Virtual Technologies in Medicine

№2 (48) 2026

ISSN: 2686-7958
ISSN: 2687-0037

Published by the Russian Society for Simulation Education in Medicine, ROSOMED

CorView3DR, cardiac and great vessel interventions simulator

CorView3DR is the world's first radiodense heart & great vessels simulator for cardiovascular interventions.

CorView3DR realistically simulates the anatomical structures of the heart and great vessels of an adult, ostia of coronary arteries and coronary sinus of the heart are patent, interatrial septum in the area of the oval fossa is accessible for puncture.

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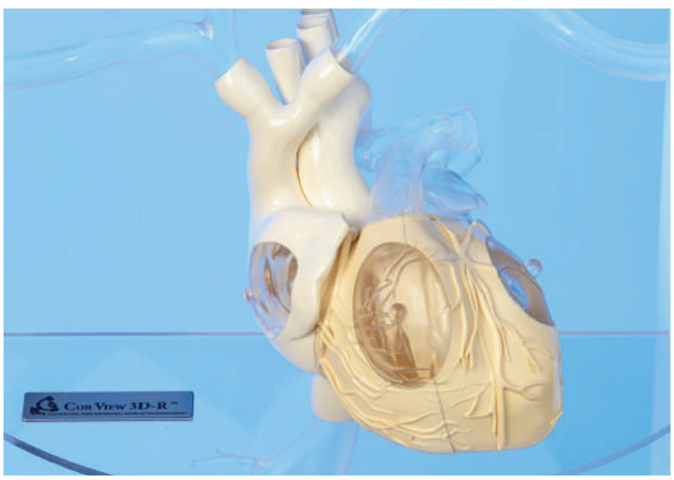
Intended Use

The **CorView3DR** simulator is designed for educating cardiovascular surgeons and practicing technical, tactile and practical skills in x-ray surgery, arrhythmology and interventional electrophysiology.



Key Features

- Imitation of tactile sensations experienced by a surgeon when manipulating a catheter inside the heart.
- Viewing ports enable monitoring the course of the surgery.
- Performing X-ray guided interventions in a Cath lab.
- Availability of various surgical access options that imitate native ones: the inferior vena cava, descending aorta, jugular veins, subclavian veins, subclavian arteries.
- Possibility of conducting, fixing and positioning diagnostic and ablation electrodes, implantable electrodes of pacemakers, cardioverter-defibrillators and devices for cardiac resynchronization therapy, as well as coronary guidewires and catheters.

VIRTUAL TECHNOLOGIES IN MEDICINE

No. 2 (48) 2026

SCIENTIFIC AND PRACTICAL JOURNAL
ON VIRTUAL AND SIMULATION TECHNOLOGIES IN MEDICAL EDUCATION
AND CLINICAL PRACTICE

Official publication of the All-Russian Public Organization
“Russian Society for Simulation Education in Medicine,” ROSOMED
www.rosomed.ru

V52
UDC 61:004(051)

The journal was founded in 2008

Frequency: quarterly (4 issues per year)
Certificate of Registration of a Mass Media Outlet
No. FS77-34673 dated December 23, 2008

Editor-in-Chief: Academician of the Russian Academy
of Sciences, Professor Valery Kubyshkin, MD

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Computer typesetting and layout: Ludmila Vasilyeva
Original layout: ROSOMED Publishing House

Format: 210 x 297 mm
ISSN: 2686-7958 — print edition
ISSN: 2687-0037 — online edition

FOREWORD
FROM THE DEPUTY EDITOR-IN-CHIEF OF THE JOURNAL

Dear Readers!

A landmark event was the adoption of the Ostergaard Declaration by the European Society of Anesthesiology and Intensive Care. According to its provisions, simulation is no longer merely a supplementary teaching tool but has become a critically important component of healthcare that must occupy its rightful place in the work schedule of every clinician and educator.

Continuing this theme is an article by authors from Saint Petersburg State University, which focuses on training non-medical professionals in basic cardiopulmonary resuscitation (CPR) skills as part of their preparation for accreditation. The authors demonstrate that a targeted 16-hour program using simulators with feedback statistically significantly improves the quality of performance of key elements of the CPR algorithm. A study by a team from South Ural State Medical University addresses a similar issue—the analysis of the experience of initial accreditation of specialists—and identifies organizational and methodological aspects requiring correction.

A study on the role of simulation technologies in training for on-site postmortem examination deserves special attention—a topic traditionally difficult to practice due to legal and ethical constraints. The authors demonstrate the significant superiority of the simulation approach over traditional methods of forensic medicine training. A paper by our Uzbek colleagues focuses on pediatrics, evaluating the effectiveness of task-oriented and self-directed learning using simulation technologies in developing clinical reasoning among future pediatricians.

This issue also presents a non-trivial example of the application of mathematical and simulation modeling—an article on the use of the AnyLogic software suite for planning the workload of laboratory staff during the pandemic, which opens up prospects for the interdisciplinary convergence of simulation approaches with the tools of systems analysis and Lean management. The issue concludes with a paper dedicated to the development of a Russian-language training simulator for Boston Scientific's cardiac pacemaker programmer—a practical solution born out of the pressing need of regional healthcare in the face of limited access to the manufacturer's original training programs.

The diversity of the topics presented—ranging from large-scale international declarations to local practical developments—once again confirms that simulation technologies today permeate all levels and areas of medical education, becoming a common language for the professional development of physicians.

Maxim Gorshkov

Deputy Editor-in-Chief of the Journal
Prof.h.c., MD, Dipl.Econ., MMSim (Uni Graz)
Chairman of the ROSOMED Expert Committee
Director of the European Simulation Institute, EuroMedSim

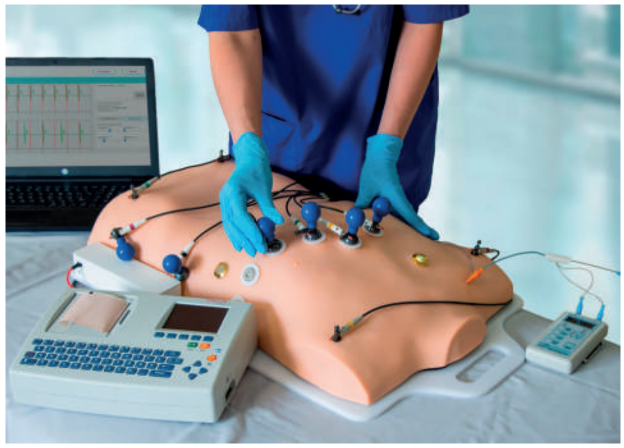
CONTENT

CorView ECG, interactive ECG simulator

CorView ECG simulator allows to practice the skill of applying the electrodes for recording 12 ECG leads. It contains the anatomical landmarks necessary for positioning the electrodes and it simulates 120 different types of heart rhythm.

CorView ECG simulator allows to independently create and reproduce a virtual ECG, it contains a plug-in module for temporary cardiac pacing (ECP) with the ability to program an external pacemaker.

CorView ECG simulator is designed to practice the skills of examining a cardiac patient and can be used for accreditation in the specialties of "General Medicine" and "Pediatrics" as well as in the station - "Diagnostics of the cardiovascular system".



Key Features

- Realistic tactile sensations;
- Anatomical landmarks for applying ECG electrodes;
- Temporary cardiac stimulation module;
- Defibrillation capability;
- The ability to independently create and reproduce any heart rhythms for temporary cardiac stimulation.

Skills to train

- Application of electrodes in accordance with anatomical landmarks;
- Registration of 12 ECG leads: 120 different types of heart rhythm;
- Cardioversion using a defibrillator;
- Conducting temporary electrical stimulation with the ability to program an external pacemaker in real time.

The 15th Anniversary Congress of the Russian Society for Simulation Education in Medicine and the International Conference “Simulation-Based Medical Education: Experience, Development, Innovation. ROSOMED–2026 is Russia’s most authoritative scientific and practical event in the field of medical simulation, with a long history and tradition. Every year, hundreds of experts from Russia, Belarus, Central Asia, the South Caucasus, and other countries gather to discuss practical experience and the prospects for the development of simulation technologies.

The conference, held with the support of the Ministry of Health of the Russian Federation, is organized by the Russian Society for Simulation Education in Medicine (ROSOMED) and the Russian Medical Association (RMA).

This year, the event will take place at the Holiday Inn Sokolniki Hotel’s convention center — the venue where, in 2018, the country’s first open public piloting of OSCE stations was held, organized by ROSOMED, which marked the beginning of the introduction of simulation methods into the accreditation system for medical specialists in Russia.

Actual information about the event, registration, and abstract submission is available at rosomed.ru

Venue: Hotel “Holiday Inn Sokolniki”, Moscow, 24 Rusakovskaya St. (“Sokolniki” Metro Station)

Dates: October 7–8, 2026

We invite you to ROSOMED-2026!

The Baltic International Medical Congress, “Family Health: A Multidisciplinary Approach from the University Classroom to Clinical Practice,” dedicated to the 20th anniversary of higher medical education in the Kaliningrad Region: rosomed.ru/conferences/214

International Scientific and Practical Conference “Simulation-Based Education in Medicine: Problems, Solutions, Prospects” will take place on November 17, 2026, at the Andijan State Medical Institute, Andijan, Republic of Uzbekistan. Further details: rosomed.ru/conferences/232

The world’s largest conference on simulation-based education, IMSH, will take place in New Orleans, USA, January 23–27, 2027. Five days packed with hands-on workshops, master classes. The event, presentations by experts from around the world, will bring together several thousand professionals and more than 130 leading manufacturers in the field of medical simulation. Registration will open in the fall of 2026. For more information: imsh2027.org

The annual conference of the European Society for Simulation in Medicine SESAM-2027 will be held June 16–18, 2027, in Riga. The previous event brought together more than 1,300 participants from over 50 countries, who attended more than 600 hours of scientific and educational content. Information will be available on the new website sesamsociety.org

The Østergaard Declaration

Just recently, in early June of this year, the European Society of Anesthesiology and Intensive Care adopted a document that, without exaggeration, can be considered a major milestone in the history of simulation-based training in healthcare: — The Østergaard Declaration, named after one of Europe's leading experts in this field, Professor Dora Østergaard from Copenhagen (the link to the full text of the document is provided below).

In recent years, professional communities have repeatedly published key statements, consensus documents, and communiqués on the role of simulation in medical education. However, here and now, a leading European medical professional organization is moving beyond the usual rhetoric and formulating fundamentally new principles.

For the first time, it has been stated so clearly: despite the convincingly and repeatedly proven effectiveness of simulation methods, the level of their implementation in healthcare practice remains unacceptably low. This is despite the fact that simulation should be viewed not so much as a teaching method, but rather as an effective tool for ensuring patient safety and improving the quality of medical care. It is no longer merely a supplementary educational technology, but an integral component of clinical medicine and the modern healthcare system as a whole.

Like other continuing professional development activities, simulation techniques should be applied at all stages of a career — from basic training and residency to postgraduate education, specialization, and continuing education — on a routine and ongoing basis.

The Declaration emphasizes the complexity of this professional tool, which requires expert knowledge in the fields of pedagogical theories, simulation scenario design, facilitation, debriefing, the human factor, team interaction, and digital technologies. Consequently, the development of simulation is impossible without specialized training for instructors, specialists, and experts in medical simulation programs.

The professional society directly appeals to healthcare administrators to stop treating simulation education as an optional activity conducted "when possible" or outside of regular working hours. On the contrary, it must become a mandatory and scheduled part of

clinical departments' work. To achieve this, time must be officially allocated within the regular work schedule — both for healthcare professionals participating in simulation sessions and for instructors responsible for their preparation and delivery.

The very logic of the discussion regarding the role of simulation in medical education is also changing. Whereas we used to cautiously state that "simulation does not replace, but merely complements, traditional training methods," today the professional community is articulating a more decisive position: "less effective forms of educational activities should give way to simulation-based methods" wherever they allow for the development of professional competencies in a safer, more effective, and more realistic manner that closely mirrors actual clinical practice.

Simulation must be integrated into educational programs, clinical protocols, team training processes, and quality management systems. The declaration elevates simulation from the category of innovation to that of a professional standard. What was once viewed as best practices at individual centers is now the expected norm for modern medicine.

For the Russian and international readership of the journal *Virtual Technologies in Medicine*, this document holds special significance. It confirms what we have been saying for many years at ROSOMED events: simulation is not a peripheral educational practice, but a strategic tool for the development of healthcare. This is a call to rethink the role of simulation in medicine — from a supplementary teaching method to a full-fledged tool for quality, safety, and the systemic development of healthcare.

