ANNOTATION

to the dissertation submitted in fulfillment of the requirements for the degree of Doctor of Philosophy (PhD) by Bekzhan Abdalimovich Permenov under the educational program 8D10139 – Public Health entitled: "Organization and Development Strategy of the Extracorporeal Membrane Oxygenation Service"

1. Relevance of the Research Topic

Extracorporeal membrane oxygenation (ECMO) is currently among the most complex and resource-intensive technologies used in the provision of high-technology medical care for patients with critical respiratory and/or cardiovascular failure. Over the past decades, ECMO has evolved from a predominantly "rescue therapy" into an increasingly standardized component of modern intensive care, and its range of application has expanded substantially beyond traditional indications [1–4]. Contemporary literature considers ECMO not only as a method of temporary support in severe respiratory and circulatory failure, but also as a technology used in severe COVID-19-associated acute respiratory distress syndrome, during pregnancy, in selected groups of patients with systemic rheumatic diseases, and as a bridge to organ recovery, transplantation, or further clinical decision-making [1, 3, 4].

As clinical indications continue to expand, the global literature increasingly emphasizes that the safety and effectiveness of ECMO are determined not only by clinical factors, but also by the organizational conditions of its implementation. Current publications and guidelines underline that the sustainable development of ECMO programs requires institutional readiness of medical organizations, the availability of a trained multidisciplinary team, standardized protocols, sufficient resource provision, well-designed patient routing, and continuous quality control [2, 5, 6]. In this regard, ECMO should be viewed not only as a separate intensive care procedure, but also as an independent organizational and functional service whose development requires a systematic scientific and managerial approach [2, 5, 9].

A significant place in the global literature is occupied by the issue of how the organizational maturity of a center affects ECMO outcomes. Data from international registries and analytical studies show that ECMO outcomes are associated not only with the severity of patients' conditions, but also with the experience of the center, the number of cases performed, the structure of the team, and the organization's ability to ensure continuous patient support [7, 8]. Therefore, increasing attention is being paid to models of specialized ECMO centers, regional networks, and phased development of programs, which make it possible to expand access to the technology while maintaining requirements for quality and safety [2, 7, 9].

Another important area of research remains the role of the multidisciplinary approach and specialized workforce training. It has been shown that the participation of intensivists, anesthesiologists, cardiac surgeons, perfusionists, nursing staff, and other

specialists in ECMO programs contributes to more structured decision-making, better coordination of care, and improved quality of patient management [5, 10, 11]. At the same time, the literature emphasizes the importance of specialized training and certification approaches, including the training of ECMO specialists and the development of educational infrastructure, as an important condition for the standardization of practice and sustainability of the program [10–12].

The role of nursing staff within the ECMO team is also of substantial interest. The literature notes that the nurse is involved not only in direct patient care, but also in system monitoring, early detection of complications, ensuring procedural safety, and maintaining multidisciplinary interaction. Consequently, the nursing component of ECMO services should be regarded as a strategically significant element requiring separate organizational, educational, and regulatory consideration [11, 13].

Another important direction is the evaluation of the informational environment related to ECMO. Under conditions of active dissemination of medical content through the internet and social media, the quality of digital information begins to directly affect professional awareness, public perception of the technology, and the safety of its further dissemination. This makes it possible to regard the informational support of ECMO as an independent component of the organizational development of the service [14].

In addition, modern literature emphasizes the need to assess not only immediate survival, but also long-term outcomes after ECMO, including lung function, subsequent rehabilitation, quality of life, and follow-up strategies for survivors [15, 16]. This means that the assessment of the effectiveness of ECMO programs should go beyond individual clinical interventions and include a broader organizational context—from workforce training and patient selection to long-term follow-up and integration of ECMO into existing intensive care pathways [1, 15, 16-18].

Thus, the analysis of the contemporary international literature shows that, despite substantial progress in the clinical application of ECMO, the issues of organizational readiness of medical institutions, standardization of workforce training, development of the nursing component, overcoming resource limitations, quality management, and strategic development of ECMO services within the healthcare system remain insufficiently elaborated. This determines the relevance of the present study aimed at the scientific substantiation of organizational approaches and strategic directions for the development of extracorporeal membrane oxygenation services as an object of public health.

2. Aim of the Study

To provide scientific substantiation of organizational approaches and strategic directions for the development of extracorporeal oxygenation services in the healthcare system on the basis of systematization of contemporary scientific data, results of international surveys of healthcare professionals, and evaluation of digital content quality,

taking into account workforce, educational, resource, regulatory, and informational factors.

