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Impact of the COVID-19 Pandemic on Inpatient Healthcare Services in Almaty: A Longitudinal Analysis from 2017 to 2025

Maksat Mamyrkul [1], Adlet Nazarbayev [2], Kamilla Faizullina [3], Akmaral Abikulova [4*]

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[1] Assistant Professor at the Department of Health Policy and Management, Kazakh National Medical University named after S.D. Asfendiyarov, Almaty, Kazakhstan. E-mail: maksat333@mail.ru
[2] Associated Professor at the Department of Health Policy and Management, Kazakh National Medical University named after S.D. Asfendiyarov, Almaty, Kazakhstan. E-mail: anazarba@gmail.com
[3] Branch Manager of the National Scientific Center for Healthcare Development named after Salidat Kairbekova, Almaty branch, Almaty, Kazakhstan. E-mail: faizullina.k@kaznmu.kz
[4] Professor at the Department of Health Policy and Management, Kazakh National Medical University named after S.D. Asfendiyarov, Almaty, Kazakhstan. E-mail: abikulova.a@kaznmu.kz

* **Corresponding author**: abikulova.a@kaznmu.kz

Abstract

The COVID-19 pandemic significantly disrupted inpatient healthcare systems worldwide, leading to rapid reorganization of hospital capacity, patient flows, and resource allocation. Urban healthcare systems were particularly affected due to high population density and increased demand for services.

Objective: To assess changes in the performance of inpatient healthcare services in Almaty from 2017 to 2025, with a focus on differences between pre-pandemic, pandemic, and post-pandemic periods.

Methods. A retrospective observational study was conducted using aggregated annual data from inpatient healthcare facilities in Almaty. Key indicators included hospitalizations, bed capacity, average length of stay (ALOS), in-hospital mortality, bed occupancy, workload indicators, patient routing, and quality measures. The study period was divided into three phases: pre-pandemic (2017–2019), pandemic (2020–2022), and post-pandemic (2023–2025). Descriptive statistics, one-way ANOVA, and linear regression analysis were applied to assess temporal trends and differences between periods.

Results. Hospitalizations increased by approximately 33% from the pre-pandemic to post-pandemic period. Bed capacity expanded during the pandemic and remained elevated thereafter. ALOS decreased over time, indicating improved efficiency. In-hospital mortality increased during the pandemic and declined below pre-pandemic levels in the post-pandemic period. Bed occupancy showed a temporary decline followed by recovery. The pandemic led to a substantial redistribution of bed capacity, with a marked increase in infectious beds. Hospital workload increased significantly, while patient routing shifted toward outpatient referrals. Complication rates declined consistently, indicating improvements in quality of care.

Conclusions. The COVID-19 pandemic acted as a catalyst for structural transformation of inpatient healthcare services in Almaty. The post-pandemic period was characterized by recovery, improved efficiency, and enhanced quality of care. These findings highlight the importance of strengthening health system resilience and optimizing resource allocation to sustain long-term improvements.

Keywords: COVID-19, inpatient care, hospital performance, Kazakhstan.

1. Introduction

The COVID-19 pandemic has profoundly disrupted healthcare systems worldwide, placing unprecedented pressure on inpatient services and necessitating rapid organizational and structural changes. Hospitals were required to expand capacity, reallocate resources, and adapt clinical pathways in response to surges in demand. These challenges highlighted both the vulnerabilities and adaptive capacities of healthcare systems [1-3].

Globally, the pandemic led to a substantial reorganization of inpatient care. Many countries reported increases in infectious and intensive care capacity alongside reductions in elective hospitalizations. At the same time, healthcare utilization patterns shifted, with declines in non-COVID admissions during early pandemic phases followed by a rebound due to accumulated unmet needs [4-6]. These changes were accompanied by fluctuations in key performance indicators, including mortality, length of stay, and bed occupancy [7-10].

At the city level, large urban centers were particularly affected due to high population density and concentration of healthcare facilities [11]. Almaty, as the largest metropolitan city in Kazakhstan, experienced a significant burden on inpatient services during the COVID-19 pandemic. The city played a central role in managing patient flows, including both COVID-19 and non-COVID cases, requiring rapid expansion of infectious beds, reorganization of hospital networks, and redistribution of healthcare resources.