Full-text link: https://esaic.org/wp-content/uploads/2026/06/The-Ostergaard-Declaration-ESAIC-Statement-on-Advancing-Simulation-Based-Education-1.pdf

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SPECIFICS OF PREPARATION FOR ACCREDITATION AT THE “BASIC CPR” STATION FOR PROFESSIONALS WITHOUT A MEDICAL BACKGROUND

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DOI: 10.46594/2687-0037_2026_2_2180

Abstract. During the initial specialized accreditation of professionals with non-medical backgrounds conducted by the St. Petersburg State University Accreditation Center, it was found that the candidates’ level of preparedness for the “Basic Cardiopulmonary Resuscitation for Adults and Airway Management” station was critically low. To address this issue, a 16-hour supplementary educational program was developed (theory and practice on simulators with feedback). The results of 207 candidates were compared, of whom 52 had undergone training and 155 had not. In the training group, 90–100% of the key elements of the algorithm were performed correctly, compared to 70–85% in the group that did not receive training. The observed differences were statistically significant ($p < 0.05$–0.001) for most items on the checklist. Thus, a deficit in practical CPR skills was identified among professionals with non-medical education. The developed program proved highly effective and demonstrated the need to include a practical CPR module in their training.
Keywords: accreditation, non-medical professionals, basic CPR.
Conflict of interest: The authors declare no conflict of interest.
Funding: This study was conducted without external funding.
Citation: Gudukhin A. A., Bekrenyov D. A. Features of preparation for accreditation at the “Basic CPR” station among professionals with non-medical education // Virtual Technologies in Medicine. 2026. No. 2. Pp. 51–53. DOI: 10.46594/2687-0037_2026_2_2180

Received by the editorial office on June 15, 2026.
Received after peer review on June 29, 2026.
Accepted for publication on July 1, 2026.

Introduction
Modern medicine is closely integrated with various fields of natural science: biology, embryology, biochemistry, genetics, and others. Many medical research projects cannot be carried out without collaboration between specialists with medical and non-medical backgrounds. The list of priority areas for fundamental and exploratory scientific research for 2021–2030, in accordance with Order No. 3684-r of the Government of the Russian Federation dated December 31, 2020 [1], the list includes such areas as medical technologies, physiological sciences, biomedical sciences, clinical medicine, and preventive medicine.

On January 1, 2023, Order No. 709n of the Ministry of Health of the Russian Federation, dated October 28, 2022, “On the Approval of the Regulations on the Accreditation of Specialists,” came into effect [2], according to which specialists with non-medical education who seek employment in medical institutions are required to undergo the initial specialized accreditation procedure. The “Basic Cardiopulmonary Resuscitation for Adults and Airway Management” module is mandatory for all non-medical specialties and positions.

Relevance
In February 2025, the Resource Educational Center for Advanced Medical Technologies “Center for Medical Accreditation” at St. Petersburg State University conducted the first-ever initial specialized accreditation for the position of “Medical Speech-Language Pathologist.” During the analysis of the accreditation results, a significant number of serious errors were identified during the completion of station “Basic Cardiopulmonary Resuscitation for Adults and Airway Management.” Most of the candidates either failed to perform or incorrectly performed the following items on the checklist for the “Basic Cardiopulmonary Resuscitation for Adults and Airway Management” station [3]: assessing the safety of the care environment, performing the Heimlich maneuver, checking for breathing, calling an ambulance, hand positioning during compressions, quality indicators for chest compressions and ventilation, and using an automated external defibrillator.

Purpose of the Work
To prepare non-medical staff to undergo accreditation in the module “Basic Cardiopulmonary Resuscitation for Adults and Airway Management.”

Materials and Methods
To achieve this goal, we developed a continuing professional education program titled “Preparation for the Accreditation Process at the station “ Basic Cardiopulmonary Resuscitation for Adults and Airway Management.” Program duration: 16 hours of in-person instruction, including a theoretical component and a practical course focused on developing practical skills in per-

forming basic cardiopulmonary resuscitation (CPR) for adults and maintaining airway patency; the program is offered in a blended learning format (in-person and distance learning). The training was conducted using modern, highly realistic simulation equipment with feedback functionality, allowing for the assessment of skill performance accuracy.

The total number of specialists admitted to the accreditation process for the position of "Medical Speech-Language Pathologist" during the period from February 2025 to February 2026 was 207. Since participation in the program was voluntary, only 52 individuals completed the preliminary training for accreditation.

Given the heterogeneity of the comparison groups, a non-parametric statistical method was used to analyze the results: Pearson's χ^2 test with the Yates correction.

Results and Discussion

A comparative analysis of the results of the OSCE station performance by the identified groups is presented in Table 1.

Table 1

Comparative Analysis of Practical Skills Performance at the "Basic Cardiopulmonary Resuscitation for Adults and Airway Management" Station by Accredited Individuals with Non-Medical Education (Position: "Medical Speech-Language Pathologist") Based on Whether They Have Completed Additional Training

Performance of the Accredited Individual	Individuals who completed the Additional Training (% of graduates)	Individuals who did NOT complete the additional training (% of graduates)	χ^2 (with Yates' correction)	p-value	Differences
Assessment of the safety of care conditions	100	80	10.71	< 0.05	significant
Performing the Heimlich maneuver	100	70	16.69	< 0.001	significant
Assessment of breathing	100	80	10.71	< 0.05	significant
Incomplete information when calling emergency medical services	100	85	6.49	< 0.05	significant
Interlocking hands during compressions	100	75	13.24	< 0.001	significant
Nose Pinch During Ventilation	100	80	10.71	< 0.05	significant
Placement of AED electrodes on the chest	100	70	16.69	< 0.001	significant
Depth of compressions	90	70	6.42	< 0.05	significant
Hand position during compressions	100	80	10.71	< 0.05	significant
Full chest expansion during compressions	100	75	13.24	< 0.001	significant
Compression rate	95	85	2.63	> 0.05	not significant
Ventilation volume during artificial respiration	90	70	6.42	< 0.05	significant

A comparative analysis of the results of the initial specialized accreditation among professionals with non-medical backgrounds holding the position of "Medical Speech-Language Pathologist" revealed significant differences in the level of training between the group that completed additional training under the program "Preparation for the Accreditation Procedure at the 'Basic Cardiopulmonary Resuscitation for Adults and Airway Management' Station," and the group that did not undergo such training. The results demonstrate a consistent and statistically significant correlation between completion of the additional training and success in performing practical skills. In the group that underwent training ($n = 52$), a score of 100% or close to 100% was achieved on 11 of the 12 items analyzed on the assessment sheet.

In the group that did not receive training ($n = 155$), the success rate in performing the skills was significantly lower. The performance rate ranged from 70 to 85%, indicating systemic gaps in the training of non-medical professionals in basic cardiopulmonary resuscitation.

Application of Pearson's χ^2 test with Yates' correction confirmed that the differences between the groups were highly statistically significant for most items ($p < 0.05$; for items 6, 23, 37, and 45, $p < 0.001$).

Conclusions

- Specialists without a medical background who did not undergo specialized training at an accreditation and simulation center were found to have a critical lack of practical skills in performing CPR, as evidenced by statistically significantly lower scores at the corresponding station of the OSCE.
- The continuing professional education program that was developed and implemented has proven to be highly effective. Specialists who have completed the training demonstrate high-quality performance of the basic cardiopulmonary resuscitation algorithm in simulated conditions.

The data obtained support the need to include an in-depth module on first aid and cardiopulmonary resuscitation — with mandatory skill practice using simulation equipment — in professional retraining and continuing education programs for non-medical specialists.

Practical Recommendations

Incorporate a mandatory, practice-oriented module titled "Basic Cardiopulmonary Resuscitation for Adults and Airway Management" into the curricula of professional retraining and continuing education programs for professionals with non-medical backgrounds (biologists, psychologists, speech-language pathologists, etc.).

Authors' Contribution

Gudukhin A. A., Bekrenev D. A.: development of the methodology, data processing, and analysis of the research results. All authors participated in the discussion and editing of the manuscript. All authors approved the final version of the article.

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EXPERIENCE IN CONDUCTING INITIAL ACCREDITATION OF SPECIALISTS AT THE FEDERAL ACCREDITATION CENTER OF SOUTH URAL STATE MEDICAL UNIVERSITY IN 2025

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DOI: 10.46594/2687-0037_2026_2_2163

Abstract. This paper analyzes the author's own experience in conducting the initial accreditation (IA) procedure for specialists. The study identified notable factors, specifically weaknesses in the training of graduates, which serve as a basis for addressing these issues.
Keywords: simulation-based training, testing, initial accreditation, situational tasks, accreditation center.
Conflict of Interest. The authors declare no conflict of interest.
Funding. This study was conducted without external funding.
Citation: Moskvicheva M. G., Matsuganov D. A., Astakhov A. A., Abramovskikh O. S. Experience in Conducting Initial Accreditation of Specialists at the Federal Accreditation Center of the South Ural State Medical University in 2025 // Virtual Technologies in Medicine. 2026. No. 2. Pp. 54–56. DOI: 10.46594/2687-0037_2026_2_2163
Scientific specialty. 3.2.3 Public Health and Health Care Organization, Sociology and History of Medicine.

Received by the editorial office on March 13, 2026.
Received after peer review on May 25, 2026.
Accepted for publication on June 1, 2026.

Relevance

To practice medicine professionally, all graduates of medical programs are required to complete the initial accreditation procedure, as stipulated in Federal Law No. 323 of November 21, 2011 "On the Fundamentals of Public Health Protection in the Russian Federation" and regulated by Order No. 709n of the Ministry of Health of the Russian Federation dated October 28, 2022, "On the Approval of the Regulations on the Accreditation of Specialists" [1; 2]. The primary objective of the modern federal state educational standard is to equip graduates with the ability to apply their knowledge and skills to solve professional problems. The components of these competencies are theoretical knowledge and practical skills acquired during university studies. In 2025, the Federal Accreditation Center at South Ural State Medical University conducted initial accreditation of individuals who had completed core professional educational programs in higher medical and pharmaceutical education in five specialties: 31.05.01 "General Medicine," 31.05.02 "Pediatrics," 31.05.03 "Dentistry," 33.05.01 "Pharmacy," and 32.05.01 "Preventive Medicine."

Objective

To analyze our own experience in conducting the initial accreditation, identify the main issues, and develop an action plan to address and prevent them in the future.

Materials and Methods

In 2025, based at the Federal Accreditation Center (hereinafter referred to as the FAC) of the South Ural State Medical University of the Ministry of Health of the Russian Federation, 606 students were admitted to initial accreditation: 337 in the specialty "General Medicine," 137 in "Pediatrics," 99 in "Dentistry," 22 in "Pharmacy," and 11 in "Preventive Medicine." Students were prepared for the initial accreditation exam throughout the academic year. This preparation included: independently completing test and case-based assignments on the official website of the Methodological Center for Specialist Accreditation, as well as practical training organized at the FAC to hone their skills.

Results

The initial accreditation of specialists took place in three stages: testing, assessment of practical skills, and solving case studies.

Testing took place simultaneously at 40 workstations in the FAC's computer lab. Each candidate answered 80 test questions within a 60-minute time limit. Each test question had four answer choices, only one of which was correct. Upon completion of this stage, the software generated a single hard copy of the test report, which was signed by the candidate and handed over on the same day to a designated FAC staff member for safekeeping. Based on the test results, the accreditation subcommittee decided whether candidates had passed this stage of accreditation: "passed" for a score of 70% or more correct answers and "failed" for a score of 69% or less. Twenty-seven people (4.45%) failed the first stage: 14 in "General Medicine," 5 in "Pediatrics" and "Dentistry," 1 in "Pharmacy," and 2 in "Preventive Medicine."

The assessment of practical skills was conducted in five specially equipped classrooms (stations) with audio and video recording. Candidates were allotted 10 minutes to complete the task at each station. After the second stage was completed, the accreditation subcommittee determined whether candidates had passed this stage of accreditation—defined as "pass" for a score of 70% or higher on all practical skill tasks and "fail" for a score of 69% or lower. Four candidates (0.7%) failed the second stage: one in the "General Medicine" specialty and three in "Pediatrics."

The case studies were also conducted in the FAC computer lab simultaneously at 40 workstations. Each candidate was required to solve two case studies by answering 12 questions in each. Candidates were allotted 30 minutes to complete each case study. The third stage was conducted for three specialties ("General Medicine," "Pediatrics," and "Dentistry"). One person (0.2%) in the "Pediatrics" specialty failed this stage. Candidates who did not pass one of the stages on their first attempt were entitled to two retakes. The total number of accredited individuals, including those who passed on retakes, was 574 (94.7%); the number of non-accredited individuals was 32 (5.3%).