3. Objectives of the Study

1. To systematize current data on unresolved issues and prospects for ECMO development, including clinical, organizational, educational, and rehabilitation aspects.
2. To assess healthcare professionals' knowledge and opinions on the use of ECMO, accessibility of standards, workforce training, and resource barriers on the basis of an international survey of specialists.
3. To study healthcare professionals' perceptions of qualification requirements for ECMO nurses, priorities of their training, and organizational barriers to expanding their role in the ECMO team.
4. To evaluate the quality and reliability of ECMO-related information in the digital environment using YouTube video content as a component of the public and professional information field.
5. To formulate practical proposals for the organizational development of ECMO services in the healthcare system taking into account workforce, resource, regulatory, and informational factors.

4. Object and Subject of the Study

Object of the study — ECMO service as an organizational and functional system for the provision of high-technology medical care.

Subject of the study — workforce, educational, resource, regulatory, and informational aspects of the organization and strategic development of ECMO services.

5. Research Methods

The dissertation was completed on the basis of a set of publications and includes five interrelated scientific studies: a review-analytical study, an international online survey on the use of ECMO, standards, training, and resource barriers, an international online survey on the role and competencies of ECMO nurses, a study of the quality of digital ECMO-related content, and a retrospective analytical study aimed at developing practical recommendations for implementation of an ECMO program in multidisciplinary hospitals on the basis of international literature and institutional experience.

The first publication used a review-analytical method with systematization of current ECMO-related data in international scientific literature databases. The literature search was carried out in the international scientometric databases Web of Science Core Collection, Scopus, Medline/PubMed, and DOAJ using combinations of terms related to ECMO, COVID-19, pregnancy, rheumatologic diseases, coagulation, antibacterial therapy, clinical guidelines, survey studies, and rehabilitation. The review was qualitative-analytical in nature and aimed to identify unresolved issues and prospects for ECMO development in various clinical and organizational contexts.

The second publication was an international cross-sectional online study of healthcare professionals' knowledge and opinions regarding ECMO use, standards,

training, and resource barriers. The survey was conducted on the SurveyMonkey platform from July 23 to September 26, 2024. A total of 89 respondents from 12 countries were included. The questionnaire was developed on the basis of current ELSO recommendations, underwent expert assessment by 5 specialists, a two-stage revision, and pilot testing among 10 healthcare professionals. The final version of the questionnaire included 37 questions, among them 22 multiple-choice questions, 7 Likert-scale questions, 1 open-ended question, and a block of sociodemographic characteristics. To ensure completeness of information, all questions were mandatory, and the data were stored in anonymized form after completion of the survey. Statistical analysis of the materials of the second study was performed using IBM SPSS Statistics version 25.0. Descriptive statistics were used to present data as absolute numbers and percentages; age and work experience were characterized by median and range. Pearson's χ^2 test was applied to compare groups by categorical variables. The level of statistical significance was set at $p < 0.05$. Additionally, a comparative analysis of two aggregated geographical groups—Kazakhstan and other countries—was conducted. No statistically significant differences were found between the groups in ECMO availability, professional experience, or duration of work in emergency medicine.

The third publication was an international cross-sectional online study devoted to the role, qualification requirements, and educational needs of ECMO nurses. The survey was conducted on the SurveyMonkey platform from February 17 to May 10, 2025. The study involved 93 healthcare professionals from 12 countries. The questionnaire was developed on the basis of ECMO guidelines and included questions on basic knowledge, professional functions of nurses, training requirements, organizational barriers, and demographic characteristics. To assess content validity, expert review by 5 experts was used, followed by pilot testing among 10 specialists. The survey included multiple-choice questions, binary questions, Likert-scale questions, and one open-ended question. Statistical processing of the third study materials was carried out using Microsoft Excel. Data were presented as absolute numbers, percentages, median, and range (minimum–maximum). Content analysis with subsequent categorization and interpretation of qualitative data was applied to open-ended responses.