Local data indicate that during peak pandemic periods, healthcare facilities in Almaty underwent a substantial restructuring, including the conversion of general hospital beds into infectious units and increased demand for intensive care services. These changes were accompanied by shifts in patient routing, temporary reductions in planned hospitalizations, and increased workload for medical personnel. Understanding the dynamics of inpatient care at the city level is essential, as urban healthcare systems often serve as focal points during public health emergencies. However, despite the importance of city-level analyses, there is a lack of comprehensive longitudinal studies examining the impact of the COVID-19 pandemic on inpatient healthcare performance in Almaty across pre-pandemic, pandemic, and post-pandemic periods.

The aim of this study was to assess changes in the performance of inpatient healthcare services in Almaty from 2017 to 2025, with a focus on differences between pre-pandemic, pandemic, and post-pandemic periods. The study evaluates trends in hospital activity, bed capacity, workload, patient routing, resource availability, and quality indicators, as well as the impact of COVID-19 on these parameters.

2. Materials and methods

Study design and data sources: This study is a retrospective observational analysis based on aggregated annual data obtained from the National Scientific Center for Healthcare Development (Almaty branch) of the Republic of Kazakhstan. The dataset includes official statistical indicators of inpatient healthcare facilities for the period from 2017 to 2025. The data were collected as part of routine national health system monitoring and reporting. The study covers key indicators of hospital activity, including hospitalizations, bed capacity, average length of stay, in-hospital mortality, bed occupancy, workload indicators, patient routing, staffing levels, and COVID-19-specific parameters.

Study period and grouping: To assess the impact of the COVID-19 pandemic, the study period was divided into three analytical phases:

Pre-pandemic period: 2017–2019

Pandemic period: 2020–2022

Post-pandemic period: 2023–2025

This classification was used to evaluate structural and functional changes in inpatient care delivery across different stages of the pandemic.

Variables and definitions: The following indicators were analyzed: Hospitalizations — total number of inpatient admissions per year; Bed capacity — total number of hospital beds; Average length of stay (ALOS) — mean duration of hospitalization (days); In-hospital mortality - percentage of deaths among hospitalized patients; Bed occupancy rate — percentage of bed utilization; Bed turnover — number of treated patients per bed per year; Average daily number of patients — mean inpatient census; Patient routing - distribution of admission sources (emergency, self-referral, outpatient referral, transfers); Staffing levels - number of physicians and nursing personnel; COVID-19 indicators — number and proportion of COVID-19 hospitalizations and associated mortality

Bed occupancy rate was calculated as:

BOR = (Total inpatient days / (Bed capacity × 365)) × 100%

Bed turnover was defined as:

BT = Number of discharges / Average number of beds

Statistical analysis: Descriptive statistics were used to summarize the data, including mean values for each study period. To compare differences between periods, one-way analysis of variance (ANOVA) was applied for continuous variables.

In addition, linear regression analysis was performed to assess temporal trends and the impact of the pandemic. The model included time (year), a binary

variable representing the pandemic period (2020–2022), and a post-pandemic indicator (2023–2025):

$Y_t = \beta 0 + \beta 1\ Time + \beta 2\ Pandemic + \beta 3\ Post + \varepsilon$

Where:

Y_t — outcome variable,

Time - continuous variable (year),

Pandemic - binary variable (1 for 2020–2022, 0 otherwise),

Post — binary variable (1 for 2023–2025, 0 otherwise),

ε — error term.

Regression coefficients (β), 95% confidence intervals (CI), and p-values were calculated. A p-value < 0.05 was considered statistically significant.

All analyzes were conducted using standard statistical approaches for longitudinal aggregated health system data.

The study was conducted in accordance with the fundamental ethical principles. Ethical approval was obtained from the Local Ethics Committee (Protocol No. 14 (120), dated 28 October 2021).

3. Results

Changes in hospital activity and efficiency. A significant increase in hospital activity was observed across the study period. Hospitalizations increased by 33.3% from the pre-pandemic to the post-pandemic period (p<0.01). Bed capacity expanded substantially during the pandemic and remained elevated afterward. Average length of stay (ALOS) decreased significantly (− 6.8%, p<0.05), indicating improved efficiency. In-hospital mortality increased during the pandemic but decreased significantly in the post-pandemic period (p<0.01). Bed occupancy showed a temporary decrease during the pandemic, followed by recovery (Table 1).

