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Scientific-medical educational cluster as a tool for addressing strategic objectives in public health and healthcare organization at the regional level

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Abstract

The current stage of technological evolution in healthcare is characterized by the synergy of biomedical sciences and digital technologies, shaping a new paradigm of evidence-based medicine. Generative artificial intelligence (GenAI), with its potential to process heterogeneous data and generate predictive models, is a key driver for the personalization of medical services. This study conducted a multi-level analysis of the institutional and technological aspects of developing a scientific and medical cluster. A scientific-medical educational cluster (SMEC) represents a promising organizational and economic model aimed at consolidating the resources of science, education, practical healthcare, and business to achieve strategic public health goals.

Aim: to study modern approaches to the development of scientific-medical educational clusters as a tool for addressing strategic objectives of public health and healthcare organization on the regional level.

Material and methods. The study utilized a systems approach, a content analysis method for research data on the issue, and an analytical method for assessing the effectiveness of the cluster model in the context of Russian regions.

Results. Key systemic limitations were identified: fragmented management, shortage of personnel and management competencies, and insufficient focus of scientific research on public health priorities. The challenges of forming scientific and medical educational clusters in the current context and ways to address them were identified.

Conclusion. Organization of scientific-medical clusters is a key factor in the development of an innovative healthcare ecosystem, ensuring the integration of academic science, educational institutions, the business sector, and government regulation. Key factors for the success of scientific and medical educational clusters in the region include the leading role of the healthcare authority in coordinating all cluster participants; focus on public health priorities determined based on epidemiological analysis and monitoring data; integration of educational programs in artificial intelligence management and healthcare economics into cluster activities to train personnel capable of working in an interdisciplinary environment; investments in innovations with achievable medical, demographic and economic indicators.

Keywords: scientific-medical cluster, healthcare management.
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Научно-медицинский образовательный кластер как инструмент решения стратегических задач в области охраны общественного здоровья и организации здравоохранения в регионе

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Аннотация

Современный этап технологической эволюции в здравоохранении характеризуется синергией медико-биологических наук и цифровых технологий, формирующей новую парадигму доказательной медицины. Генеративный искусственный интеллект (генИИ), обладающий потенциалом обработки гетерогенных данных и генерации предиктивных моделей, выступает ключевым драйвером персонализации медицинских услуг. В рамках данного исследования проведен многоуровневый анализ институциональных и технологических аспектов формирования научно-медицинского кластера. Научно-медицинский образовательный кластер (НМОК) представляет собой перспективную организационно-экономическую модель, направленную на консолидацию ресурсов науки, образования, практического здравоохранения и бизнеса для достижения стратегических целей в области общественного здоровья.

Цель: изучить современные подходы к формированию научно-медицинских образовательных кластеров как инструмента решения стратегических задач в области охраны общественного здоровья и организации здравоохранения в регионе.

Материал и методы. В исследовании применены системный подход, метод контент-анализа данных научных исследований по проблеме, аналитический метод для оценки эффективности кластерной модели в условиях российских регионов.

Результаты. Выявлены ключевые системные ограничения: фрагментарность управления, дефицит кадров, управленческих компетенций и недостаточная ориентация научных разработок на приоритеты общественного здоровья. Определены проблемы формировании научно-медицинских образовательных кластеров в современных условиях и путей их решения.

Заключение. Формирование научно-медицинских кластеров выступает ключевым фактором развития инновационной экосистемы здравоохранения, обеспечивающей интеграцию академической науки, образовательных институтов, предпринимательского сектора и государственного регулирования. Ключевыми условиями успешности НМОК в регионе являются такие показатели, как лидирующая роль органа управления здравоохранением в координации всех участников кластера; ориентация на приоритеты общественного здоровья, определяемые на основе эпидемиологического анализа и данных мониторингов; интеграция образовательных программ в сфере управления искусственным интеллектом и экономики здравоохранения в деятельность кластера для подготовки кадров, способных работать в междисциплинарной среде; инвестиции в инновации с достигаемыми медико-демографическими и экономическими показателями.

Ключевые слова: научно-медицинский кластер, управление здравоохранением.

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Список сокращений
НМОК – научно-медицинский образовательный кластер;
ИИ – искусственный интеллект.

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INTRODUCTION

Modern technology plays a key role in the development and enhancement of competitive capacity of countries on the international arena. The Russian Federation independently shapes the technological policy by continuously improving its effort in the sphere of science and innovation, by controlling the critically important technology ensuring their stability and independent development. It is worthwhile analyzing the country's internal approaches to identify the priorities of development in the sphere of technology via integration of science, education and technology [1, 2].

Medicine is one of the dynamically developing areas of science and practice. Innovative approaches towards diagnostics, treatment and prevention of diseases necessitate

continuous updating of knowledge and technology. At the same time, successful implementation of scientific ideas is impossible without the joint effort of scientists, doctors, entrepreneurs and state structures. Development of modern medicine calls for a comprehensive approach comprising close cooperation between the scientific, medical, educational, commercial and state public institutions. In the context of the global technological race, formation of scientific medical clusters becomes a strategic priority to ensure competitive capacity of the nation [3, 4].

