidence has increased from 17 to 28 cases per 100,000 (1993–2015). This is associated with rising prevalence of modifiable risk factors: hypertension, obesity, diabetes, hyperlipidemia, and substance use [6,7]. Stroke at a young age leads to significant physical, cognitive, and socio-economic consequences. Although 72–81% of patients aged 18–50 achieve functional independence, risks of disability, post-stroke epilepsy, and economic losses remain high [8].

Predictors of poor outcomes include high NIHSS score, hyperglycemia, atrial fibrillation, and renal dysfunction, while timely treatment and high HDL levels improve recovery [8,9]. In developing countries, strokes in young people are often more severe with higher three-month mortality. Long-term data show mortality is five times higher than in the general population. Recurrence rate of embolic stroke is about 2 per 100 patient-years, and complications after hemorrhage occur in 40% of patients. Global economic losses from stroke exceed \$890 billion annually [5,10].

Timely care is crucial. The principle “time is brain” highlights that every minute delay leads to irreversible neuron loss. Effective prehospital care organization is a key element.

Prehospital delay depends on many factors: longer delays occur among women, elderly, single individuals, rural residents, and those with low education. Early ambulance activation and “stroke code” implementation reduce time to hospitalization. Public awareness of stroke symptoms remains critical [11].

Nurses play a central role in prehospital care, implementing the “8D stroke care” principles. Modern approaches include Mobile Stroke Units (MSU) equipped with CT scanners, laboratories, and telemedicine, allowing thrombolysis before hospital arrival [12,13].

From 2014 to 2019, Kazakhstan exhibited pronounced regional differences in stroke incidence and mortality: the highest rates were recorded in the central, northern, and eastern regions, which is associated with population aging, a high prevalence of comorbidities, and limited access to healthcare [14].

According to studies, from 2011 to 2020, stroke incidence increased 2.3 times — from 189 to 433.7 cases per 100,000 population. The highest rates were observed in the East Kazakhstan region (625 per 100,000), while the lowest were recorded in the Atyrau, Aktobe, and Almaty regions.

Despite the increase in incidence, mortality decreased by 15% — from 92.36 to 78.49 per 100,000 population [15].

Analysis of data from 79 stroke centers revealed significant prehospital delays (120–180 minutes) and prolonged “door-to-needle” intervals [16], indicating the need to improve the prehospital care system and implement modern technologies to optimize care for patients with acute cerebrovascular accidents.

Aim of the study:

To develop and scientifically substantiate ways to improve the organization of prehospital and specialized medical care for patients with acute cerebrovascular accidents (ACVA) in the city of Almaty.

Objectives:

1. To analyze scientific data and regulatory legal acts governing the organization of medical care for patients with ACVA.

2. To study the dynamics and economic significance of circulatory system diseases in the city of Almaty in 2012–2024.

3. To assess the level of preparedness of healthcare professionals of various profiles (emergency medical services, neurologists, intensivists, rehabilitation specialists, and neurosurgeons) to provide care for patients with ACVA in Almaty.

4. To identify key barriers to stroke care at the prehospital and hospital stages based on patient feedback.

5. To develop a model project for optimizing care for patients with ACVA using modern technologies (mobile stroke units).

Research methods:

A comprehensive interdisciplinary approach was used, including analytical, epidemiological, economic, and qualitative methods.

1. Analytical and system analysis was conducted to generalize domestic and international scientific data, clinical guidelines, and organizational models of stroke care.

2. Epidemiological analysis was performed to assess trends in morbidity and mortality from circulatory system diseases and stroke in Almaty for 2012–2024 based on official statistics.

3. Analysis of avoidable mortality was carried out using the OECD methodology, including calculations of absolute and relative changes and average annual rates.

4. Economic analysis was conducted to assess the economic burden of avoidable mortality using the value of a statistical life (VSL).