Table 1 - Hospital activity and efficiency indicators across study periods

Indicator	Pre-pandemic	Pandemic	Post-pandemic	% change	p-value	95% CI
Hospitalizations	311,036	375,032	414,483	+33,3%	<0,01	1,22–1,44
Bed capacity	8,914	11,043	11,452	+28,5%	<0,01	1,18–1,39
ALOS (days)	8,87	8,33	8,27	−6,8%	<0,05	0,89–0,98
Mortality (%)	0,93	1,43	0,80	−14,0%	<0,01	0,72–0,91
Bed occupancy (%)	96,9	83,7	96,2	−0,7%	0,21	0,95–1,02

Structural transformation of bed capacity. The pandemic resulted in a major redistribution of bed types. Infectious beds increased nearly threefold during the pandemic (p<0.001), followed by partial normalization. Therapeutic beds declined significantly (p<0.01), while surgical beds demonstrated sustained growth across all periods (p<0.01). These changes indicate long-term structural transformation of inpatient care (Table 2).

Table 2 - Structural changes in bed capacity

Bed type	Pre-pandemic	Pandemic	Post-pandemic	% change	p-value	95% CI
Infectious	513	1,763	1,015	98%	<0,001	1,65–2,31
Therapeutic	3,743	2,171	2,308	−38%	<0,01	0,52–0,71
Surgical	3,841	6,283	6,482	69%	<0,01	1,41–1,82
Other	223	170	227	+1,8%	0,64	0,91–1,12

Workload, patient routing, and quality of care. Hospital workload increased significantly, with daily patient volume rising by over 30% (p<0.01). Bed turnover improved in the post-pandemic period (p<0.05), reflecting increased efficiency. A shift toward planned care was observed: outpatient referrals increased significantly (p<0.01), while emergency admissions decreased (p<0.05). Quality of care improved, with complication rates decreasing significantly across periods (p<0.01) (Table 3).

Regression analysis demonstrated a significant upward trend in hospitalizations over time (β=+18,500 per year, p<0.01). The pandemic period was associated with a significant increase in in-hospital mortality (β=+0.42, p<0.01), whereas the post-pandemic period showed a significant reduction (β=−0.35, p<0.01).

Table 3 - Hospital workload and efficiency indicators

Indicator	Pre-pandemic	Pandemic	Post-pandemic	% change	p-value	95% CI
Daily patients	854	1,031	1,141	+33,6%	<0,01	1,24–1,45
Bed turnover	35,0	34,9	36,3	+3,7%	<0,05	1,01–1,08
Emergency (%)	32,5	30,4	29,3	−3,2	<0,05	0,89–0,98
Self-referral (%)	20,6	18,3	22,0	+1,4	0,08	0,97–1,09
Outpatient (%)	28,9	34,1	35,9	+7,0	<0,01	1,12–1,26
Transfers (%)	13,0	12,4	09,2	−3,8	<0,05	0,72–0,91
Complications (%)	0,28	0,15	0,11	−60,7%	<0,01	0,31–0,68

A decreasing trend in average length of stay was also observed (β=−0.08 per year, p<0.05), indicating improved efficiency of inpatient care. ANOVA results confirmed statistically significant differences between periods for key indicators, including hospitalizations, bed capacity, and complication rates (p<0.01) (Table 4).

Table 4 - Linear regression analysis of key indicators

Outcome variable	β (Time)	β (Pandemic)	β (Post-pandemic)	95% CI	p-value
Hospitalizations	18,5	42	25	12,000 to 29,000	<0.01
Bed capacity	520	2,1	900	300 to 1,800	<0.01
Mortality (%)	+0.02	+0.42	−0.35	−0.48 to −0.12	<0.01
ALOS (days)	−0.08	−0.25	−0.30	−0.45 to −0.05	<0.05
Daily patients	52	210	110	40 to 180	<0.01
Complications (%)	−0.03	−0.10	−0.12	−0.18 to −0.04	<0.01

4. Discussion

This study provides a comprehensive assessment of inpatient healthcare transformation in Kazakhstan over a nine-year period, highlighting the substantial impact of the COVID-19 pandemic and the subsequent recovery phase.

The findings demonstrate a significant increase in hospital activity, with hospitalizations rising by more than 30% from the pre-pandemic to post-pandemic period. This trend is consistent with national reports from Kazakhstan, which indicate a recovery and expansion of inpatient services following pandemic-related disruptions. According to national health statistics, healthcare utilization declined during the early pandemic period and rebounded thereafter, reflecting deferred demand and restoration of planned care [12].

Globally, similar patterns have been observed. A systematic review by Moynihan et al. reported a substantial reduction in healthcare utilization during the pandemic, followed by a compensatory increase [7]. These findings align with the trends identified in Kazakhstan.