According to the "Triple Helix" theory of H. Etzkowitz (2017), an innovative ecosystem emerges at the intersection of interests of three stakeholders: the academic institutions, the business and the state; each of them having its specific features. However, they all are interconnected and are indispensable for the national sovereignty. At present, the Triple Helix model gains more importance in the light of implementation of "Healthcare" and "Science" national projects, both focusing on the development of critical technologies [5].

The scientific, educational and technological components in the sphere of healthcare promote the formation of a specific scientific and technological environment, the scientific and medical educational cluster (SMEC). Studies show that the medical industry has a multiplicative effect: every Ruble invested in the healthcare generates up to three Rubles of added value via creation of jobs, development of related industries improvement of quality of human capital. At the same time, some researchers note an imbalance between the scientific potential and commercialization of research: only 12% of medical patents are implemented in clinical practice [6, 7].

The formation of the SMEC is an effective tool to achieve sustainable growth and improved competitive capacity of regions. This opportunity allows for integration of resources and competences of all stakeholders by creating conditions to scale scientific achievements and implementation of advanced technologies in the daily medical practice [8, 9].

Development of artificial intelligence (AI) technologies has transformed approaches to the interaction between the doctor and the patient making remote follow-up, automated data processing and creation of new decision-making support tools possible. The major contribution of AI lies in its capacity of processing heterogeneous medical data creating substantially new possibilities to customize medical assistance. The rapid development of AI and the specifics of management in the medical sphere necessitate AI product developers and medical institutions to cooperate within the cluster in order to focus on specific areas of medicine and to select those AI products that meet their business model, have potential for further commercialization and can be smoothly and organically implemented in the regional healthcare systems. It is obvious therefore that some of the most important characteristics of a modern SMEC include its digital infrastructure [10–12].

AIM

To study modern approaches to the development of scientific-medical educational clusters as a tool for addressing strategic objectives of public health and healthcare organization on the regional level.

MATERIAL AND METHODS

The materials were scientific publications on the country's SMEC over the past ten years.

The study utilized a content analysis and generalized the literature data to assess the potential effect of clustering on the key indicators of people's health and efficiency of resource use considering the results of analysis of opinions on the work of scientific and medical educational clusters from heads of medical organizations, representatives of executive authorities and profile departments in regional healthcare structures.

The analytical method was used to study the successful practices of integration of structural components of science, education and medicine into clusters, specifically, the project "Smart platform of cardiovascular pathology diagnostics" (Oryol), that allowed for appraisal of the effect for the healthcare system, viz. reduction of diagnostic time and reduction of load on X-ray specialists, and results of the "MedBioTech" acceleration program.

The system analysis and the method of organizational modeling was used for the structural and functional characteristics of the cluster, its participants, and for the identification of methods of solving the problems related to scientific and medical clusters from the perspective of healthcare management in the regions.

RESULTS

In the course of the study, the modern SMEC was defined as a system of related organizations and institutions united with a single goal of promoting medical innovations and improvement of efficiency of provision of medical services [3].

The major components of the cluster are institutions of higher medical and pharmaceutical education, research institutes and laboratories, clinical hospitals and specialized medical organizations, pharmaceutical and medical device manufacturing companies, and state structures regulating the industry and supporting the financing programs [8, 13].

The advantages of SMEC organization include improved performance and reduced cost of research, improved availability of high-quality medical services for the population, stimulation of technological progress and development of new approached towards disease diagnostics and treatment, improvement of regional economic activity by increase of number of jobs and amount of tax revenue.

In the modern conditions, medical clusters also have some fundamental specific features related to additional sources of external financing, lack of fixed linkage to geographical location of stakeholders, importance of implementation of modern information and computer technologies, as well as different approaches to administration of emergency and planned medical intervention [14].

Cluster approach in the knowledge-based economy became one of the driving forces in the strategies of social and economic development of Russia, which lead to state that the cluster approach is actively used in education [15].

At the same time, there are some barriers that preclude active formation of a full-scale scientific and medical cluster: insufficient coordination of actions between representatives of

Strengths	Weaknesses
Availability of scientific research projects with patents in the sphere of biotechnologies. Support of state digital programs.	Low investment activity (below 5% of the gross regional product). Outflow of young specialists (approx. 12% over five years).
Opportunities	**Threats**
Participation in federal grants (national projects). Partnership with JSC "Aviaavtomatika" (transfer of technology).	Competition with Moscow clusters. Sanctions restricting equipment export.

Table 1. *SWOT analysis of the medical cluster potential in the Oryol region*
Таблица 1. *SWOT-анализ потенциала медицинского кластера Орловской области*

different structures; limited financial resources to implement ambitious projects; insufficient motivation of commercial companies to invest in long-term projects; low level of public awareness of the existing initiatives and prospects of cluster development [16, 17].

We performed a SWOT-analysis of the potential of the medical cluster and considered its strengths, weaknesses, opportunities and threats using the example of the Oryol Region (**Table 1**) [18].

The SWOT-analysis of the potential of the Oryol Region revealed that the key threats are not just the sanctions but rather the internal organizational barriers, namely low investment activity, outflow of workforce and weak coordination of efforts.