Discussion

Since 2017, significant organizational experience in accreditation has been accumulated, and a high level of motivation has been fostered among graduates. During the initial accreditation process, we did not observe any serious organizational or pedagogical issues, as evidenced by the strong accreditation results at all stages. However, there are a number of points that warrant attention. The main challenges in preparing students for the practical phase included a lack of time to master the necessary skills due to the heavy course load, as well as the late publication of the test question bank and station descriptions.

We conducted an anonymous survey of graduates who had completed the accreditation process. Analysis of the data revealed that the greatest difficulties during the second stage were encountered at the "Emergency Medical Care" station, due to the wide range of actions required of the candidate and the need to perform them in the correct sequence (87.7%). The heavy workload of the curriculum was linked to the high burden on the FAC, which, acting alone, served both as an accreditation site (including for initial specialized accreditation) and as a training facility.

In light of this, we reorganized the management structure for accreditation and simulation education and established a new structural unit — the Simulation Education Center, one of which main tasks will be to create the organizational, pedagogical, and logistical conditions necessary for conducting practical sessions that enhance the quality of student training through new organizational forms and teaching methods. This task will be carried out at separate sites using dedicated simulation equipment.

An analysis of the results from all stages revealed a high percentage of candidates who failed the testing — 4.45%. It is worth noting that preparation for the first stage of accreditation is the personal responsibility of each candidate.

A survey of candidates revealed typical mistakes that prevented them from passing the first stage: lack of preparation time — 57.4%, inability to take the practice test — 22.3%, and stress — 20.3%. The second and third stages were successfully completed, and the main difficulties were related to the algorithms for performing tasks, a lack of standardized assessment tools, and the absence of clear answer keys, which may indirectly indicate a degree of subjectivity in the evaluation of candidates.

Thus, our experience in conducting initial accreditation of specialists has allowed us to identify vulnerabilities in the organization and implementation of the accreditation stages, as well as weaknesses in the preparation of graduates, which serves as a basis for addressing these issues.

Conclusions

1. All changes regarding station specifications and the introduction of additional stations during the accreditation stages must be published well in advance, no later than the start of the academic year.
2. To ensure year-round preparation of specialists for the practical phase and the conduct of accreditation, accreditation centers must be fully staffed, adequately funded, and equipped with the necessary facilities and equipment.
3. The problem of an overloaded curriculum and the inability to provide graduating students with sufficient time to prepare for the practical phase of the initial accreditation procedure can be resolved by establishing a specialized, independent structural unit.
4. Graduates' independent preparation for the testing phase is insufficient and requires a comprehensive approach, namely: mock testing under conditions as close as possible to the accreditation procedure, with the aim of objectively assessing readiness and minimizing stress reactions during initial accreditation; increasing the number of hours allocated to this stage in the curriculum; analyzing typical mistakes and the most difficult questions; and updating the test question database with the necessary adjustments (if any).

Authors' Contributions

D. A. Matsuganov — development of the research concept and design;
M. G. Moskvicheva, D. A. Matsuganov, O. S. Abramovskikh, A. A. Astakhov — preparation and creation of conditions for conducting the accreditation;

D. A. Matsuganov, A. A. Astakhov — development and preparation of scenarios;
M. G. Moskvicheva, D. A. Matsuganov, O. S. Abramovskikh, A. A. Astakhov — data collection, analysis, and interpretation.

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PRACTICAL SESSION "EXAMINATION OF A CADAVER AT THE SITE OF DISCOVERY" USING SIMULATION TECHNOLOGIES

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DOI: 10.46594/2687-0037_2026_2_2174

Abstract. This article presents the results of a comparison between the preparation of the protocol "Examination of a Corpse at the Site of Discovery" using traditional teaching methods and teaching methods that incorporate simulation technologies. It describes systemic issues in the practical training of students in the higher medical education system based on modern pedagogical concepts (andragogy, the theory of purposeful practice, Bloom's taxonomy) and empirical research conducted at the simulation center of N. A. Semashko National Research Institute of Clinical Medicine at the Russian University of Medicine (a Federal State Budgetary Educational Institution of Higher Education under the Ministry of Health of Russia), and substantiates the effectiveness of simulation technologies in developing professional competencies. The results of a retrospective cohort study involving 5th- and 6th-year students are presented. Four scenarios for the session "Examination of a Cadaver at the Scene of an Incident" were developed and tested. The simulation method was shown to be significantly superior to the traditional method. Recommendations for implementing the developed methodology into the educational process are formulated.
Keywords: simulation-based education, medical education, practical skills, forensic medicine, andragogy, pedagogical supervision.
Conflict of interest. The authors declare no conflict of interest.
Funding. This study was conducted without external funding.
Citation: Kosukhina O. I., Leonova L. A., Leonov S. V., Shcherbak M. M., Konyayeva O. E. Practical session "Examination of a corpse at the scene of discovery" using simulation technologies // Virtual Technologies in Medicine. 2026. No. 2. Pp. 57–62. DOI: 10.46594/2687-0037_2026_2_2174
Scientific specialty. 3.2.3 Public Health and Health Care Organization, Sociology and History of Medicine. 3.3.5 Forensic Medicine.
Received by the editorial office on April 30, 2026.
Received after peer review on May 29, 2026.
Accepted for publication on June 1, 2026.

Introduction

The Current State of Practical Training in Medical Education

Modern higher medical education in the Russian Federation and abroad faces a persistent contradiction: while graduates have a high level of theoretical training, their practical skills often fall short of employers' expectations. This gap, known as the "qualification paradox," is recognized as one of the key challenges in professional education in the healthcare sector. Numerous studies show that the traditional educational system, based primarily on the transmission of information and observation of clinical cases without active hands-on practice and practical skill development, does not provide a sufficient level of preparation for practical work.

The main factors contributing to this gap are multifaceted: first, there are organizational constraints, such as the absence of patients with the required medical conditions in clinics at the time of the training session; second, there are legal and ethical barriers, such as patients' refusal to participate in the training process; the need to maintain patient confidentiality; and restrictions imposed by health care legislation; third, pedagogical challenges: large class sizes prevent every student from performing a procedure a sufficient number of times. As a result, the development of practical skills occurs spontaneously, through "trial and error," right at the start of independent professional practice, which poses risks to patients [6; 2; 12; 13; 18].

In the global field of higher education pedagogy, simulation-based medical education (SBME) is considered one of the most effective ways to bridge this gap. Simulation-based learning refers to the reproduction, under controlled conditions, of a segment of professional practice using technical aids (mannequins, simulators, virtual environments) followed by an analysis of the actions taken. The key advantage of SBME is the ability to repeatedly practice procedures—in a manner that is safe for both the patient and the student—with immediate feedback [3; 7; 8; 15; 17].

Several fundamental pedagogical concepts serve as the theoretical basis for the simulation approach.

The first of these is the theory of deliberate practice, developed by Ericsson. According to this theory, a skill becomes automatic not through mere repetition, but through systematic practice with a clearly defined goal, immediate feedback, and correction of errors. A simulation environment perfectly meets these conditions: the learner performs a task, the instructor (or the system) identifies deviations, and during the debriefing, the performance is analyzed and a standard of performance is established [5; 6].

The second significant theoretical component is andragogy (adult education). Upperclassmen (5th–6th years of study) already possess a significant body of theoretical knowledge and initial clinical experience; many students enter universities not "straight out of high school," but after completing college or gaining work experience as mid-level medical personnel. For this category of students, the most effective methods are those based on independent problem-solving, reflection, and the meaningful application of knowledge in a practical context. The andragogical model assumes that the instructor acts not as a conveyor of ready-made solutions, but as an organizer of cognitive activity, creating conditions for self-directed learning [7; 8; 10; 11].

The third theoretical foundation is Bloom's taxonomy in the cognitive and psychomotor domains. Developing the skill of conducting a postmortem examination at the scene of an incident falls within the psychomotor domain and requires progressing through levels ranging from imitation (repeating after the instructor) to automatic performance [13; 16]. A simulation exercise allows for the development of a clear progression: from reproducing the algorithm (the lowest level) to making decisions in non-standard scenarios (the highest level).

Finally, the fourth — and most important — regulatory and methodological guideline is the INACSL (International Nursing Association for Clinical Simulation and Learning) standards, which define the mandatory components of effective simulation: pre-briefing, a realistic scenario, a structured debriefing, and evaluation of results. Debriefing is recognized as "the heart of simulation," since it is precisely during the discussion of actions that reflective understanding and the integration of new experiences take place [6].

Simulation technologies have been actively implemented in the Russian medical education system since the early 2010s, but their use remains uneven. They are most widely used in anesthesiology and intensive care, surgery, and obstetrics [9]. At the same time, as rightly noted in the literature, the discipline of "Forensic Medicine" remains the least covered by simulation-based approaches [2]. Traditionally, practical classes in forensic medicine are based on the analysis of photographic materials, the solution and description of pre-prepared case studies based on expert opinions, or, at best, the observation of a forensic autopsy — the organization of which is currently extremely difficult.

However, according to Part 1 of Article 178 of the Criminal Procedure Code of the Russian Federation (hereinafter referred to as the CPC RF), the investigator conducts an examination of the body with the participation of a forensic medical expert, or, if the expert is unable to participate, a physician [1]. In other words, a physician of any specialty may be called upon to perform this procedure, regardless of their field of expertise. Consequently, all medical school graduates, regardless of their specialty — not only forensic medical experts, but also dentists, pediatricians, and gynecologists — must possess the practical skills to examine a corpse at the scene where it was discovered.

The examination of a corpse at the scene where it was discovered is a specific procedure that follows a set protocol, requires the use of specialized equipment (a forensic pathologist's kit), and, most importantly, involves inter-agency cooperation (investigator, forensic scientist, witnesses) [4; 14]. It is practically impossible to simulate such a situation in real life due to legal restrictions (Article 310 of the Criminal Code of the Russian Federation (hereinafter—the Criminal Code of the Russian Federation) regarding the non-disclosure of preliminary investigation data) and the lack of access to actual crime scenes for educational purposes [2]. This is precisely why the simulation approach in forensic medicine is not merely desirable but the only feasible way to develop comprehensive skills.

Research Goal, Objective, Topic, and Hypothesis

The research object is a practical session on the topic "Examination of a Corpse at the Scene of Discovery," conducted in a simulation center.

The subject of the research is the organizational and pedagogical system for conducting this session, including scenarios, checklists, and stages of pedagogical monitoring.

The research objective is to develop scenarios for the practical session "Examination of a Cadaver at the Site of Discovery" for fifth-year dental students and sixth-year medical students and to demonstrate its effectiveness compared to traditional teaching methods.

The hypothesis is that implementing the developed training program at the simulation center will improve the overall level of professional training, help students develop consistent practical skills in performing postmortem examinations, and allow them to hone their communication skills in a teamwork setting. The success of this endeavor depends on two conditions: pedagogical supervision must strictly align with the objectives of each stage, and the simulators used must provide a high degree of realism and immersion in a professional environment.

Materials and Methods

The study was conducted using a quasi-experimental design with randomized assignment of treatment groups. The data consisted of autopsy reports completed by fifth-year students in the School of Dentistry (624 students in the 2024–2025 academic year) and sixth-year students in the School of Medicine (580 students). The historical control group consisted of similar protocols from students in the previous cohort (2023–2024 academic year): 593 students (5th year) and 571 students (6th year). Students in the historical control group worked with photographic images (1 to 4 images per scenario). Assessment was conducted using standardized checklists developed for four types of scenarios: blast injuries, gunshot wounds, and injuries caused by blunt and sharp objects (Figs. 1–4). Classes in both the experimental and historical control groups were conducted by the same three instructors.