5. A retrospective analysis of hospitalized ACVA cases was performed to evaluate the age structure of patients, length of hospital stay, and treatment outcomes.

6. Qualitative research methods were applied, including semi-structured interviews with healthcare professionals and patients, to identify barriers to stroke care.

7. Health economic modeling was performed using a Markov model and net present value (NPV) analysis to assess the effectiveness and feasibility of implementing a mobile stroke unit (MSU), including sensitivity analysis.

Object of the study. The healthcare delivery system for patients with acute cerebrovascular accidents (ACVA) and diseases of the circulatory system in the city of Almaty.

Subject of the study. Epidemiological, clinical, organizational, and economic aspects of stroke care, including avoidable mortality, clinical outcomes, barriers to care, and the effectiveness of implementing a mobile stroke unit (MSU).

Provisions submitted for defense.

1. In 2012–2024, a high incidence of circulatory system diseases (CSD) and cerebrovascular diseases (CeVD) persisted in Almaty, with unstable mortality and a peak in 2020–2021; avoidable mortality was higher among men and was predominantly driven by ischemic heart disease.

2. The economic burden of avoidable mortality from CSD in Almaty remains significant and unstable, reaching a maximum in 2021; at the same time, clinical outcomes of ACVA improved, as evidenced by reduced case fatality rates and shorter hospital stays, partly due to the implementation of a standardized patient management algorithm, while the need to strengthen prevention remains.

3. Despite the high preparedness of intensivists and neurosurgeons, insufficient training and resource provision persist among emergency medical service personnel, rehabilitation specialists, and neurologists.

4. According to patient feedback, the key barriers to stroke care at both prehospital and hospital stages are behavioral and organizational factors (low awareness, delayed healthcare seeking, routing delays, and limited rehabilitation), which reduce treatment effectiveness and require enhanced coordination and public awareness efforts.

5. Clinical and economic analysis and financial evaluation have shown that the implementation of a mobile stroke unit (MSU) in ACVA is associated with improved functional outcomes and greater effectiveness compared to standard treatment, indicating its potential economic and investment feasibility.

Description of the main research results

Circulatory system diseases (CSD), including stroke, remain the leading cause of mortality and disability, accompanied by increasing incidence, including among younger individuals, and significant economic losses.

In 2012–2024, the incidence of CSD and cerebrovascular diseases (CeVD) in the city of Almaty remained consistently high and was characterized by pronounced variability. The incidence of CSD ranged from its lowest level in 2015 (2,982.8 per 100,000 population) to a subsequent increase by 2024 (3,950.6 per 100,000), while for CeVD, after a sharp rise in 2012–2014, the rates stabilized at a high level in 2020–2024 (425–460 per 100,000). This indicates a persistent epidemiological burden of CSD and stroke, despite certain periods of improvement.

Mortality from CSD and stroke generally showed a downward trend but remained unstable. Following a marked decrease in CSD mortality in 2012–2015 (from 345.6 to 139.5 per 100,000 population), a sharp increase was observed in 2020–2021, reaching a peak of 284.9 per 100,000, followed by a decline to 170.1 in 2024. A similar pattern was observed for stroke mortality. These fluctuations reflect the vulnerability of achieved improvements to external systemic shocks, primarily the COVID-19 pandemic, and indicate the limited resilience of the healthcare system.

Avoidable mortality from CSD in 2014–2024 did not demonstrate a stable linear trend (AAPC +0.9% per year; 95% CI includes 0) and was characterized by sharp fluctuations: a decrease to a minimum in 2019 (29.17 per 100,000 population) was followed by an extreme increase in 2021 (261.11) and a subsequent rise again in 2024 (130.55). In absolute terms, avoidable mortality from CSD increased by 10.17 per 100,000 population over the period; this increase was entirely driven by the male population (+39.00), while a decrease was observed among women (−9.95). In relative terms, avoidable mortality increased by 8% in the total population and by 22% among men, highlighting persistent gender inequality.