The fourth publication was an original study of the quality and reliability of ECMO-related digital content on the YouTube platform. The search was conducted on September 17, 2024 using the key phrases "Extracorporeal Membrane Oxygenation" and "ECMO treatment." Initially, 100 videos were assessed, and after applying exclusion criteria, 55 videos were included in the final analysis. Each video was independently evaluated by two researchers, and in cases of disagreement the final decision was made by a third researcher. Validated international instruments were used to assess quality and reliability: Global Quality Scale (GQS), modified DISCERN, JAMA Benchmark Criteria, and Patient Education Materials Assessment Tool for Audio/Visual Materials (PEMAT-A/V). Additionally, the number of views, likes, comments, video duration, publication date,

presentation type, source of the video, and image quality were taken into account. Statistical analysis of the fourth study materials was performed in IBM SPSS Statistics version 29.0 using the Shapiro–Wilk test, Kruskal–Wallis test, Spearman's rank correlation coefficient, and Cohen's kappa coefficient.

The fifth publication was devoted to the development of practical recommendations for ECMO implementation in multidisciplinary hospitals without in-house cardiac surgery. This work used a combined approach, including a narrative review of international literature on ECMO program development, workforce organization, and implementation strategies, as well as a retrospective observational analysis of the institutional experience of Heart Center Shymkent from January 2019 to December 2024. Within the framework of the study, clinical indications, ECMO configurations, organizational aspects of program development, the structure of the multidisciplinary team, and patient outcomes were analyzed, with special attention given to staged implementation of the technology and its integration into existing intensive care pathways. If the first four studies allowed consistent characterization of current unresolved ECMO issues and prospects, evaluation of healthcare professionals' opinions on workforce training, standards, and resource limitations, determination of the significance of the nursing component of the ECMO team, and identification of variability in the quality of digital medical content, the fifth publication translated these results into the domain of practical organizational modeling. Thus, the application of this set of methods ensured a comprehensive study of ECMO service as a multicomponent organizational system.

6. Scientific Novelty of the Study

The scientific novelty of the study lies in the fact that, within the framework of a set of publications, ECMO service was for the first time considered not only as an independent object of public health, but also as a system for which a staged organizational model of implementation in multidisciplinary hospitals without in-house cardiac surgery was proposed. For the first time, on the basis of the integration of the review study, international surveys, digital content analysis, and retrospective analysis of institutional experience, a reproducible organizational approach was proposed, including assessment of institutional readiness, restriction of initial indications at the early stage, formation of a specialized multidisciplinary team, internal protocolization of processes, structured workforce training, and continuous quality control.

7. Main Research Results

The conducted study showed that the development of extracorporeal membrane oxygenation services under current conditions goes beyond the traditional understanding of ECMO as exclusively an intensive care technology and should be considered in a broader clinical and organizational context. The review-analytical publication demonstrated that current directions of ECMO application include severe COVID-19-associated acute respiratory distress syndrome, pregnancy, use in patients with systemic

rheumatic diseases, issues of anticoagulation therapy, peculiarities of antibacterial pharmacokinetics, as well as problems of rehabilitation and long-term outcomes. Generalization of these data made it possible to conclude that further development of ECMO is impossible without a combination of clinical and organizational strategy, and that ECMO service itself requires a systemic approach within public health.

According to the international cross-sectional online study devoted to healthcare professionals' knowledge and opinions on ECMO use, standards, training, and resource barriers, 89 specialists from 12 countries participated, of whom 67.4% represented Kazakhstan. Only 33.7% of respondents indicated the presence of a specialized ECMO department or service in their organization. Although 82.0% of participants were familiar with the definition of ECMO, only 61.8% were familiar with ELSO recommendations, and 61.8% believed that ECMO procedures should be performed only by certified specialists. According to the respondents, the ECMO team should most often include certified ECMO specialists, intensivists, cardiac surgeons, perfusionists, and ECMO nurses. The main barriers to ECMO implementation were identified as the high cost of the procedure, insufficient qualification of physicians, insufficient training of nurses, and limited availability of equipment. Among the most востребованные forms of ECMO training, respondents identified didactic courses in specialized centers, simulation training, and certification in the relevant specialty. These results made it possible to quantitatively characterize the key workforce, educational, and resource deficits limiting the development of ECMO services.

The results of the international study devoted to the role of ECMO nurses showed that 93 healthcare professionals from 12 countries participated, with nurses and ECMO specialist nurses constituting the largest share of participants. Only 34.4% of respondents reported the availability of specialized ECMO nurse training in their institutions. Prevention of complications was most often indicated as the priority area of training. The most important practical competencies of the ECMO nurse included monitoring device integrity and recognizing signs of hypoperfusion. The principal organizational barriers were inadequate training, shortage of ECMO nurses, and excessive workload, while 75.3% of participants noted that the main condition for strengthening the nurse's role in the ECMO team was the development of educational infrastructure. The obtained data confirm that the nursing component of ECMO services has an independent strategic significance and requires a standardized model of professional training, organizational support, and clearer regulatory consolidation of functions.