Fig. 1. “Injury Caused by Sharp Objects” Scenario

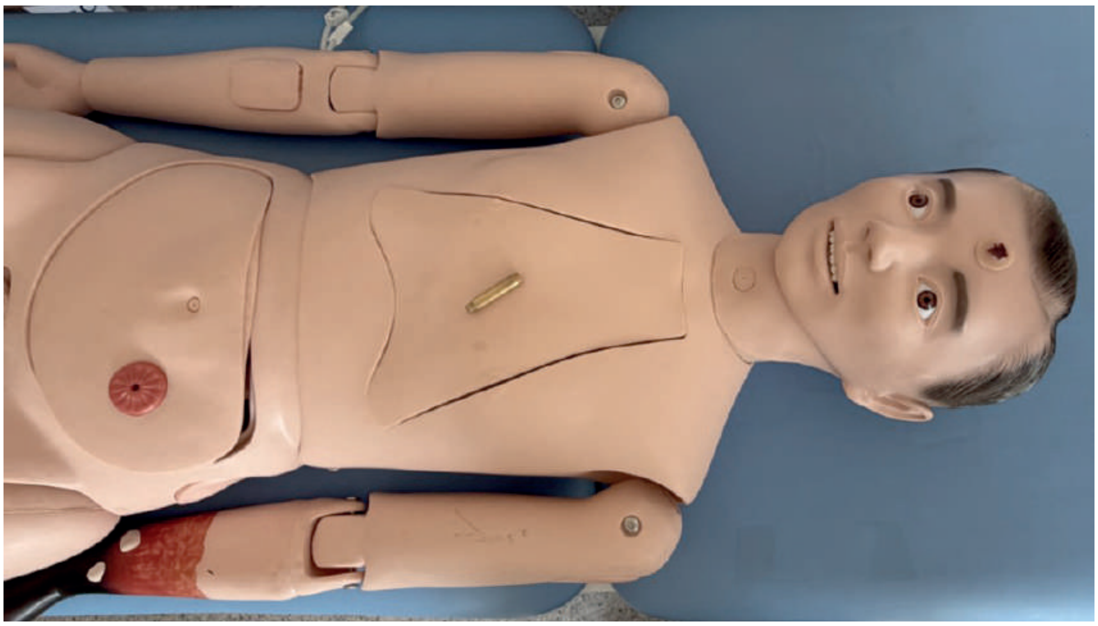

Fig. 2. Scenario: “Gunshot Wound”

Each item on the checklist was scored either on a binary scale (100 points for full compliance, 0 for non-compliance) or on a continuous scale (1–99 points for partial compliance). Groups of three to five people were randomly assigned a scenario, and the analysis was conducted based on individual protocols.

Fig. 3. Scenario: "Injury Caused by a Blunt, Solid Object"

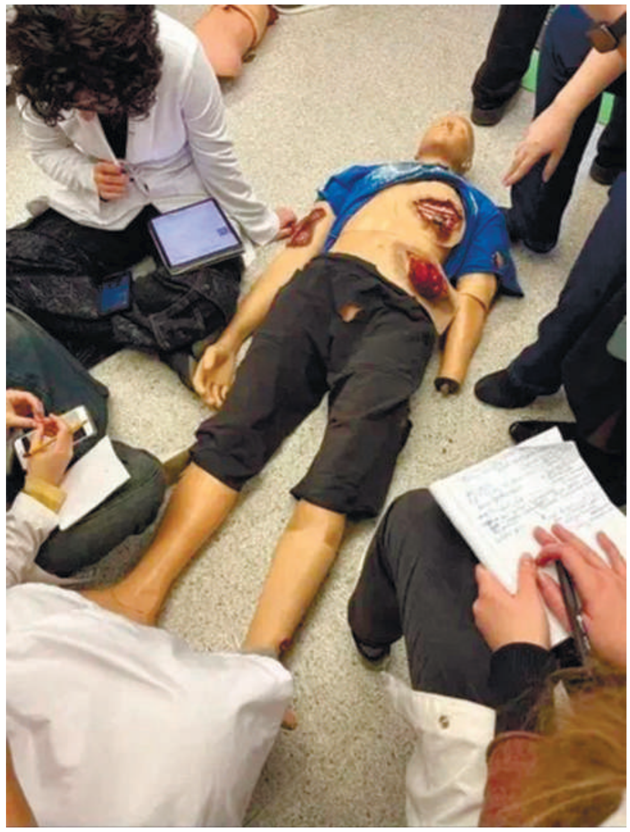

Fig. 4. Scenario: "Mine- and Explosive-Related Injury"

The event was held at the simulation center of N. A. Semashko Scientific and Educational Institute of Clinical Medicine. The equipment and supplies included: three adult male manikins, one adult female manikin, and one infant manikin; sets of injury simulators (50 units), a set of internal organs; a forensic medical examiner's kit with standard equipment; mock trauma instruments, blood and clot simulators, bullets and shrapnel, and sheets. The total duration of each session was 240 minutes.

The lesson structure (breakdown) included the following stages with the following time allocations: initial assessment (5%), instruction and goal setting (20%), completion of the learning task in teams (50%), debriefing with error analysis (15%), and final preparation of the examination report at the simulation center (10%). The report was submitted for review no later than three days before the assessment session and was included in the student's portfolio as a prerequisite for the assessment.

The entrance assessment took the form of a 15-question multiple-choice quiz. Preparatory materials (lectures, presentations) were made available to students online.

Results

Comparative effectiveness. In the experimental group (simulation education), sixth-year medical students achieved an average protocol completion score of 93 (out of a maximum of 100), with a standard deviation of 5.7. The confidence interval ranged from 92.54 to 93.46, meaning that, with 95% probability, the true mean lies within this range. In the historical control group, which worked with photographs, the mean score was 67, with a standard deviation of 8.0; the confidence interval ranged from 66.34 to 67.66. The analysis used Student's t-test, which yielded a value of $t = 63.41$ — an extremely high value, indicating that the variation in the sample was not random. For fifth-year students in the School of Dentistry, the difference was similar: 87 versus 64 points. In the experimental group, the standard deviation was 6.2, and the confidence interval was 86.51–87.49. In the historical control group, the standard deviation was 8.4; the confidence interval ranged from 63.32 to 64.68, and the Student's t-test for the dental groups yielded a value of 54.4. The difference between the means (87 and 64), given these sample sizes and variances, cannot be accidental, indicating that the differences are statistically significant ($p < 0.01$) and are consistent with meta-analysis data showing that the simulation approach yields a 20–30 percentage point advantage over traditional methods in the assessment of practical skills (Fig. 1).

Following the training, students demonstrated the development of these skills. The use of mannequins, attachable injury simulators, and a forensic medical examiner's kit allowed students to practice the sequence of actions in conditions as close to real-life as possible. Students had the opportunity to repeatedly practice procedures (body examination, documentation of injuries, and collection of physical evidence) without the risk of compromising the evidentiary value of the evidence or violating procedural rules.

Development of Team Collaboration. The assignment of roles (investigator, expert, forensic specialist, witnesses) within each scenario helped develop communication skills. During the debriefing, not only technical errors but also communication breakdowns (failure to convey information, duplication of actions, role conflicts) were noted.

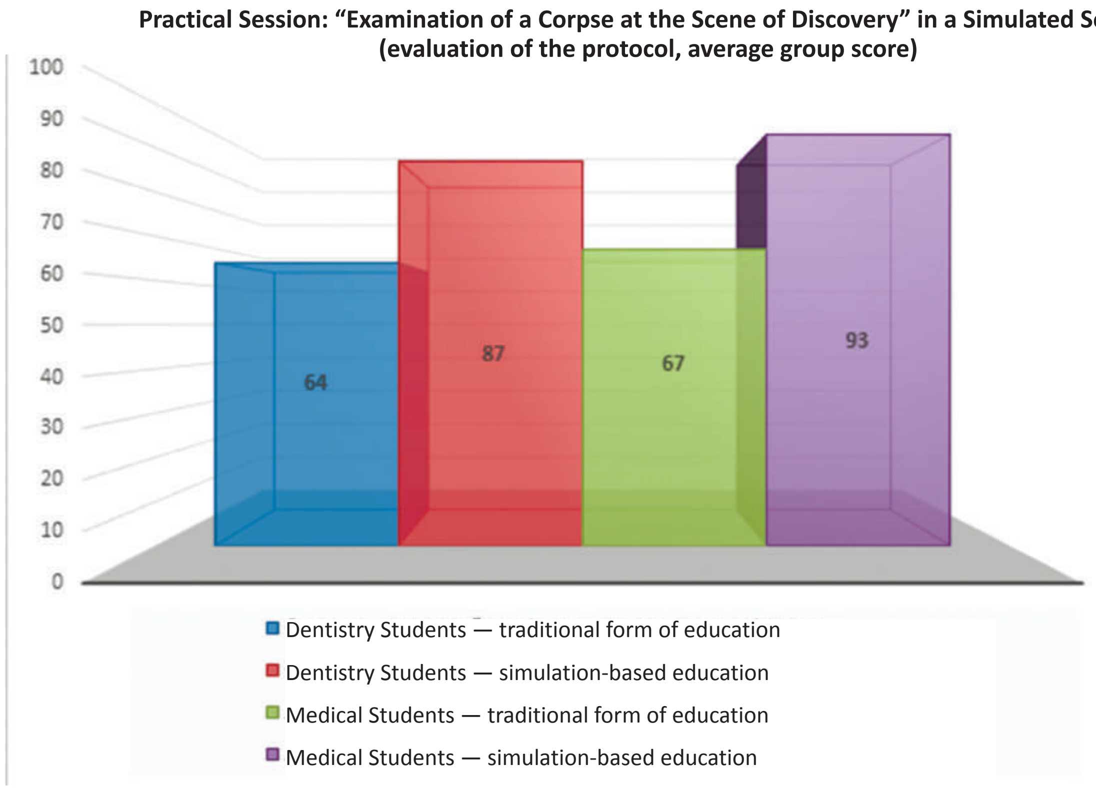

Figure 1. Comparison of traditional teaching methods with simulation-based methods among 5th-year dental students and 6th-year medical students

Students recognized the experience of working in an interdisciplinary team as one of the most valuable aspects of the class.

Overcoming the Limitations of Traditional Methods. The study confirmed that the simulation approach allows for the circumvention of key barriers: the inability to visit a real incident site for organizational reasons, the lack of a guaranteed occurrence of a suitable case during class hours, and legal restrictions (Article 310 of the Criminal Code of the Russian Federation). Simulation provides standardized conditions for all trainees, which is impossible with variable real-life cases.

Discussion

The results obtained fit into the broader context of research on the effectiveness of simulation-based education. According to the theory of deliberate practice, the key factor is not the duration of training but its structure: the presence of a clear goal, immediate feedback, and the opportunity for correction. In our study, these conditions were implemented through debriefing — a mandatory component that took place immediately after the task was completed and accounted for 15% of the session time. The literature indicates that debriefing increases the effectiveness of simulation by 2–3 times compared to simply repeating the procedure without analyzing errors.

The andragogical context is also important: 5th- and 6th-year students already have experience working with real patients (as part of their clinical rotations). For them, simulation is not a “toy” but a tool for practicing algorithms that are rarely encountered in real life or involve high risks. The students’ self-assessment scores, collected through an anonymous survey, indicate a high level of satisfaction specifically with the realism of the scenarios and the opportunity to “make mistakes safely.”

It is important to emphasize that the proposed methodology fully complies with INACSL standards: a pre-briefing was conducted (including an overview of “hot spots”), the scenario was authentic to a professional situation, the debriefing was structured according to the “pros/cons/recommendations” model, and the results were evaluated using structured checklists. A distinctive feature of our approach is the integration of interagency collaboration into the simulation—an aspect that is rarely modeled in standard medical simulation courses.

Conclusion

The system developed and tested for conducting the practical training session “Examination of a Cadaver at the Scene of Discovery” in a simulation center has proven effective. Students who trained using mannequins and simulators scored an average of 93 points (School of Medicine) and 87 points (School of Dentistry) on their protocols, which significantly exceeded the results of the control groups (67 and 64 points, respectively). Simulation technologies enabled students to develop practical skills in conducting a postmortem examination, including the use of specialized instruments and the documentation of findings in procedural records, under conditions that simulate real-world scenarios.

Teamwork within an interdisciplinary group (investigator, expert, forensic specialist, witnesses) helped develop effective communication strategies and coordinate actions. Simulation-based training overcomes the organizational, ethical, and legal limitations of the traditional approach (in particular, the prohibition on disclosing preliminary investigation data). It ensures repeated, controlled practice of the skill with step-by-step debriefing.

The research hypothesis has been confirmed: pedagogical supervision synchronized with the objectives of each stage, combined with the use of highly realistic simulators, guarantees an improvement in the level of training for future forensic medicine physicians.

It is recommended that the developed scenarios (four types of mechanical trauma) and methodological guidance be incorporated into the curricula of disciplines for the medical and dental faculties, as well as for other medical specialties, whose practitioners, pursuant to Article 178 of the Criminal Procedure Code of the Russian Federation, may be called upon to examine a corpse at the scene of an incident.

Authors' Contributions

O. I. Kosukhina — development of the research concept and design;
M. M. Shcherbak, O. E. Konyayeva — preparation of simulators and creation of conditions for conducting classes; Leonova L. A., Leonov S. V., Kosukhina O. I. — development and preparation of scenarios; Kosukhina O. I., Leonova L. A. — data collection, analysis, and interpretation;
Kosukhina, O. I., Leonov, S. V., Shcherbak, M. M., and Konyayeva, O. E. — statistical analysis of data and article design.