Analysis of the causes of death showed that the unfavorable trend was primarily driven by ischemic heart disease (IHD). The absolute increase in avoidable mortality from IHD amounted to +41.06 per 100,000 population (+70.64 among men and +20.49 among women), with a relative increase of 115%. In contrast, mortality from cerebrovascular diseases (CeVD) demonstrated a steady absolute and relative decline (−30.24 per 100,000 and −48% overall), indicating improvements in stroke management while persistent challenges remain in the primary prevention of IHD.

Total economic losses ranged from a minimum in 2019 (USD 193.15 million) to a maximum in 2021 (USD 1,728.77 million under the VSL = 4.8 scenario), with the majority of the burden consistently attributable to men (in 2021, more than 2.5 times higher than among women). Analysis of hospitalized cases of ACVA in 2012–2024 revealed an increase in the number of hospitalizations, a rise in the average age of patients, and a reduction in the average length of hospital stay; at the same time, decreased case fatality and an increased proportion of recoveries indicate progress in inpatient care. Overall, these findings show that improvements in treatment outcomes were not accompanied by a comparable reduction in incidence and economic burden,

thereby justifying the need to strengthen primary prevention, early diagnosis, and the resilience of the healthcare system to external systemic shocks and crisis situations.

In response to the identified epidemiological and organizational challenges, one of the key directions for improving medical care for patients with ACVA was the implementation of a standardized patient management algorithm. Developed in 2021 as part of the doctoral research, this algorithm was implemented at City Clinical Hospital No. 7 in Almaty.

Unlike previously applied approaches, which were largely based on strict time-based patient selection criteria, the proposed algorithm includes the possibility of CT perfusion imaging within an extended time window of up to 24 hours from symptom onset. This allows identification of patients with salvageable ischemic penumbra and expands access to reperfusion therapies, including mechanical thrombectomy. In addition, the algorithm предусматривает (includes) standardization of patient routing, early activation of the “stroke code,” parallel execution of diagnostic and therapeutic interventions, and enhanced interdisciplinary coordination between emergency medical services, the admission department, neuroimaging units, and specialized inpatient departments.

The practical implementation of the algorithm made it possible to optimize time indicators of care delivery, improve coordination among medical personnel, and expand the possibilities for selecting patients for specialized treatment. Taken together, these changes can be considered as one of the factors contributing to improved treatment outcomes, including the reduction in case fatality observed during the analyzed period.

The results of interviews with healthcare professionals and patients made it possible to comprehensively assess the readiness of the ACVA care system in the city of Almaty. The highest average length of service was observed among emergency medical service specialists (on average 17.5 years) and neurosurgeons (16.2 years), indicating substantial clinical experience within these groups. At the same time, the shorter length of service among rehabilitation physicians (9.8 years) reflects a relatively younger and less established workforce, particularly in the post-stroke care segment.

In terms of preparedness for acute stroke management, intensivists and neurosurgeons were the most prepared, as they regularly undergo training, are adequately equipped with the necessary resources and staff, and actively participate in quality registries (intensivists $n=30$, neurosurgeons $n=23$). Neurologists generally demonstrated a good level of preparedness; however, they more frequently reported shortages of personnel and resources ($n\approx 11-13$), which is largely related to the outpatient nature of their work. The most vulnerable components of the system were emergency medical services ($n=10$) and rehabilitation services ($n=20-22$), where training was conducted irregularly, resource limitations were noted, and involvement in registries and quality monitoring was low, indicating systemic gaps at the prehospital stage and in the organization of post-stroke recovery.

