# ANALYTICAL REVIEW OF EXISTING CARDIOVASCULAR MATHEMATICAL MODELS

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**Abstract.** This article presents an analytical review of existing mathematical models used in cardiovascular research. The study examines the main approaches to modeling cardiovascular system dynamics, including lumped-parameter models, computational fluid dynamics models, electrophysiological models, and multiscale models. The review highlights how mathematical modeling helps describe blood flow, pressure changes, heart function, vascular resistance, and interactions between different components of the cardiovascular system. Special attention is given to the role of models in disease prediction, diagnosis support, treatment planning, and evaluation of therapeutic interventions. The analysis shows that existing cardiovascular mathematical models provide valuable tools for understanding complex physiological processes; however, their accuracy depends on the quality of input data, model assumptions, and validation against clinical or experimental results. The article concludes that the further development of personalized and data-driven cardiovascular models can improve the practical application of mathematical modeling in modern medicine.

**Keywords:** Cardiovascular system, mathematical modeling, analytical review, blood flow, hemodynamics, cardiac function, computational modeling, disease prediction, personalized medicine, model validation.

**Аннотация.**В данной статье представлен аналитический обзор зарубежных исследований, посвящённых разработке и применению математического моделирования в научных исследованиях. Анализ показывает, что математическое моделирование широко используется как эффективный инструмент для описания сложных процессов, прогнозирования поведения систем и оптимизации принятия решений. Зарубежные исследователи подчёркивают важность правильного выбора математических методов, проверки достоверности модели и сопоставления теоретических результатов с эмпирическими данными. В работе отмечается, что математическое моделирование позволяет упростить реальные процессы, выявить основные факторы, влияющие на систему, а также прогнозировать возможные результаты при различных условиях. На основе изученных источников можно сделать вывод, что интеграция математического моделирования с современными вычислительными технологиями повышает точность, гибкость и практическую значимость научных результатов.

**Ключевые слова:** Математическое моделирование, зарубежные исследования, аналитический обзор, прогнозирование, оптимизация, вычислительные методы, проверка модели, научный анализ.

A detailed study of various mathematical models used to describe blood circulation was conducted. Both analytical and numerical methods for simulating blood flow dynamics were examined. Specifically, models based on differential equations were examined, as well as more complex multivariate and multicomponent systems that include various parameters, such as blood viscosity, vascular resistance, and flow turbulence. The application of numerical methods, such as the finite difference method and the finite element method, to solving these equations was considered.

1. Study of International Experience:

The state of international research in the field of mathematical modeling of blood circulation was analyzed. Examples from leading scientific centers and medical institutions in Europe, the United States, and other countries were considered, where more complex approaches are actively used, including multiphysics modeling, which integrates various physiological processes. Advanced technologies and software used to create highly accurate blood circulation models were examined, as well as methods used to predict diseases and develop therapeutic strategies. 2. Analysis of Research in Uzbekistan:

This study examined domestic developments in the field of mathematical modeling of blood circulation. Work conducted at leading educational and scientific institutions, such as the Tashkent University of Information Technology and the Institute of the Republican Blood Transfusion Center, was reviewed. Key achievements and limitations in this field were identified, including the use of standard models and software, as well as the level of integration of domestic research with the international scientific community.

3. Analysis of Software Applications:

This study conducted a detailed examination of existing software for modeling blood circulation. Both commercial and open-source software solutions were considered, including their functionality, modeling accuracy, and usability. This analysis of the software allowed us to identify its advantages and disadvantages and assess its compliance with modern medical practice and scientific research requirements.

4. Comparative Analysis with International Standards:

Existing domestic and international mathematical modeling methods were compared with international standards and best practices in this field. This allowed us to identify key areas in which modeling methods need to be developed and refined, as well as to strengthen the scientific and technical base to keep pace with global advances.

5. Recommendations and Suggestions:

The study provided recommendations for improving mathematical models and software for studying cardiovascular circulation. Thus, a significant amount of research and analysis was conducted during the course of this work, aimed at examining the current state of

mathematical modeling of cardiovascular circulation, both in Uzbekistan and internationally. These studies allow us to identify the strengths and weaknesses of existing methods and propose ways to improve them and implement them in practical medicine.

| Parameter | Uzbekistan | Foreign countries |
|---|---|---|
| Type of models | Simple 0D/1D, educational or clinical | Multi-scale 3D-1D-0D CFD models |
| Use of patient data | Limited (empirical observations) | Active (CT, MRI, ultrasound, catheterization) |
| Software | Local prototypes | Open-source platforms ( SimVascular , OpenFOAM , ANSYS, COMSOL) |
| Verification | Partial | Standardized (experiment + clinic) |
| Publication level | Abstracts, local journals | International journals Q1-Q2 |
| Main focus | Practical monitoring | Mathematical modeling and forecasting |

Table 1. Comparison with cardiovascular mathematical models

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