According to the original study of the quality and reliability of ECMO-related digital content on YouTube, among the 55 analyzed English-language videos, 30.9% were of low quality, 21.8% were of intermediate quality, and 47.3% were of high quality. The highest proportion of high-quality materials was represented by videos published by physicians, whereas the largest proportion of low-quality content was attributed to news sources. No statistically significant differences between quality groups were identified by

daily number of views, likes, and comments, which indicates the absence of a direct relationship between content popularity and its quality. At the same time, statistically significant positive correlations were established between video duration and the scores on the GQS, modified DISCERN, JAMA, PEMAT Understandability, and PEMAT Actionability scales. These results indicate pronounced heterogeneity of the digital informational environment related to ECMO and confirm the need for more active participation of the professional community in creating high-quality and reliable content.

An important result of the dissertation research was the generalization of the institutional experience of Heart Center Shymkent and its interpretation in the context of the international literature on ECMO program development. It was established that from January 2019 to December 2024, 91 ECMO procedures were performed at the center in patients with severe cardiopulmonary failure refractory to standard therapy. The main indications included cardiogenic shock, severe respiratory failure, extracorporeal cardiopulmonary resuscitation, and post-cardiotomy heart failure. It was shown that the development of the ECMO program proceeded in stages and was accompanied by the formation of a multidisciplinary team, protocol standardization, improvement of patient routing, and structured workforce training. On this basis, the preparatory phase, the initial implementation phase, and the program expansion phase were identified, and for each of them key workforce, resource, protocol, and logistical tasks were determined. This made it possible to formulate practical organizational recommendations for the safe implementation of ECMO in multidisciplinary hospitals without in-house cardiac surgery.

Taken together, the results of all publications showed that the development of ECMO services is determined not only by clinical necessity, but also by the level of institutional readiness, the availability of specialized infrastructure, the quality of training and certification of specialists, the development of the nursing component, regulatory standardization of processes, resource provision, and the quality of informational support. Thus, the dissertation scientifically substantiated the transition from considering ECMO as an isolated clinical technology to understanding ECMO as a complex organizational and functional service, the development of which requires systemic and strategic management within public health.

8. Theoretical and Practical Significance of the Study

The theoretical significance of the study lies in expanding scientific understanding of ECMO service as a complex multidisciplinary system combining clinical, workforce, educational, organizational, informational, and institutional components. The results of the study provide grounds for considering ECMO not only as an intensive care technology, but also as an independent direction of public health.

The practical significance of the study lies in the possibility of using the obtained results:

- in the development of national and local programs for ECMO service development;

- in the formation of criteria for the institutional readiness of medical organizations for ECMO implementation;
- in the creation of certification and continuing professional development programs for physicians, perfusionists, and nursing staff;
- in the development of standardized educational modules for ECMO nurses;
- in improving the regulatory and informational support of ECMO technology;
- in developing an organizational model for staged ECMO implementation in multidisciplinary hospitals;
- in forming a professional digital communication policy in the field of high-technology medical care.

9. Main Provisions Submitted for Defense

1. ECMO service should be considered an independent object of public health requiring systemic organizational and strategic management.
2. The main conditions for sustainable ECMO service development are standardized workforce training, specialist certification, expansion of educational infrastructure, improvement of institutional readiness of medical organizations, and staged organizational implementation of the service.
3. Nursing staff are a strategically significant component of ECMO services and require a separate model of professional training, regulatory consolidation of functions, and corresponding organizational support.
4. The high cost of the technology, shortage of trained physicians and nurses, limited availability of equipment, insufficient dissemination of specialized training, and absence of a standardized implementation model are the main systemic barriers to ECMO development.
5. The quality of digital ECMO-related information and the availability of practical organizational recommendations for staged implementation of the service influence the professional and public perception of the technology, as well as the safety of its expansion in the healthcare system.