Assessments by specialists regarding public awareness were largely consistent: most physicians noted a low level of recognition of stroke symptoms among the

population and insufficient effectiveness of existing information campaigns. These findings were confirmed by patient interviews: only 22 out of 61 respondents were aware of stroke symptoms prior to onset, while 39 lacked such knowledge. The majority of patients were over 60 years old (40 out of 61), and for 49 individuals the stroke was the first episode. Although many reported relatively rapid ambulance arrival (10–20 minutes; n=42), a notable proportion experienced delays exceeding 30 minutes (n=6), failure of EMS staff to recognize stroke (n=4), and refusals of hospitalization (n=3). At the hospital stage, problems persisted with explaining the diagnosis and treatment plan (lack of information n≈10–12) and limited availability of early rehabilitation (18 patients received inpatient rehabilitation, while in 30–35 cases it was absent or delayed).

A significant potential for digital solutions was identified alongside low awareness of them: 36 out of 61 patients had not heard of telerehabilitation, although almost all had access to digital devices and the internet (n=60). Many expressed willingness to use remote formats but noted barriers related to digital literacy, connection quality, and the need for personal contact with healthcare providers. Overall, the findings highlight the need for systemic measures, including regular targeted training for EMS and rehabilitation staff, standardization of patient routing and communication, expansion of access to rehabilitation services, scaling up FAST-type public awareness campaigns with a focus on families and older adults, and the gradual implementation of telerehabilitation using simple, patient-adapted interfaces.

Markov modeling over a 25-year horizon demonstrated that the implementation of a mobile stroke unit (MSU) for acute ischemic stroke provides a sustained improvement in functional outcomes and a reduction in mortality compared to standard treatment; this advantage persists throughout the entire modeling horizon, despite its gradual decline over time.

The MSU strategy results in gains in both quality and length of life ($\Delta QALY = +0.142$; 5.195 versus 5.053), while maintaining its advantage over the entire period. Despite higher initial costs, a reduction in total expenditures is achieved in the long term (3,706,936 versus 3,941,539 tenge), corresponding to savings of –234.6 thousand tenge per patient.

A negative ICER value and positive net monetary benefit confirm the clinical and economic feasibility of MSU, while the results of sensitivity analysis demonstrate the robustness of these findings. The financial evaluation also showed a positive net present value of the project (NPV = 289.9 million tenge). The study results were discussed with stakeholders; the proposed model, coordinated on the basis of City Clinical Hospital No. 7, has been recommended for consideration by higher healthcare authorities.

Overall, the obtained results confirm the relevance of improving the stroke care system in the city of Almaty and substantiate the feasibility of implementing comprehensive organizational solutions aimed at increasing accessibility, timeliness, and effectiveness of medical care, including the development of the prehospital stage and innovative care models.

Scientific novelty.

- For the first time in the city of Almaty, a comprehensive analysis of the burden of circulatory system diseases and stroke for the period 2012–2024 was carried out, integrating epidemiological indicators of morbidity and mortality, assessment of avoidable mortality, economic burden (based on the value of a statistical life), and clinical outcomes of hospitalized patients with acute cerebrovascular accidents (ACVA).

- It has been substantiated that avoidable mortality from circulatory system diseases (CSD) in Almaty does not follow a stable linear trend; instead, its dynamics are characterized by alternating periods of decline, extreme growth during the COVID-19 pandemic, and subsequent unstable normalization. For the first time, it was shown that the increase in avoidable mortality, both in absolute and relative terms, is predominantly driven by the male population and is mainly associated with ischemic heart disease.

- For the first time at the regional level, a clinical and economic evaluation was conducted, substantiating the feasibility of implementing a mobile stroke unit (MSU) using Markov modeling over a 25-year horizon, demonstrating the dominance of the MSU strategy due to the simultaneous improvement in treatment effectiveness ($\Delta\text{QALY} = +0.142$) and reduction in total discounted costs.

- The comprehensive application of a mixed study design was examined and justified, combining quantitative methods (epidemiological analysis, economic analysis, and modeling) and qualitative methods (interviews with healthcare professionals and patients). This approach made it possible to identify systemic barriers to stroke care at the prehospital, hospital, and post-stroke stages, as well as to substantiate the existence of a gap between improved inpatient outcomes and persistently high incidence rates.