A key finding of this study is the structural transformation of bed capacity. In Kazakhstan, the rapid expansion of infectious disease beds during 2020–2021 was a central component of the national response to COVID-19 [13]. The present analysis demonstrates that although the number of infectious disease beds decreased after the pandemic, it remained higher than pre-pandemic levels, suggesting long-term structural adaptation.

This pattern is consistent with international experience. Countries such as Italy and the United States rapidly increased intensive and infectious care capacity during peak pandemic periods [14-19]. However, the persistence of expanded capacity in Kazakhstan may indicate a strategic shift toward improved preparedness for future public health emergencies.

The observed reduction in average length of stay (ALOS) reflects improvements in hospital efficiency. In Kazakhstan, national healthcare reforms, including the development of day-care services and clinical protocols, have contributed to reducing inpatient duration [12]. Similar trends have been reported internationally, where hospitals adopted more efficient care pathways during and after the pandemic [20-22].

Mortality trends observed in this study are also consistent with both national and global data. In Kazakhstan, excess increased mortality during the pandemic, particularly in 2020–2021, due to both direct and indirect effects of COVID-19 [12,13]. The subsequent decline in mortality below pre-pandemic levels may reflect improvements in clinical management, vaccination coverage, and system recovery.

Changes in patient routing patterns in Kazakhstan indicate a shift toward more structured and planned care. The increase in outpatient referrals suggests strengthening of primary healthcare and referral systems, which has been a key priority of national health policy [23,24]. Internationally, similar shifts have been associated with efforts to reduce unnecessary hospital admissions and improve care coordination [25-27].

The increase in hospital workload and daily patient volume reflects sustained pressure on inpatient services. In Kazakhstan, this may be linked to both demographic factors and the backlog of postponed care. At the same time, improvements in bed turnover and reductions in complexity rates suggest enhanced efficiency and quality of care delivery.

Workforce dynamics observed in this study mirror national trends. Kazakhstan implemented rapid workforce mobilization during the pandemic, including temporary staff expansion and redeployment [12,13,23,24]. However, as in many countries, post-pandemic stabilization has been accompanied by workforce challenges, including retention and burnout [28,29].

Importantly, the consistent decrease in complication rates indicates improved quality of care. This may be associated with the implementation of standardized clinical protocols, increased training, and digitalization of healthcare processes in Kazakhstan during recent years.

This study has several limitations. First, the use of aggregated national data limits the ability to perform more granular analyzes and may mask regional variability within Kazakhstan. Second, the relatively small number of observations restricts the statistical power of inferential methods. Third, the findings may not fully capture the heterogeneity of healthcare delivery across different regions and facility types.

Despite these limitations, the study provides important insights into the resilience and adaptability of Kazakhstan's healthcare system. The results suggest that the COVID-19 pandemic acted as a catalyst for structural transformation, accelerating reforms that have persisted into the post-pandemic period.

Future research should focus on regional analyses, patient-level data, and long-term outcomes to better understand the sustainability and impact of these changes on population health in Kazakhstan.

Strengths and Limitations: This study has several important strengths. First, it is based on nationwide data from Kazakhstan, covering a nine-year period and capturing pre-pandemic, pandemic, and post-pandemic phases. This allows for a comprehensive longitudinal assessment of healthcare system transformation. Second, the study integrates multiple dimensions of inpatient care, including hospital activity, bed capacity, workload, patient routing, staffing, and quality indicators. Such a multidimensional approach provides a holistic understanding of system performance. Third, the application of both descriptive and inferential statistical methods, including ANOVA and regression analysis, enhances the robustness of the findings and allows for the identification of temporal trends and pandemic-related effects.

However, *several limitations* should be considered. The study is based on aggregated annual data, which limits the ability to perform more detailed patient-level analyzes and may mask intra-year variability. In addition, the relatively small number of observations (nine time points) restricts the statistical power of inferential analyzes and may affect the precision of regression estimates. Furthermore, the use of national-level data does not capture regional heterogeneity in healthcare delivery across Kazakhstan, which may be substantial differences in infrastructure and resource availability. Finally, some variables (e.g., ICU utilization, waiting times, and detailed COVID-19 severity indicators) were not available, limiting the depth of analysis for certain aspects of healthcare performance.

Despite these limitations, the study provides valuable insights into the structural and functional transformation of inpatient care at the national level.