10. Personal Contribution of the Author

The author's personal contribution included formulation of the scientific concept, setting the aim and objectives of the study, analysis of domestic and foreign literature, participation in research design, collection, systematization, processing and interpretation of data, preparation of scientific publications, and formulation of the main conclusions and practical recommendations. In the course of the work, organizational aspects of ECMO service development were analyzed, the main workforce and educational deficits were assessed, and an applied model of staged ECMO program implementation based on institutional experience was systematized.

11. Approbation of Dissertation Results

The main provisions and results of the dissertation research were presented and discussed at international and national scientific and practical events devoted to ECMO,

intensive care, resuscitation, and organizational aspects of high-technology medical care:
– in 2021 in Astana at the international congress dedicated to the 10th anniversary of the National Scientific Cardiac Surgery Center, with a report on the use of ECMO in pregnant and postpartum women with severe COVID-19-associated pneumonia;

– in 2022 in Astana at the 5th Congress of the Kazakhstan Society of Anesthesiologists and Resuscitators, with a report on the features of ECMO use in pregnant and postpartum patients with severe COVID-19-associated pneumonia;

– in 2022 in Saint Petersburg, with a report devoted to the integration of ECLS into resuscitation algorithms;

– in 2023 in Astana, with a report entitled “ECMO in Clinical Practice: Difficulties and Ways of Solution”;

– in 2024 in Saint Petersburg, with a report devoted to organizational aspects of ECMO use;

– in 2024 in Turkistan at the 7th Congress of the Kazakhstan Association of Anesthesiologists and Resuscitators, with a report on the use of artificial intelligence algorithms for ECMO optimization.

12. International Internships and Scientific-Practical Training

Within the framework of the dissertation research, the following international internships and training programs were completed:

– training at the American Heart Association, USA, on modern cardiopulmonary resuscitation algorithms;

– internship at Marmara University Hospital, Türkiye, on the organization of intensive care unit work;

– internship at Rabin Medical Center, Beilinson Hospital, Israel, on the clinical application of extracorporeal life support technologies;

– internship at Tokyo Medical University, Japan, on research and publication ethics;

– internship at Jagiellonian University Hospital, Poland, on the use of ECMO in intensive care;

– overseas training at Koç University Hospital, Türkiye, within the international “Bolashak” program devoted to the extracorporeal membrane oxygenation program.

The acquired knowledge and practical experience were used in shaping the concept of the dissertation research, interpreting the results, and developing practical recommendations for ECMO service development.

13. List of Publications

1. Permenov BA, Zimba O, Yessirkepov M, Anartayeva M, Suigenbayev D, Kocyigit BF. Extracorporeal membrane oxygenation: unmet needs and perspectives. Rheumatol Int. 2024;44(12):2745–2756.

2. Permenov BA, Zimba O, Yessirkepov M, Suigenbayev D, Kocyigit BF. Healthcare professionals’ views on training, standards, and resources for extracorporeal membrane oxygenation: a cross-sectional survey. Croat Med J. 2025;66:419–428.

3. Permenov BA, Zimba O, Satibaldiyeva Z, Suigenbayev D, Kocyigit BF. Healthcare professionals' perceptions of nurses' qualifications and roles in extracorporeal membrane oxygenation: an online cross-sectional survey. Rheumatol Int. 2026;46:25.

4. Permenov BA, Zimba O, Yessirkepov M, Qumar AB, Suigenbayev D, Kocyigit BF. Evaluating the Quality and Reliability of YouTube as a Source of Information on Extracorporeal Membrane Oxygenation: A Call to Publish More Quality Videos by Professionals. J Korean Med Sci. 2025;40(13):e34.

5. Permenov B, Suigenbayev D, Anartayeva M, Toiyeva G, Zhunissov S, Pernebayev N. Practical Recommendations for ECMO Implementation in Multidisciplinary Hospitals Without Cardiac Surgery: Lessons Learned from the Five-Year Experience of the Heart Center Shymkent. Cent Asian J Med Hypotheses Ethics. 2026;7(1):61–69.

14. Conclusion

The dissertation, completed on the basis of a set of publications, is a completed scientific study devoted to solving an issue relevant to public health, namely the scientific substantiation of organizational approaches and strategic directions for the development of extracorporeal membrane oxygenation services.

The conducted study showed that the development of ECMO services is a complex task that should be implemented within the healthcare system through coordination of clinical, organizational, workforce, educational, resource, regulatory, informational, and scientific solutions. The obtained results demonstrated that sustainable ECMO development is ensured not only through the description of existing problems, but also through the transformation of these problems into concrete organizational models and practical recommendations.

15. References

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