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MODERN APPROACHES TO TEACHING MEDICAL STUDENTS IN THE DEPARTMENT OF PEDIATRICS: PROBLEM-BASED AND INDEPENDENT LEARNING USING SIMULATION TECHNOLOGIES

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DOI: 10.46594/2687-0037_2026_2_2166

Abstract. The aim of this study is to evaluate the effectiveness of task-based and self-directed learning among students in the Department of Pediatrics, using simulation technologies, in the development of practical skills and clinical reasoning. The study included 120 fourth- and fifth-year students from the Faculty of Pediatrics at Tashkent State Medical University. The participants were divided into a main group (n = 60), which was trained using a task-oriented and self-directed learning model incorporating simulation technologies, and a comparison group (n = 60), which was trained using traditional methods. The results showed that a high level of practical skill development, as assessed by the OSCE, was observed in 86.7% of students in the experimental group, which was significantly higher than the corresponding figure in the control group—61.7% ($p < 0.05$). The mean total score for performing a pediatric examination was 84.3 ± 6.2 points in the main group and 72.5 ± 7.1 points in the comparison group ($p < 0.01$). The number of errors in assessing vital signs was significantly lower in the main group (0.9 ± 0.3) compared with the comparison group (1.6 ± 0.4; $p < 0.05$). In addition, the proportion of students demonstrating confidence and logical consistency in their clinical decisions was 81.7% in the main group versus 58.3% in the comparison group ($p < 0.05$). The results obtained demonstrate the high effectiveness of task-oriented and independent learning using simulation technologies. This educational model contributes to improving students' practical training, developing clinical reasoning, and reducing the number of diagnostic errors, thereby enhancing the readiness of future pediatricians for professional practice.
Keywords: simulation-based education, medical education, pediatrics, problem-based learning, clinical reasoning, practical skills, OSCE.
Conflict of Interest. The authors declare no conflict of interest.
Funding. This study was conducted without external funding.
Citation: Tadzhiev M. M., Mirkhoshimova K. M., Kholmirzayev Z. R. Modern approaches to teaching students in the pediatric faculty: problem-based and independent work using simulation technologies // Virtual Technologies in Medicine. 2026. No. 2. Pp. 63–66. DOI: 10.46594/2687-0037_2026_2_2166
Scientific specialty: 3.2.3 Public Health and Health Care Organization, Sociology and History of Medicine.

Received by the editorial office on March 31, 2026.
Accepted after peer review on June 24, 2026.
Accepted for publication on July 1, 2026.

Introduction

Modern medical education is focused on developing a set of professional competencies in future physicians, including clinical reasoning, practical skills, and the ability to make independent decisions. In the context of the transition to a competency-based model of education, the implementation of educational technologies aimed at stimulating students' learning activities and fostering their independence has become particularly important [2; 9].

One of the promising areas for modernizing medical education is the use of simulation technologies. Simulation-based training allows for the modeling of clinical situations that closely resemble real-world practice, while providing a safe environment for honing professional skills [1; 3; 4]. This approach is particularly relevant for training students in the pediatric department, as working with children requires a high degree of responsibility, diagnostic accuracy, and the ability to make clinical decisions quickly. According to several studies, simulation-based training methods significantly improve students' clinical preparedness and help them develop lasting professional skills [5; 6; 7; 8].

Problem-based learning, combined with simulation technologies, promotes the development of analytical thinking, the formulation of clinical examination algorithms, and an increase in students' level of independence [4; 6; 8]. Within this educational model, students are actively involved in solving clinical problems, analyzing symptoms and examination findings, formulating diagnostic hypotheses, and determining patient management strategies [5; 6].

Research objective

To evaluate the effectiveness of problem-based and independent learning among students in the pediatric faculty using simulation technologies in the development of practical skills and clinical reasoning.

Materials and Methods

The study included 120 fourth- and fifth-year students from the Faculty of Pediatrics at Tashkent State Medical University. All study participants were divided into two groups: the main group (n = 60) and the comparison group (n = 60).

Students in the main group were taught using a problem-based and self-directed learning model at the university's simulation center. The presented structure of the educational process reflects a phased model of task-oriented learning for students in the Faculty of Pediatrics using simulation technologies. This model includes sequential stages of professional competency development — from the acquisition of theoretical knowledge to the comprehensive assessment of clinical skills (Table 1).

The first stage of training consists of theoretical instruction aimed at teaching students clinical algorithms for pediatric examinations, as well as the principles of diagnosis and symptom interpretation. The main objective of this stage is to build a foundation of theoretical knowledge and develop algorithmic clinical thinking. Mastery of the material is assessed through tests and oral examinations.

The next stage involves familiarizing students with simulation equipment.

Table 1

Structure of Task-Oriented Student Learning Using Simulation Technologies

Training Stage	Learning Content	Skills Developed	Form of Assessment
Theoretical Training	Study of clinical algorithms for pediatric examination, diagnosis, and interpretation of symptoms	Theoretical knowledge, algorithmic thinking	Testing, oral examination
Familiarization with simulation equipment	Working with manikins and simulators, learning to use simulation center equipment	Basic practical skills, proficiency with equipment	Instructor supervision
Practicing clinical scenarios	Simulation of typical pediatric situations (fever, respiratory disorders, dehydration, etc.)	Clinical reasoning, diagnosis, decision-making	Practical skills checklists
Independent student work	Independent completion of clinical assignments and analysis of examination results	Independence, analytical thinking	Instructor observation
Review of clinical situations (debriefing)	Analysis of errors, discussion of diagnostic and treatment algorithms	Reflection, clinical analysis	Group discussion
Final Skills Assessment	Conducting an Objective Structured Clinical Examination (OSCE)	Comprehensive Clinical Competence	OSCE

During this stage, students learn to work with manikins and simulators used in the simulation center, which helps them develop basic practical skills and proficiency in using medical equipment. The instructor monitors the correctness of the students' actions.

During the clinical scenario training phase, typical pediatric situations are simulated, such as febrile episodes, respiratory distress, dehydration, and other clinical conditions. This phase is designed to develop clinical reasoning and build diagnostic and clinical decision-making skills. Task performance is assessed using practical skills checklists.

The stage of independent student work plays a particularly important role in the educational process. During this period, students independently complete clinical assignments, analyze examination results, and formulate diagnostic conclusions. This approach fosters the development of independence, analytical thinking, and the ability to make clinical decisions. Supervision takes the form of observation by the instructor.

An important element of the training is the review of clinical scenarios (debriefing), during which mistakes are analyzed, diagnostic and treatment algorithms are discussed, and students' actions are evaluated. This stage helps students develop reflective thinking and deepen their clinical analysis.

The final stage is a summative assessment of the skills acquired, which takes the form of an Objective Structured Clinical Examination (OSCE). This assessment format allows for a comprehensive evaluation of students' practical skills, clinical reasoning, and readiness for professional practice.

Thus, the presented structure of simulation-based education ensures the sequential development of theoretical knowledge, practical skills, and clinical competencies among students in the pediatric department. This approach is widely used in international medical education and has proven effective in developing clinical competencies [5; 9].

Students in the comparison group were trained using a traditional educational model based on lectures and practical sessions without the use of simulation technologies.

The effectiveness of the training was assessed using:

- an objective structured clinical examination (OSCE);
- checklists for assessing practical skills;
- a final theoretical and practical assessment.

Statistical analysis of the data was performed using standard methods of variational statistics. The statistical significance of differences between groups was assessed at a significance level of $p < 0.05$.

Study Results

Analysis of the presented data reveals statistically significant differences between the main group and the comparison group for most of the studied indicators of learning effectiveness.

A high level of practical skills, as assessed by the Objective Structured Clinical Examination (OSCE), was observed in 52 students in the main group, accounting for 86.7%. In the comparison group, this figure was significantly lower, at 61.7% (37 students). The differences between the groups are statistically significant ($p < 0.05$), indicating the greater effectiveness of the educational model used in the main group (Table 2).

The mean total score for the pediatric examination was also significantly higher among students in the main group, at 84.3 ± 6.2 points, whereas in the comparison group this score was 72.5 ± 7.1 points. The observed differences are statistically significant ($p < 0.01$) and indicate a higher level of clinical skill development and the ability to interpret clinical data among students in the main group.

Table 2

Comparative Assessment of Student Learning Outcomes

Indicator	Main group (n = 60)	Comparison group (n = 60)	p
High level of practical skills on the OSCE	52 (86.7%)	37 (61.7%)	< 0.05
Average score for pediatric examination (points)	84.3 ± 6.2	72.5 ± 7.1	< 0.01
Number of errors in assessing vital signs	0.9 ± 0.3	1.6 ± 0.4	< 0.05
Students demonstrating confidence and logical consistency in clinical decision-making	49 (81.7%)	35 (58.3%)	< 0.05

An analysis of the error rate in assessing vital signs revealed that in the main group, this rate was significantly lower, at 0.9 ± 0.3 errors per student, whereas in the comparison group it reached 1.6 ± 0.4. The differences between the groups are statistically significant ($p < 0.05$), reflecting more accurate performance of diagnostic procedures by students in the main group.

In addition, students in the main group demonstrated confidence and logical consistency in clinical decision-making significantly more often. This indicator was observed in 49 students (81.7%), whereas in the comparison group, it was observed in 35 students (58.3%). The differences between the groups are also statistically significant ($p < 0.05$).

During the error analysis, it was found that students in the main group made significantly fewer errors when assessing vital signs and interpreting physical examination data. The frequency of such errors decreased by a factor of 1.8 compared to students in the comparison group.

Thus, the results indicate that the use of task-oriented and independent learning with simulation technologies contributes to a higher level of practical skill development, a reduction in the number of diagnostic errors, and the development of clinical reasoning among students in the pediatric faculty.

Discussion

The results confirm the high effectiveness of simulation technologies in the educational process at a medical university. The use of a task-oriented approach significantly increases student engagement in the learning process and contributes to the development of lasting practical skills [6; 8]. Simulation technologies create conditions for repeated practice of clinical procedures, which is particularly important when training students in the pediatric department, where many procedures require a high degree of precision and accuracy [7]. The ability to simulate various clinical situations contributes to the development of clinical reasoning and the formation of diagnostic and treatment algorithms [9]. In addition, students' independent work in a simulation center stimulates their cognitive activity, promotes the development of self-control skills, and increases their motivation to learn.

Conclusion

The results of this study showed that task-oriented and independent learning among students in the pediatric faculty, using simulation technologies, is an effective educational tool. The application of this learning model contributes to a significant improvement in students' practical training, the development of clinical reasoning, and a reduction in the number of diagnostic errors. The use of simulation technologies creates a safe educational environment for developing professional skills and enhances the readiness of future pediatricians for clinical practice within the modern healthcare system.

Authors' Contributions:

M. M. Tadzhiev — development of the study concept and design, scientific supervision, preparation, and final editing of the manuscript; H. M. Mirkhoshimova — data collection and processing, statistical analysis, and formatting of the article; Z. R. Kholmirzaev — participation in the analysis and interpretation of the results.

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PLANNING THE WORKLOAD OF LABORATORY STAFF DURING A PANDEMIC USING THE ANYLOGIC SOFTWARE SUITE

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DOI: 10.46594/2687-0037_2026_2_2167

Abstract. The sharp increase in the burden on the healthcare system during the COVID-19 pandemic revealed the ineffectiveness of traditional methods for calculating labor productivity based on mathematical formulas. These methods do not account for the dynamics of work processes or challenges in planning human resources, equipment, and space. This leads to inefficient workload distribution, especially when — as in the case of clinical laboratories — there was a need to process thousands of samples for PCR testing daily. The aim of this study is to develop and analyze a method for planning workload using simulation modeling in AnyLogic, which allows for the visualization and optimization of laboratory processes. The objectives include analyzing existing approaches, describing the methodology, applying it to a PCR laboratory case study, and evaluating its benefits in a pandemic context. The proposed approach involves timing technological processes, collecting data in tabular form, and creating a digital model of the laboratory to identify "bottlenecks," equipment downtime, and staff downtime. Using a PCR laboratory as an example, the paper demonstrates the ability to optimize resources, calculate maximum throughput, and justify procurement decisions. This method allows for improving the efficiency of laboratory operations in situations of unpredictable demand, minimizing the risks of disruptions and financial losses.