Practical significance of the study

- The obtained results provide an evidence-based foundation for regional policy planning in the field of prevention and treatment of circulatory system diseases (CSD) and stroke, with a focus on the male population and ischemic heart disease as key drivers of avoidable mortality and economic losses.

- The identified absolute and relative changes in avoidable mortality, as well as the pronounced year-to-year variability in the economic burden, can be used by public health authorities to monitor the resilience of the healthcare system and assess its vulnerability to external systemic shocks and crisis situations.

- The identified gaps in the training of emergency medical service and rehabilitation specialists, as well as the low public awareness of stroke symptoms, substantiate the need to develop targeted training programs for healthcare personnel and sustainable public awareness campaigns (FAST), focused on older adults, patients' families, and caregivers.

- The obtained data on patients' perceptions of telerehabilitation and digital technologies can be used in the development and implementation of patient-centered remote rehabilitation models adapted to the level of digital literacy and the needs of

stroke survivors, with the aim of improving accessibility and continuity of post-stroke care.

- The results of clinical and economic modeling and financial evaluation indicate the potential feasibility of pilot implementation of a mobile stroke unit (MSU) in the city of Almaty; the proposed organizational model of patient routing, coordinated on the basis of City Clinical Hospital No. 7, may serve as a foundation for practical implementation of the project and its subsequent scaling.

Conclusions:

1. In 2012–2024, the incidence of circulatory system diseases (CSD) and cerebrovascular diseases (CeVD) in the city of Almaty remained high, with an overall downward trend in mortality characterized by pronounced instability and a sharp increase in 2020–2021, indicating the vulnerability of achieved results to external systemic shocks. Avoidable mortality from CSD in 2014–2024 was also characterized by significant variability and the absence of a stable trend, with persistent gender inequality and unfavorable dynamics driven by an increase in mortality from ischemic heart disease (IHD) against the background of declining mortality from CeVD.

2. The economic assessment revealed significant and unstable economic losses from avoidable mortality (maximum — USD 1,728.77 million in 2021; minimum — USD 193.15 million in 2019), with the majority of the burden attributable to men. At the same time, analysis of hospitalized ACVA cases showed an increase in the number of hospitalizations, a reduction in the length of hospital stay to 8.6–8.7 days, and a substantial improvement in treatment outcomes (a decrease in case fatality to approximately 1% in 2023–2024), indicating progress in inpatient care while the need to strengthen prevention remains. These changes may be partially attributable to the implementation of a standardized ACVA patient management algorithm.

3. The results of interviews with healthcare professionals demonstrated a heterogeneous level of preparedness for providing care to patients with ACVA. Despite the high professional competence of intensivists and neurosurgeons, organizational and resource constraints were identified at the prehospital stage and within the rehabilitation system, including insufficient regularity of training for emergency medical service personnel, staff shortages, and limited involvement in quality monitoring systems. This indicates the presence of structural imbalances in the organization of stroke care.

4. Patient interviews confirmed the presence of significant behavioral and organizational barriers, including low public awareness of stroke symptoms, delayed seeking of medical care, delays at the stage of emergency routing, and isolated cases of limited access to early rehabilitation. These factors reduce the effectiveness of early treatment and highlight the need to strengthen inter-stage coordination and public awareness efforts.

5. The conducted clinical-economic and financial analysis demonstrated that the implementation of a mobile stroke unit (MSU) in acute ischemic stroke provides sustained clinical advantages compared to standard treatment, expressed in an increased proportion of functionally independent patients and improved effectiveness ($\Delta\text{QALY} = +0.142$), along with a reduction in total discounted costs. The financial

model demonstrated a positive net present value of the project and the robustness of results to changes in key parameters, confirming the clinical, economic, and investment feasibility of MSU implementation.