It is worthwhile mentioning some economic effects of clusterization. Implementation of an AI diagnostic platform in 12 medical institutions of the region (2022-2023) resulted in reduced time of processing of CT scans by 40%; reduced expenditure on repeated examinations by 18 million Rubles per year; increased patient satisfaction up to 89% in 2023 (vs. 67% in 2021). According to the forecast of the cluster multiplicative effect, by the year 2030, additional 1200 jobs will be created and the tax revenue will increase by 2.3 billion Rubles.

Organization of scientific and medical clusters is an important element of innovative development of the Oryol Region, but this process involves some administrative obstacles and institutional complications.

DISCUSSION

Organization of the scientific and medical cluster is a vital factor of innovative development of the region. Thanks to the consolidated effort of all stakeholders, it is possible to achieve a qualitatively new level of provision of medical services, enhancement of investment attractiveness of the region and strengthening of positions of Russian manufacturers of drugs and medical equipment. Successful implementation of these tasks will necessitate energetic interaction between all stakeholders of the process, and consistent implementation of proposals and recommendations.

Having analyzed the existing experience, we identified some challenges in the organization of scientific and medical educational clusters and methods of their resolution (**Table 2**).

To address these challenges, it is necessary to create effective mechanisms of interaction between all participants of the process. These mechanisms include the following components: organization of a coordination council for regular discussions of issues of interaction and development of a reconciled strategy; financial support, i.e. raising of grants and focused financing to implement significant projects; informational openness, or transparency in the questions of resource distribution and promotion of successful practices; preparation of workforce reserve – development of special training and internship programs for aspiring specialists; use of AI technologies that improve training outcomes by creating a personalized, immersive and interactive environment and support clinical

Challenge	Core	Methods of resolution
High initial expenditure	Deployment of SMEC infrastructure requires substantial financial investment. Construction of laboratories, medical institutions, procurement of equipment and modern jobs require investment of capital. Without state support and raising of private investment, such projects render economically unviable.	Public-private partnership (PPP), raising of grants and subsidies from federal and regional authorities, use of tax incentives and preferences for investors.
Underqualified workforce	Scientific and medical centers require highly qualified specialists including doctors, researchers and engineers. Understaffing in Russian regions is a serious problem related to low standard of living, lack of social conditions and low salaries.	Creation of attractive working conditions, increased salaries, development of educational programs to train specialists in the local higher educational institutions, relocation and adaptation programs for new employees.
Limited access to financing of scientific research	Financing of scientific projects largely depends on state grants and contracts that are distributed in a centralized fashion. Regional scientific institutions face limited access to such resources, especially in the conditions of competition with large federal scientific centers.	Forming of a regional scientific policy aimed to support local initiatives, development of mechanisms of targeted financing of prospective areas of science and medicine.
Underdeveloped technological chains	Successful performance of SMECs required close links between the science, education and industry. Lack of established technological chains complicates implementation of research achievements into practice and decreases competitive capacity of products and services.	Development of cooperation between universities, research institutions and industry, support of startups and innovative companies, organization of specialized technoparks and business incubators.
Problems of interaction between business and science	Private investors and entrepreneurs are often under-informed about the prospects of cooperation with the scientific community. Low level of trust and lack of experience of management of joint projects also preclude effective interaction.	Organization of conferences, workshops and forums focusing on making contacts between the science and the business; organization of special agencies and foundations assisting development of mutually beneficial relations.

Table 2. *Ways to solve problems related to scientific-medical clusters*
Таблица 2. *Пути решения проблем, связанных с научно-медицинскими кластерами*

decision-making and sharpening of practical skills [19]; raising private investment by initiating partnership with large companies ready to invest funds in science-intensive projects.

The potential for consolidating the resources of the region in the field of medical education to subsequently create globally competitive medical products should incorporate the aforementioned competency synergies. Analysis of the conducted research on this topic also leads to the conclusion that integrating all elements of the regional SMEC will enable the selection of priority training vectors for specialists, based on an assessment of the current needs of the constituent entity of the Russian Federation [20].

CONCLUSION

Organization of scientific and medical clusters is a key factor of development of an innovative healthcare system that integrates the academic science, educational institutions, private sector and state regulation. Organization of SMEC under governance and with direct involvement of healthcare stakeholders is a strategic tool to enhance the efficiency of the system of public health and to improve its performance indicators. The cluster model enables a shift from the disparate efforts of individual institutions to targeted, coordinated activities focused on the ultimate outcome: improvement of public health.

Key conditions for the success of a regional scientific and medical education cluster include such indicators such: the leading role of the public health authority in coordinating all cluster participants; focus on public health priorities determined through epidemiological analysis and monitoring data; the integration of educational programs in AI management and health economics into the cluster activities to train personnel capable of working in an interdisciplinary environment; and investments in innovations with achievable medical-demographic and economic indicators.

A prospective area of further research is the development of a system of performance indicators of the SMEC integrated with criteria of evaluation of work of administrators of health authorities and medical institutions.

ADDITIONAL INFORMATION	ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ
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