Keywords: simulation modeling, AnyLogic, workload planning, laboratory production, the COVID-19 pandemic, Lean management.
Conflict of Interest: the authors declare no conflict of interest.
Funding: this study was conducted without external funding.
Citation: Orlov D. V., Nazarov N. O., Kovaleva E. S., Donsckaia A. R. Workload planning for laboratory staff during the pandemic using the AnyLogic software suite // Virtual Technologies in Medicine. 2026. No. 2. Pp. 67–75. DOI: 10.46594/2687-0037_2026_2_2167
Scientific specialty: 3.2.3 Public Health and Health Care Organization, Sociology and History of Medicine.
Received by the editorial office on April 3, 2026.
Received after peer review on May 21, 2026.
Accepted for publication on June 1, 2026.

Introduction

Traditional planning methods in healthcare rely on regulatory documents, such as Order No. 380 of the Ministry of Health of the Russian Federation (hereinafter "Ministry of Health of the Russian Federation"), in which staffing needs are calculated using a formula that takes into account the number of tests, an employee's tenure, and time standards. Such approaches have been implemented using general-purpose software, such as Microsoft Excel, to model economic processes [1]. However, they do not allow for the consideration of stochastic factors and real-time interactions.

The following patents were considered as prototypes: RU 2216038 C2 (a method for forecasting production volumes and planning resources) [7] and Patent No. 521569 (a device for queue simulation) [8]. These methods describe the stages of resource flow but are not adapted for clinical medicine and do not identify bottlenecks in laboratory processes.

Recent studies highlight the role of simulation modeling in healthcare during pandemics. For example, studies modeling the spread of COVID-19 using AnyLogic analyze vaccine logistics and evaluate various scenarios [17]. Other studies use discrete-event modeling to optimize testing [16] and assess the workload on laboratories [13]. AnyLogic integrates agent-based, discrete-event, and system dynamics modeling, making it well-suited for complex systems such as laboratories [17].

In Russian practice, the GOST R ISO 15189-2015 and GOST R ISO 15190-2023 standards establish key requirements for the operation of medical laboratories, while the Ministry of Health's recommendations on laboratory diagnosis of COVID-19 focus on three stages of the laboratory process. GOST R ISO 15189-2015 establishes requirements for the competence of medical laboratories, while GOST R ISO 15190-2023 establishes requirements for safety. The Russian Ministry of Health's recommendations on laboratory diagnosis of COVID-19 [2] emphasize the need to consider the pre-analytical, analytical, and post-analytical stages.

The aim of this study is to develop and analyze a method for workload planning using simulation modeling in AnyLogic, which allows for the visualization and optimization of laboratory processes. The objectives include analyzing existing approaches, describing the methodology, applying it to a PCR laboratory as a case study, and evaluating its advantages in the context of a pandemic.

Materials and Methods

The workload planning method using simulation modeling in AnyLogic was developed based on the PCR laboratory at the State Budgetary Healthcare Institution "City Children's Polyclinic No. 2" and consisted of three stages.

In *the first stage*, process timing was conducted — measuring the time required for each stage of laboratory production, including equipment operation at full capacity. The data was compiled into a table with the following parameters: room, stage number, time per person, equipment name, specifications, equipment operating time, number of tests, and number of staff (lab technicians, doctors). At this stage, processes were timed multiple times (at least 30 measurements for each operation) at different times of the day and on different days of the week to account for possible fluctuations in workload and other factors. The timing results were statistically analyzed, including calculations of the average time, standard deviation, and minimum and maximum times.

Statistical analysis of the timing results was performed using StatSoft Statistica 10 according to the following procedure: for each operation, at least 30 independent measurements ($n \geq 30$) were collected, taken at different times of the day and on different workdays. Standard descriptive statistics were used to describe the data: mean, median, standard deviation, minimum and maximum values, and quartiles. Histograms and QQ plots were constructed for an initial visual assessment of the distributions.

A formal test of the empirical data's conformity to standard distributions was performed using the Shapiro — Wilk test for small- to medium-sized samples and the Kolmogorov — Smirnov test with the Lilliefors correction for large samples. To assess the suitability of alternative parametric distributions (log-normal, Weibull, exponential), the Anderson — Darling goodness-of-fit test was applied, along with a comparison using the AIC/BIC information criteria when fitting parametric models. Distribution parameters (μ and σ for the normal distribution) were estimated using the maximum likelihood method; 95% confidence intervals are additionally provided for key parameters. The choice of distribution for specification in AnyLogic was made according to the following rule: if normality tests did not reject H0 ($p \geq 0.05$) and a visual assessment did not reveal pronounced asymmetry, the normal distribution was used; in the case of pronounced positive skewness, a log-normal or Weibull distribution was used (selected based on the lower AIC); for complex distribution shapes, an empirical nonparametric distribution was loaded into the model.

To model the execution times of operations in AnyLogic, probability distributions were used, whose parameters (mean and standard deviation for the normal distribution) were determined based on the results of statistical analysis of the timing data.

The second stage consisted of data collection and processing — the table is filled out based on observations. An example for a PCR laboratory includes the stages of nucleic acid (NA) extraction, amplification, and recording of results.

The *third stage* involves simulation modeling, during which data is imported into AnyLogic to create a digital model. The model simulates the flow of samples, visualizing capacity utilization (green — sufficient capacity, yellow — risk of overload, red — resource shortage). Iterative optimization is possible by increasing staff or equipment.

Simulation is conducted in discrete-event mode, taking into account stochastic variables (sample arrival times, variability of operations). The following metrics are used for analysis: maximum number of tests per shift, downtime, and employee utilization rate.

From a systems analysis perspective, a PCR laboratory is described as a network of stages $s \in S$ through which each sample passes. At each stage, there is a limited number of staff members n_s and pieces of equipment m_s, which determine the throughput $\mu_s (n_s, m_s)$. The flow of samples arrives at an average rate of λ. For stable operation, the condition $\rho_s = \lambda / (\mu_s(n_s, m_s)) \leq 1$ must be satisfied, which prevents overload and the growth of queues.

The end-to-end processing time for a sample passing through the laboratory can be expressed as:

$$T_{flow} = \sum s \in S \, (W_{q,s} + t_s),$$

where $W_{q,s}$ is the average waiting time in the queue at a stage, and t_s is the processing time. This indicator is a key performance metric, as it directly reflects the speed at which diagnostic results are obtained.

Thus, the problem boils down to minimizing the average throughput time:

$$T_{flow} \rightarrow \min(n_s, m_s),$$

provided that $\rho_s \leq 1$ for all stages. Simulation modeling in AnyLogic allows us to vary the number of employees and pieces of equipment, evaluate the impact of these parameters on the metrics T_{flow} and $W_{(q,s)}$, and thereby identify the optimal workload planning scenario.

Visualization is achieved by entering data from Table 1 into the AnyLogic software and constructing a digital model of the laboratory production process (Fig. 1).

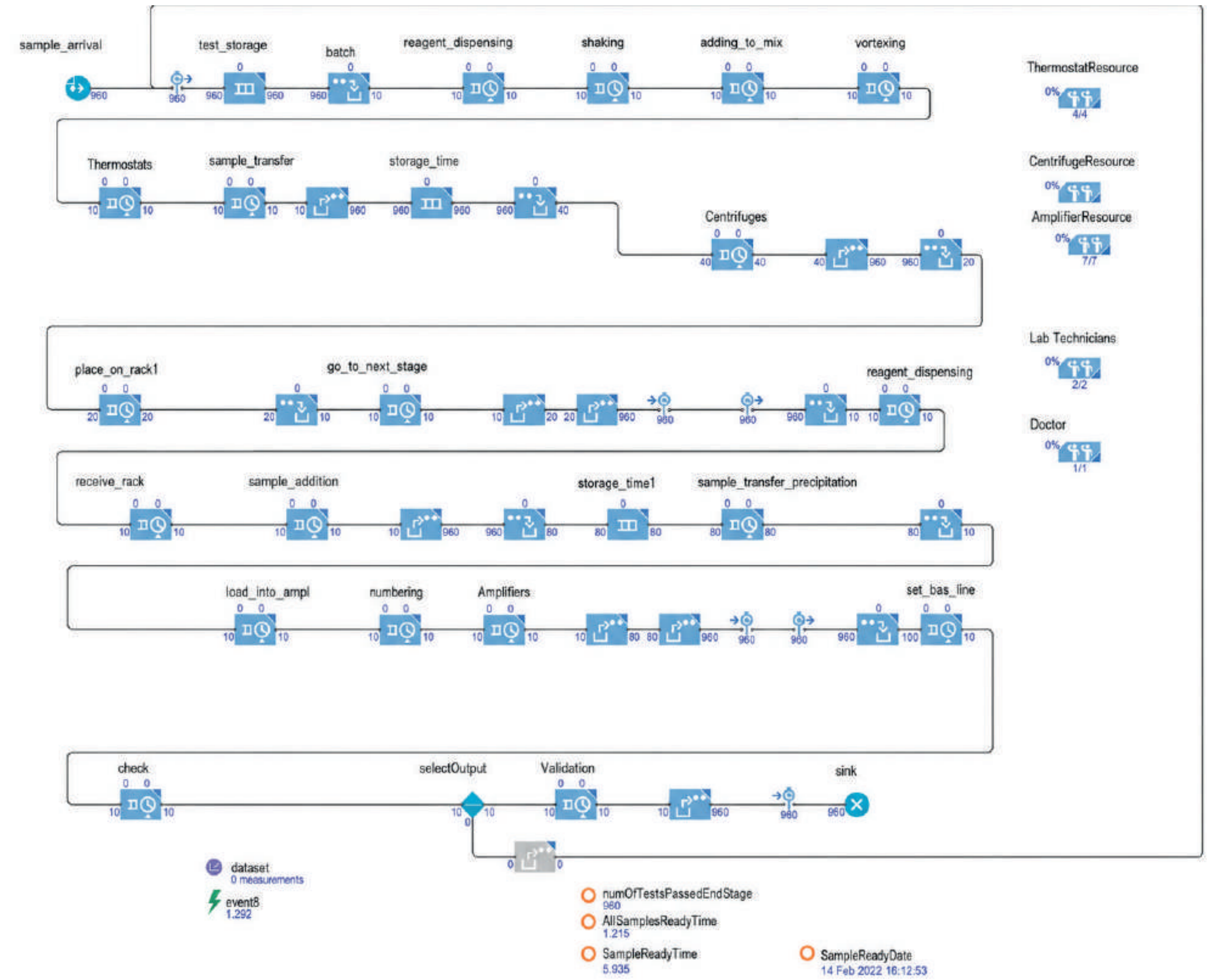

Fig. 1. Visualization of laboratory production

Model validation and verification

The model was validated and verified to assess its adequacy in reflecting actual processes in a PCR laboratory. To validate the model, a comparison was conducted between the model's output data (throughput, analysis turnaround time) and actual laboratory data for a comparable time period.

Model validation consisted of three components: 1) a statistical comparison of the model's output metrics and observed data, 2) an expert assessment of the model's realism, and 3) a sensitivity analysis.

1. Key Performance Indicators (KPIs):
   - average daily throughput (tests/day);
   - average end-to-end sample processing time Tflow (hours);
   - proportion of repeat tests (%);
   - utilization rate of key equipment (% of operating time);
   - average staff downtime (hours per shift).
2. Comparison data:
   - actual observations prior to implementation: average daily workload of 2,099 tests/day, monthly volume of 40,370 (source data from the laboratory's archives).
   - Actual observations after implementation: average daily workload of 4,416 tests/day, total monthly volume of 73,138.
   - Timing data: for each operation, n ≥ 30 measurements (see Table 1).
   - Simulation results: Each scenario configuration had R = 500 independent Monte Carlo replications; descriptive statistics were extracted from each replication, and then the means and 95% confidence intervals were aggregated across the replications.
3. Statistical tests:
   - To compare continuous mean measures, the two-sample t-test (Welch) was used when the normality assumption was met; when normality was not met, the nonparametric Mann–Whitney test was used. The mean ± SD, test statistic, 95% CI for the difference in

Table 1

Statistical Tests

Measure	Before (mean ± SD, n)	After (mean ± SD, n)	Difference (after – before)	95% CI	p
Daily throughput (tests/day)	2099 ± 210 (n = 60)	4416 ± 340 (n = 120)	+2317	2236–2398	<0.001
Proportion of repeat examinations (%)	9.63% (x = 3,888; N = 40,370)	1.67% (x = 1,221; N = 73,138)	−7.96 percentage points	−8.21% — −7.71%	<0.001

means, and p-value are presented (Table 1).