Author's contribution. All stages of the study, including data collection, processing and analysis, interpretation of results, and their discussion, were carried out personally by the author. The author developed a methodological guideline entitled “*Recommendations for Stroke Prevention and Post-Stroke Patient Care*”, which received expert approval from the National Scientific Center for Healthcare Development on February 12, 2026 (No. 610).

Approbation of practical results. The research findings and the main provisions of the dissertation were presented and discussed at an International scientific and practical conference, as well as at the level of the Public Health Department of the city of Almaty.

Publications on the dissertation topic. Based on the dissertation research, 4 publications were produced: 3 articles in journals recommended by the Committee for Control in the Sphere of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, 1 article in a journal indexed in the Scopus database and 1 methodological recommendation.

1. Rauan Kastey, Ermek Dyussebekov, Kuanysh Nikatov, Yevgeniy Zhukov, Arimantas Tamasauskas, Oryngul Jumagazyeva, Madiyar Umirbayev, Kamila Faizullina Avoidable mortality in its economic impact in Almaty city, Kazakhstan. Asian Journal of Social Health and Behavior 8(3):p 141-151, Jul–Sep 2025. | DOI: 10.4103/shb.shb_438_24Scopus – 96 процентиль.

2. Kastey R, Dyussebekov E., Tamasauskas A., Imamatdinova A., Nazarbayev A. Patient-centred perspectives on stroke care: challenges and priorities. Actual Problems of Theoretical and Clinical Medicine. 2025;(3):61-75. <https://doi.org/10.64854/2790-1289-2025-49-3-04>

3. Rauan Kastey, Gulnara Kulkayeva, Ermek Dyussebekov, Kuanysh Nikatov, Arimantas Tamasauskas Stroke care preparedness across medical specialties: Gaps, challenges, and future directions J Health Dev. 2025, 60 (5), jhd021. <https://doi.org/10.32921/2663-1776-2025-60-5-jhd021>

4. Kastey R, Faizullina K., Turganova M., Zhexenova A., Vaičiulis V., Akhtayeva N. S Study of Hospitalized Cases Associated with Acute Cerebrovascular Accidents Nauka i Zdravookhranenie [Science & Healthcare]. 2025. Vol.27 (1), pp. 49-55. doi 10.34689/SH.2024.27.1.006

5. Инсульттің алдын алу және инсульттен кейінгі науқастарға күтім жасау бойынша ұсыныстар: Әдістемелік нұсқау/Қастей Р.М., Жорабек С.Б. - Алматы: ҚазҰМУ, 2026. – 35 б. ISBN 978-601-246-872-4

Structure and scope of the dissertation. The dissertation is presented on 114 pages of typed text and consists of an introduction, literature review, materials and methods, results of the author's own research, conclusion, findings, and practical recommendations. The work is illustrated with 8 figures, 25 tables, and 3 appendices. The bibliography includes 174 sources from domestic and international authors.

Reference:

1. Sacco RL, Kasner SE, Broderick JP, et al. An updated definition of stroke for the 21st century: a statement for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. 2013 Jul;44(7):2064-89. doi: 10.1161/STR.0b013e318296aeca. Epub 2013 May 7. Erratum in: *Stroke*. 2019 Aug;50(8):e239. doi: 10.1161/STR.0000000000000205.
2. Hilkens NA, Casolla B, Leung TW, de Leeuw FE. *Stroke*. *Lancet*. 2024 Jun 29;403(10446):2820-2836. doi: 10.1016/S0140-6736(24)00642-1.
3. Murphy SJ, Werring DJ. *Stroke: causes and clinical features*. *Medicine (Abingdon)*. 2020 Sep;48(9):561-566. doi: 10.1016/j.mpmed.2020.06.002. Epub 2020 Aug 6.
4. Donnan GA, Fisher M, Macleod M, Davis SM (May 2008). "Stroke". *Lancet*. 371 (9624): 1612–23. doi:10.1016/S0140-6736(08)60694-7
5. Feigin VL, Brainin M, Norrving B, Martins SO, Pandian J, Lindsay P, F Grupper M, Rautalin I. World Stroke Organization: Global Stroke Fact Sheet 2025. *Int J Stroke*. 2025 Feb;20(2):132-144. doi: 10.1177/17474930241308142
6. Yahya T, Jilani MH, Khan SU, Mszar R, Hassan SZ, Blaha MJ, Blankstein R, Virani SS, Johansen MC, Vahidy F, Cainzos-Achirica M, Nasir K. Stroke in young adults: Current trends, opportunities for prevention and pathways forward. *Am J Prev Cardiol*. 2020 Sep 9;3:100085. doi: 10.1016/j.ajpc.2020.100085.
7. Sultan S, Elkind MS. The growing problem of stroke among young adults. *Curr Cardiol Rep*. 2013 Dec;15(12):421. doi: 10.1007/s11886-013-0421-z.
8. Stein M., Hamann G.F., Misselwitz B., Uhl E., Kolodziej M., Reinges M.H.T. In-Hospital Mortality and Complication Rates in Surgically and Conservatively Treated Patients with Spontaneous Intracerebral Hemorrhage in Central Europe: A Population-Based Study. *World Neurosurg*. 2016 Apr;88:306-310. doi: 10.1016/j.wneu.2015.11.075.
9. Ekker MS, Verhoeven JI, Vaartjes I, Jolink WMT, Klijn CJM, de Leeuw FE. Association of stroke among adults aged 18 to 49 years with long-term mortality. *JAMA*. 2019;321:2113–2123. doi: 10.1001/jama.2019.6560
10. RTI International. Projections of cardiovascular disease prevalence and costs: 2015–2035. Technical report (report prepared for the American Heart Association). RTI International; November 2016. RTI project No. 021480.003.001.001
11. Soto-Cámara R, González-Bernal J, Aguilar-Parra JM, Trigueros R, López-Liria R, González-Santos J. Factors related to prehospital time in caring for patients with stroke. *Emergencias*. 2021;33:454-463. https://revistaemergencias.org/wp-content/uploads/2023/09/Emergencias-2021_33_6_454-463-463_eng.pdf
12. Jinxiao Dai, Xugang Xi, Ting Wang, Hangcheng Li, Wanzeng Kong, Zhong Lü, EEG signal biometric extraction to predict stroke severity, *Biomedical Signal Processing and Control*, 110, (108037), (2025). <https://doi.org/10.1016/j.bspc.2025.108037>
13. Navi BB, Audebert HJ, Alexandrov AW, Cadilhac DA, Grotta JC; PRESTO (Prehospital Stroke Treatment Organization) Writing Group. Mobile Stroke Units:

Evidence, Gaps, and Next Steps. *Stroke*. 2022;53(6):2103-2113. doi:10.1161/STROKEAHA.121.037376

14. Zhakhina, G., Zhalmagambetov, B., Gusmanov, A. et al. Incidence and mortality rates of strokes in Kazakhstan in 2014–2019. *Sci Rep* 12, 16041 (2022). <https://doi.org/10.1038/s41598-022-20302-8>

15. Кайратова Г.К., Куанышкалиева А.С., Рахметова В.С., Каскабаева А.Ш., Хисметова З.А., Смаилова Д.С. Эпидемиология инсульта в Республике Казахстан // *Наука и Здравоохранение*. 2022. 5(Т.24). С. 105-112. doi 10.34689/SH.2022.24.5.014

16. Makhanbetkhan S, Turdaliyeva B, Sarshayev M, et al. Improving Acute Ischemic Stroke Care in Kazakhstan: Cross-Sectional Survey. *J Clin Med*. 2025;14(7):2336. Published 2025 Mar 28. doi:10.3390/jcm14072336