5. Conclusions

The COVID-19 pandemic significantly reshaped inpatient healthcare services in Kazakhstan, leading to increased demand, structural reconfiguration of bed capacity, and temporary deterioration in key

performance indicators. In the post-pandemic period, the healthcare system demonstrated recovery and improved efficiency, with reduced length of stay, stabilized bed occupancy, and enhanced quality of care. These findings suggest that the pandemic acted as a catalyst for lasting system transformation. Future efforts should focus on strengthening health system resilience, optimizing resource allocation, and expanding the role of primary and outpatient care to reduce inpatient burden. Further research is needed to evaluate long-term outcomes and ensure the sustainability of these changes.

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All authors have read and approved the final version of the manuscript and agree to its publication.

AI Declaration. The authors declare that AI was not used in the preparation of this manuscript.

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COVID-19 пандемиясының Алматы қаласындағы стационарлық медициналық қызметтерге әсері: 2017–2025 жылдар аралығындағы бойлық талдау

Мамыркул М. [1], Назарбаев А. [2], Файзуллина К. [3], Абикулова А. [4*]

[1] Денсаулық сақтау саясаты және менеджменті кафедрасының ассистент-профессоры, С.Д. Асфендияров атындағы Қазақ ұлттық медицина университеті, Алматы, Қазақстан. E-mail: maksat333@mail.ru

[2] Денсаулық сақтау саясаты және менеджменті кафедрасының ассистент-профессоры, С.Д. Асфендияров атындағы Қазақ ұлттық медицина университеті, Алматы, Қазақстан. E-mail: anazarba@gmail.com

[3] Алматы филиалының басшысы, Салидат Қайырбекова атындағы Ұлттық денсаулық сақтауды дамыту ғылыми орталығы, Алматы, Қазақстан. E-mail: faizullina.k@kaznmu.kz

[4] Денсаулық сақтау саясаты және менеджменті кафедрасының профессоры, С.Д. Асфендияров атындағы Қазақ ұлттық медицина университеті, Алматы, Қазақстан. E-mail: abikulova.a@kaznmu.kz

Түйіндеме

COVID-19 пандемиясы бүкіл әлем бойынша стационарлық денсаулық сақтау жүйелерінің жұмысына елеулі әсер етіп, төсек қорының, науқас ағындарының және ресурстарды бөлудің жедел қайта ұйымдастырылуына әкелді. Халық тығыздығының жоғары болуы мен медициналық қызметтерге сұраныстың артуына байланысты қалалық денсаулық сақтау жүйелері ерекше зардап шекті.

Зерттеудің мақсаты: 2017–2025 жылдар аралығында Алматы қаласындағы стационарлық медициналық көмектің қызмет көрсету көрсеткіштеріндегі өзгерістерді бағалау, пандемия алды, пандемиялық және пандемиядан кейінгі кезеңдер арасындағы айырмашылықтарға ерекше назар аудара отырып.

Әдістері. Алматы қаласындағы стационарлық медициналық ұйымдардың жинақталған жылдық деректері негізінде ретроспективті бақылаулық зерттеу жүргізілді. Негізгі көрсеткіштер ретінде госпитализация саны, төсек қоры, орташа жату ұзақтығы, стационар ішіндегі өлім-жітім, төсекпен қамтылу деңгейі, жүктеме көрсеткіштері, науқастарды маршруттау және медициналық көмектің сапа көрсеткіштері қарастырылды. Зерттеу кезеңі үш кезеңге бөлінді: пандемия алды (2017–2019 жж.), пандемиялық (2020–2022 жж.) және пандемиядан кейінгі (2023–2025 жж.). Уақыттық үрдістер мен кезеңдер арасындағы айырмашылықтарды бағалау үшін сипаттамалық статистика, бір факторлы дисперсиялық талдау (ANOVA) және сызықтық регрессия қолданылды.

Нәтижелері. Госпитализация саны пандемия алды кезеңмен салыстырғанда пандемиядан кейінгі кезеңде шамамен 33%-ға артты. Төсек қоры пандемия кезінде ұлғайып, кейін де жоғары деңгейде сақталды. Орташа жату ұзақтығының қысқаруы тиімділіктің артқанын көрсетеді. Стационар ішіндегі өлім-жітім пандемия кезінде өсіп, пандемиядан кейінгі кезеңде пандемия алды деңгейден төмендеді. Төсекпен қамтылу көрсеткіші уақытша төмендеп, кейін қайта қалпына келді. Пандемия төсек қорының айтарлықтай қайта бөлінуіне әкелді, соның ішінде инфекциялық төсек саны айқын артты. Стационарларға түсетін жүктеме едәуір өсті, ал науқастарды маршруттау амбулаториялық бағытқа ауысты. Асқынулар жиілігінің тұрақты төмендеуі медициналық көмектің сапасының жақсарғанын көрсетеді.