Experts from among the laboratory staff (the laboratory director and senior lab technicians) assessed the model's realism and its alignment with their understanding of work processes. A sensitivity analysis of the model was conducted to assess its response to changes in input parameters (operation execution time, number of staff) in order to identify the most influential parameters. The model was reviewed by the laboratory director and senior lab technicians for compliance with actual operating procedures and time standards; the experts' comments were incorporated into iterative improvements.

Sensitivity analysis: for key input parameters (operation times, number of employees, number of amplifiers), one-dimensional and factorial analyses were performed — the impact of the parameters was assessed based on changes in Tflow, throughput, and the downtime rate; the results were used to determine investment priorities (personnel/equipment).

Table 2

Timing of the Laboratory Process

Room	Stage (stage number)	Duration per employee	Average time required to operate the equipment, (h)	Number of tests	Number of people per piece of equipment	
					lab technician	doctor
Zone 1 1-room apartment	1	preparation of reagents for NK isolation	0.116	96	1	
		shaking	0.033	96	1	
		adding samples to the mixture for NC extraction	0.216	96	1	
		vortexing and transferring samples to the thermostat	0.033	96	1	
		thermostatization	0.25	96	1	
		assembly and mounting in a stand	0.033	48	1	
		centrifugation	0.016	48	1	
		plate assembly	0.016	48	1	
		centrifugation	0.016	45	1	
		placing test tubes on a rack	0.016	45	1	
		transferring the rack to the next stage	0.008	96	1	
amplification stage	2	extraction of amplification reagent	0.1	96	1	1
		acceptance of the tripod for the stage	0.016	96		1
		adding samples to the amplification mixture	0.183	96		1
		transferring samples and centrifuging them on a vortex mixer	0.016	12		1
		loading samples into the amplifier	0.033	96		1
		well numbering in the amplification program	0.05	96		1
		start the amplification program	1.28			1
Result recording stage	3	establishing the baseline	0.016	96		1
		checking controls and calculating the validation line shift	0.016	3		1
		result validation	0.066	93		1

Research Results
The results of the first and second stages of the study are presented in Table 2.

Based on the data obtained, the AnyLogic computer simulation software generates a digital model of the laboratory and the process flow, specifying the characteristics of each stage of the laboratory process. Once the model of the existing laboratory has been created, the processes are simulated on the computer. The model visualizes the duration of the tests being performed and the movement of samples at each stage. The model allows for increasing the number of staff, equipment, and stages; the output calculates the maximum number of tests that can be performed.

Using a PCR laboratory during the COVID-19 pandemic as an example, the model demonstrated:
- Step 1 (nucleic acid extraction): time required to prepare reagents — 0.116 hours per 96 tests, involving 1 lab technician; bottleneck — centrifugation (0.016 hours per 48 tests);
- Stage 2 (amplification): sample loading—0.183 hours per 96 tests; starting the amplifier — 1.28 hours;
- Stage 3 (result processing): validation — 0.066 hours per 93 tests.

The AnyLogic model identified bottlenecks in the amplification stage (red marker at > 500 samples/shift), where additional staff is required (increasing the number of lab technicians from 1 to 2 boosts productivity by 30%). The

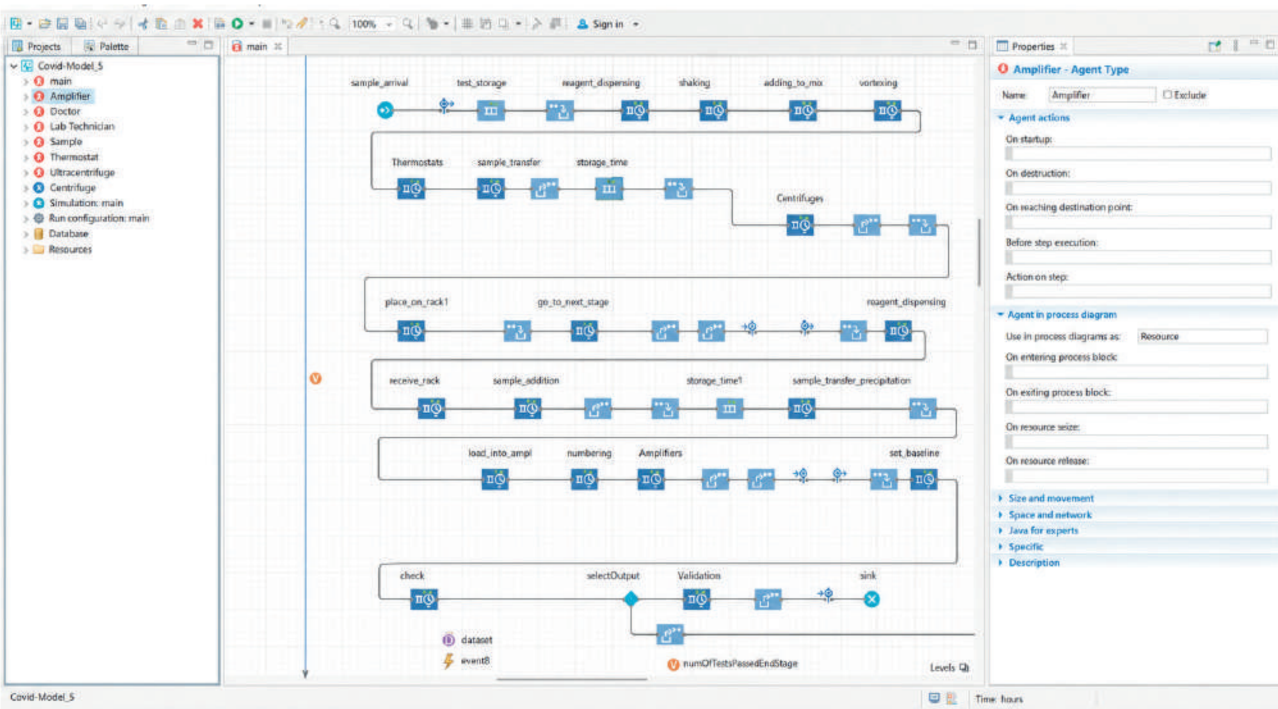

Fig. 2. Digital model of the laboratory

maximum daily capacity is 864 tests in the base configuration, with the potential to increase to 1,200 with additional equipment. Visualization (Figs. 2–4) showed the space utilization and planned volume.

The use of AnyLogic simulation modeling at the PCR laboratory of the State Budgetary Healthcare Institution “City Children’s Polyclinic No. 2” made it possible to significantly increase the laboratory’s throughput by expanding equipment capacity and reallocating staff (Fig. 5).

KPIs include:
- daily throughput — the average number of tests performed per day (tests/day);
- monthly volume — the total number of tests per calendar month (tests/month);
- percentage of repeat examinations — the ratio of the number of repeat examinations to the total number, expressed as a percentage (%);
- Number of equipment units — the number of active devices (units).

Percentage changes are calculated as (after — before) / before × 100%.

Mean values and 95% confidence intervals are shown; statistical significance of differences is indicated by $p < 0.05$, $p < 0.01$.

Before the model was implemented, the daily workload was 2,099 tests; four physicians and nine laboratory technicians worked per shift; the equipment consisted of 10 units; and the number of errors and sample mix-ups accounted for 9.63% of the total number of tests per month. The total monthly volume of tests was 40370.

After implementing the simulation model, the average daily workload increased to 4,416 tests within 6 months.

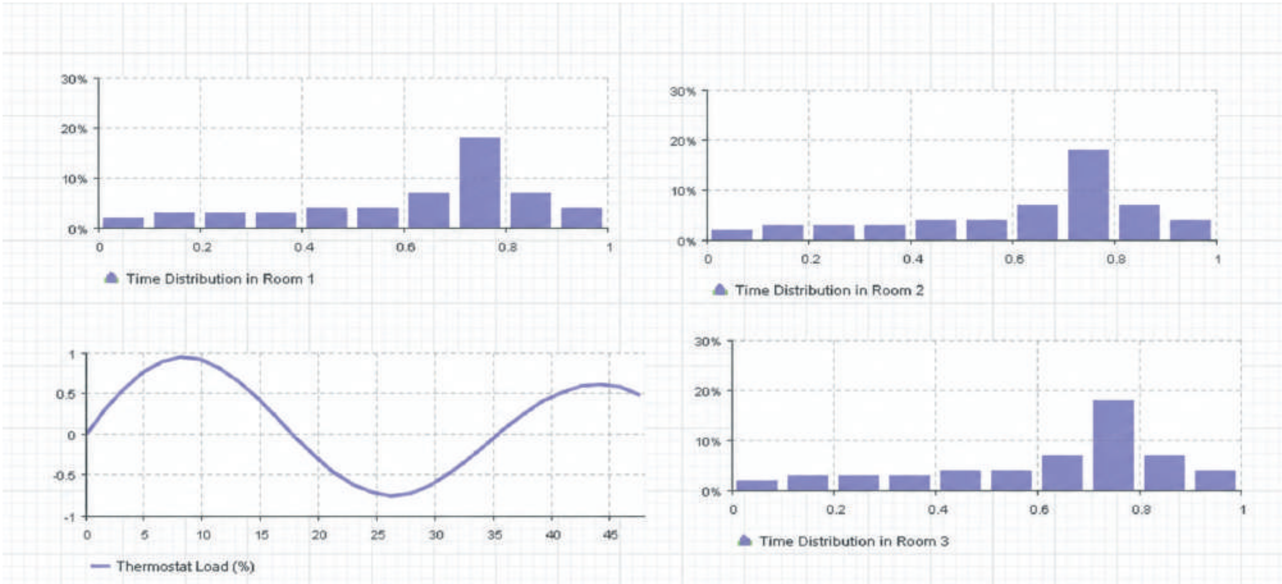

Fig. 3. Calculation of room occupancy

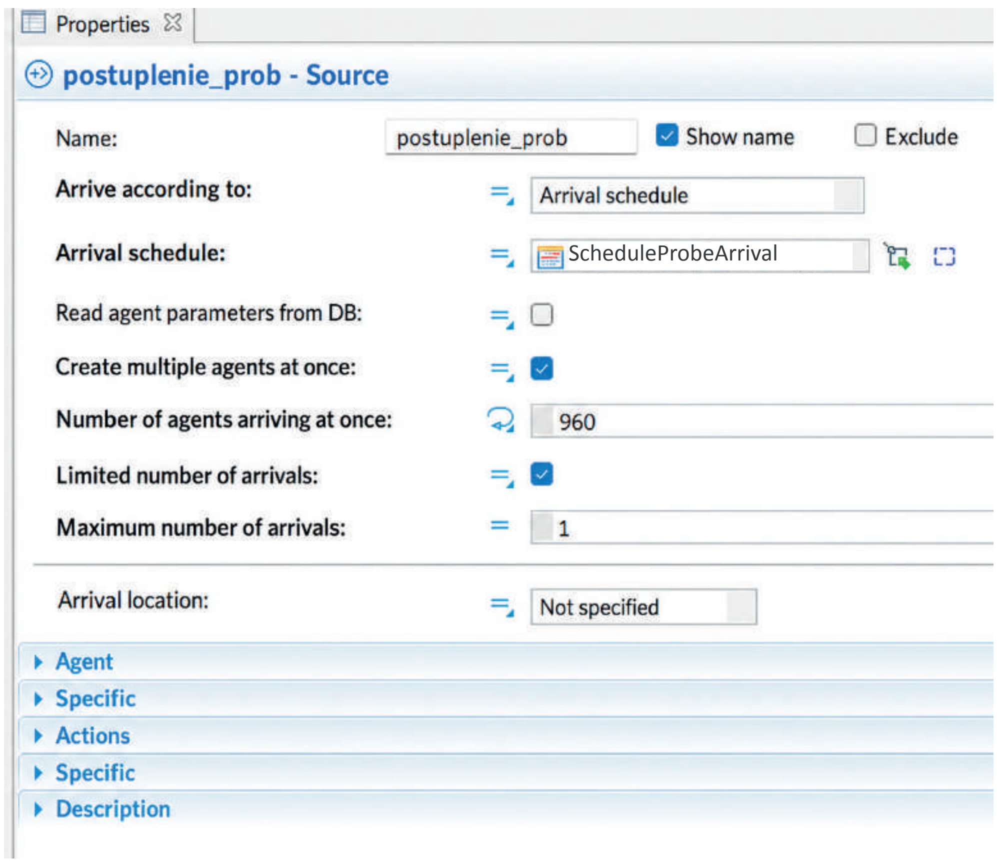

Fig. 4. Determination of the planned volume of tests

The total number of tests per month during this period reached 73,138 (over 6 months). The shift structure was changed to three physicians and four lab technicians, and the number of pieces of equipment was increased to 20. The percentage of samples requiring retesting was 1.67% ($p < 0.05$).