Қорытынды. COVID-19 пандемиясы Алматы қаласындағы стационарлық медициналық көмектің құрылымдық трансформациясының катализаторы болды. Пандемиядан кейінгі кезең қалпына келумен, тиімділіктің артуымен және медициналық көмектің сапасының жақсаруымен сипатталады. Бұл нәтижелер денсаулық сақтау жүйесінің тұрақтылығын нығайтудың және ресурстарды оңтайлы бөлудің маңыздылығын көрсетеді.

Түйін сөздер: COVID-19, стационарлық көмек, аурухана қызметі, Қазақстан.

Влияние пандемии COVID-19 на стационарную медицинскую помощь в Алматы: Продольный анализ за 2017–2025 годы

Мамыркул М. [1], Назарбаев А. [2], Файзуллина К. [3], Абикулова А. [4*]

[1] Ассистент профессора кафедры политики и менеджмента здравоохранения, Казахский национальный медицинский университет имени С.Д. Асфендиярова, Алматы, Казахстан. E-mail: maksat333@mail.ru

[2] Ассистент профессора кафедры политики и менеджмента здравоохранения, Казахский национальный медицинский университет имени С.Д. Асфендиярова, Алматы, Казахстан. E-mail: anazarba@gmail.com

[3] Руководитель Алматинского филиала, Национальный научный центр развития здравоохранения имени Салидат Каирбековой, Алматы, Казахстан. E-mail: faizullina.k@kaznmu.kz

[4] Профессор кафедры политики и менеджмента здравоохранения, Казахский национальный медицинский университет имени С.Д. Асфендиярова, Алматы, Казахстан. E-mail: abikulova.a@kaznmu.kz

Резюме

Пандемия COVID-19 существенно нарушила функционирование стационарных систем здравоохранения во всем мире, приведя к быстрой реорганизации коечного фонда, потоков пациентов и распределения ресурсов. Городские системы здравоохранения пострадали в наибольшей степени из-за высокой плотности населения и повышенного спроса на медицинские услуги.

Цель исследования: оценить изменения в показателях функционирования стационарной медицинской помощи в Алматы в период с 2017 по 2025 годы с акцентом на различия между допандемийным, пандемийным и постпандемийным периодами.

Методы. Проведено ретроспективное наблюдательное исследование с использованием агрегированных годовых данных стационарных медицинских организаций города Алматы. Анализ включал ключевые показатели: число госпитализаций, коечный фонд, среднюю длительность пребывания, внутрибольничную летальность, занятость коек, показатели нагрузки, маршрутизацию пациентов и показатели качества медицинской помощи. Период исследования был разделен на три этапа: допандемийный (2017–2019 гг.), пандемийный (2020–2022 гг.) и постпандемийный (2023–2025 гг.). Для анализа временных тенденций и различий между периодами применялись описательная статистика, однофакторный дисперсионный анализ (ANOVA) и линейная регрессия.

Результаты. Количество госпитализаций увеличилось примерно на 33% от допандемийного к постпандемийному периоду. Коечный фонд был расширен в период пандемии и сохранился на повышенном уровне после ее завершения. Средняя длительность пребывания сократилась, что свидетельствует о повышении эффективности. Внутрибольничная летальность увеличилась в период пандемии, однако в постпандемийный период снизилась до уровня ниже допандемийного. Занятость коек временно снизилась с последующим восстановлением. Пандемия привела к значительному перераспределению коечного фонда, включая выраженное увеличение инфекционных коек. Нагрузка на стационары существенно возросла, при этом маршрутизация пациентов сместилась в сторону амбулаторных направлений. Частота осложнений последовательно снижалась, что указывает на улучшение качества медицинской помощи.

Выводы. Пандемия COVID-19 выступила катализатором структурных преобразований стационарной медицинской помощи в Алматы. Постпандемийный период характеризуется восстановлением, повышением эффективности и улучшением качества медицинской помощи. Полученные результаты подчеркивают важность укрепления устойчивости системы здравоохранения и оптимизации распределения ресурсов для поддержания долгосрочных улучшений.

Ключевые слова: COVID-19, стационарная помощь, деятельность больниц, Казахстан.

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