Key indicators and their changes (Fig. 6):

- daily workload: an increase of approximately 110.7% compared to the baseline;
- monthly workload: an increase of about 81.5% compared to the baseline;
- resource base: equipment doubled (+100%); the number of rotating medical staff decreased by one, and the number of lab technicians decreased by five.

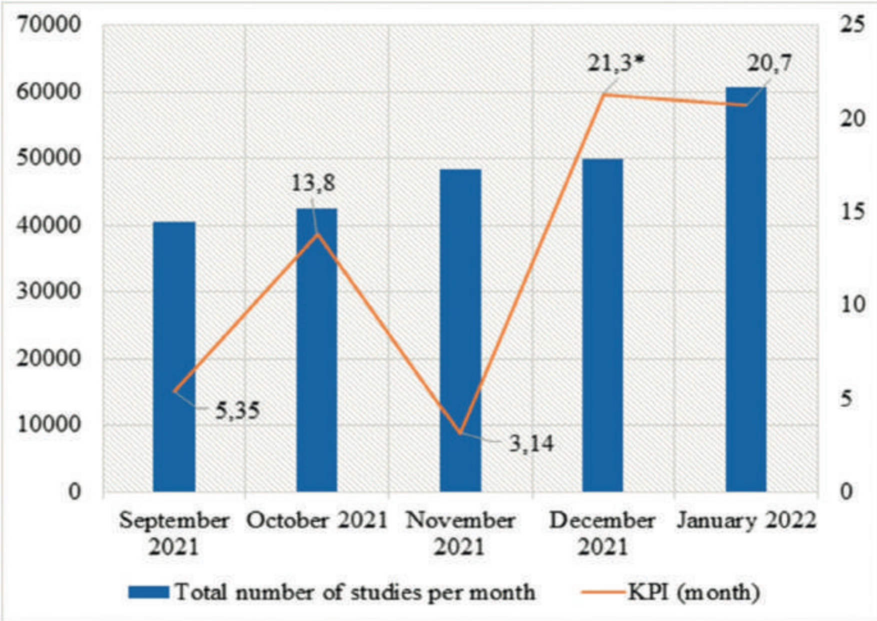

Fig. 5. Key performance indicators when using the simulation model

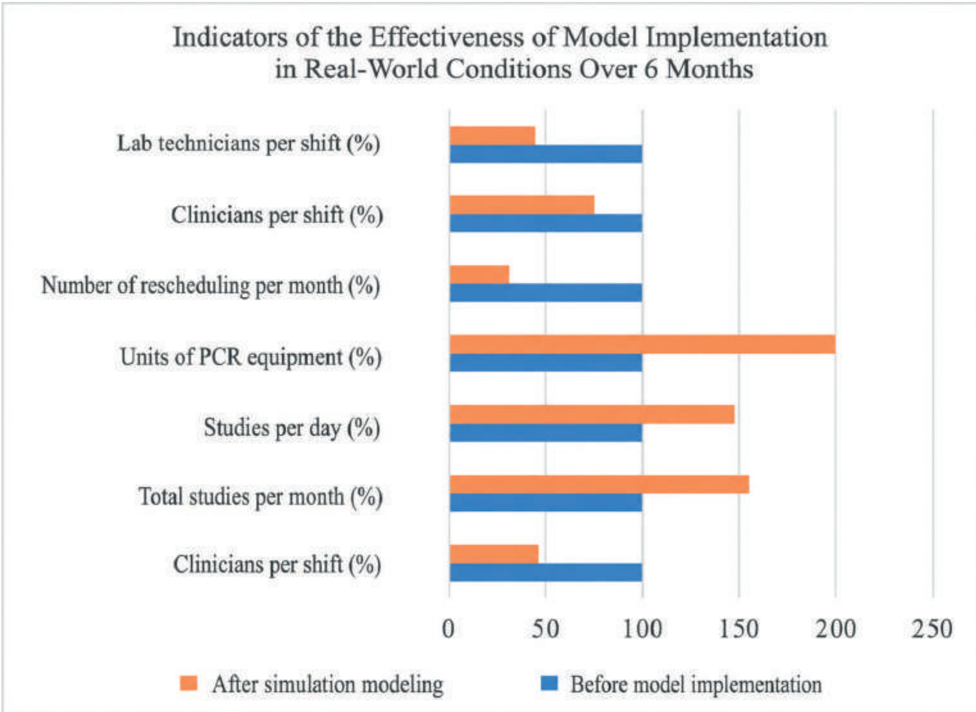

Fig. 6. Performance metrics for the model's application in real-world conditions over 6 months

The figure shows the percentage changes following the model's implementation relative to the baseline level (prior to implementation). Legend:

- "growth (%)" — percentage increase relative to the baseline level; the calculation formula is provided above;
- "staff reduction (%)" — the percentage decrease in shift headcount relative to the baseline level;
- "p-value" — the p-value of the corresponding statistical test (two-sample t-test or two-proportion z-test).

The graph illustrates changes in the laboratory's productivity before and after the implementation of the simulation model. It is clearly evident that the number of tests performed increased, while staffing requirements decreased by 53.8% ($p < 0.01$). This underscores the effectiveness of the implemented changes and may serve as a basis for further research in the field of optimizing the operations of medical institutions.

Discussion of the Results

The proposed method outperforms traditional approaches by visualizing dynamics, allowing for load forecasting without actual experiments. In the context of a pandemic, this minimizes risks and justifies procurement decisions (e.g., additional amplifiers). Limitations: dependence on the accuracy of timing data and the need for expertise in AnyLogic. A comparison with the literature confirms its effectiveness: similar models for COVID-19 testing reduce wait times by 20–40% [12].

The method complies with Russian standards, ensuring safety (GOST R ISO 15190-2023) and quality (GOST R ISO 15189-2015).

The proposed simulation modeling method allows for the assessment of the impact of various factors on workload planning in the laboratory. However, it should be noted that the simulation results are subject to uncertainties related to timing, changes in testing protocols, equipment failures, and other factors. To reduce the impact of human error on timing results, it is advisable to automate the collection of data on operation execution times using specialized software tools or industrial automation systems. To increase the model's resilience to changes in testing protocols, it is necessary to develop a flexible model architecture that allows it to be easily adapted to new conditions.

Applying the model in practice not only reduced the workload on laboratory staff but also significantly lowered the error rate and the number of process rework. The simulation modeling method has proven effective in planning laboratory staff workloads and improving process productivity and quality.

Comparison with Previous Research and Practices

The results obtained are consistent with the findings of a number of domestic and international studies that have demonstrated the effectiveness of discrete-event simulation (DES) for optimizing testing logistics and increasing laboratory throughput during a pandemic [17; 14; 15]. In particular, a study published in PLoS ONE (2021) demonstrated that proper organization of workflows and equipment layout, combined with DES, can reduce waiting times and increase the throughput of testing stations by 20–40% [14], which is comparable to the increase we observed. Reviews on the use of simulations in healthcare confirm that a combined approach (agent-based model + DES) offers additional advantages when accounting for the human factor and variability in patient flows [15; 18].

In Russian practice, attention to quality and safety standards (GOST R ISO 15189-2015, GOST R ISO 15190-2023) entails not only compliance with technical requirements but also the use of tools to optimize work processes. In our study, simulation modeling complements Lean management approaches in healthcare (e.g., value stream mapping, standardization of operations, 5S, and continuous improvement). The combination of DES and Lean techniques has been substantiated in a number of studies: simulation allows for the safe testing of changes in flows and resources before their implementation in real-world practice, while Lean measures help organize workplaces and reduce variability, which further increases the predictability and efficiency of the simulated system. It is recommended to further combine DES analysis with Lean initiatives (value stream maps, standardization of working time) to achieve a synergistic effect: simulation will demonstrate the expected effectiveness of Lean measures prior to their implementation, while Lean will reduce the variation in input times, thereby improving the model's accuracy.

Conclusions

Simulation modeling in AnyLogic is an effective tool for planning laboratory workloads during pandemics. This method allows for the identification of bottlenecks, the optimization of resources, and adaptation to increased demand. Its implementation in clinical practice is recommended to enhance the resilience of the healthcare system.

Authors' Contributions

D. V. Orlov — based on a literature review, developed the research plan, and analyzed and interpreted the data obtained during the study;
Nazarov N. O. — collected data for the study;
Kovaleva E. S. — prepared the manuscript for publication;
Donsckaia A. R. — formalized the model.

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BOSTON SCIENTIFIC'S RUSSIAN-LANGUAGE PROGRAMMER TRAINING SIMULATOR FOR CARDIOLOGISTS

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DOI: 10.46594/2687-0037_2026_2_2178

Abstract. Objective: To develop a Boston Scientific programmer training simulator for cardiologists, given the limited availability of the manufacturer's training programs in the Russian Federation. Methods: A browser-based application with a bilingual (RU/EN) interface and 13 clinical scenarios was developed. From September 2025 to May 2026, 25 participants (80% residents, 10% interns, 10% students) were trained at the Kushchevskaya Central District Hospital in three to four 1.5-hour sessions. Results: All participants mastered the basic functions; testing showed positive progress. Conclusion: The simulator is suitable for training cardiologists in settings with limited access to equipment.
Keywords: simulation-based education, pacemaker, programmer, Boston Scientific, training of cardiologists, virtual simulator, residency, distance learning, implantable antiarrhythmic devices, medical informatics.
Conflict of Interest. The author declares that there is no conflict of interest. The author has no financial, contractual, consulting, or other relationships with Boston Scientific Corporation (the manufacturer of implantable antiarrhythmic devices, whose programmer interface is replicated in the simulator described herein), nor with any other manufacturers of implantable medical devices. The development of the simulator and the pilot training were not funded by Boston Scientific or any other external organizations; the work was carried out by the author independently as a personal initiative within the scope of his professional activities as a cardiologist.
Funding. This study was conducted without external funding.
Citation: Mikhmel A. V. A Russian-language Boston Scientific programmer training simulator for cardiologists // Virtual Technologies in Medicine. 2026. No. 2. Pp. 76–79. DOI: 10.46594/2687-0037_2026_2_2178
Scientific specialty. 3.2.3 Public Health and Health Care Organization, Sociology and History of Medicine.
Received by the editorial office on June 8, 2026.
Received after peer review on June 29, 2026.
Accepted for publication on July 1, 2026.

Introduction

Implantable antiarrhythmic devices — pacemakers (PMs), implantable cardioverter-defibrillators (ICDs), and cardiac resynchronization therapy (CRT) devices — account for a significant proportion of the total patient population in cardiology departments across the Russian Federation [5; 6]. Programming and regular monitoring of these devices are performed using programmers — specialized devices provided by the manufacturer that enable telemetric communication with the implanted device, data analysis, and adjustment of pacing parameters. Each manufacturer of implantable devices uses its own programmer with a unique interface, and physicians are traditionally trained to work with a specific device through courses organized by the manufacturer.

Since 2022, access to educational programs and training materials from the largest foreign manufacturers of implantable antiarrhythmic devices—Boston Scientific, Medtronic, Abbott, and Biotronik—has been significantly limited within the Russian Federation. Nevertheless, there remains a significant number of patients in Russia with already implanted Boston Scientific devices who require regular routine checkups and optimization of pacing parameters throughout the device's service life.

An additional obstacle in training Russian specialists stems from the fact that the interface of Boston Scientific programmers is available exclusively in English. This makes it difficult for residents and physicians without an in-depth knowledge of English medical terminology to learn how to use the device. Opportunities to practice on an actual programmer outside of working hours are also limited—the clinical device is used during routine patient appointments and is not available for extended independent training.

Simulation-based training in medicine is recognized as an effective tool for acquiring and reinforcing clinical skills, especially in situations where "live patient" training involves risks or is limited by access to equipment [7; 9]. With regard to the training of specialists in cardiac pacing, there is limited domestic experience in Russia with the development of educational software solutions [3; 4]; however, as of the start of this study, no domestic open-source simulator for the Boston Scientific programmer had been identified in available sources.

The aim of this study is to develop a Russian-language training simulator for programming Boston Scientific implantable antiarrhythmic devices and to evaluate its potential for use in the training of cardiologists, residents, and medical students in settings with limited access to original clinical equipment.

Materials and Methods

Simulator Development. The program was developed by the author in June 2025 as a standalone browser application that requires no installation and runs in any modern web browser (Microsoft Edge, Google Chrome, Mozilla Firefox, Safari) on personal computers running Windows, macOS, and Linux, as well as on mobile devices with Android and iOS operating systems. The program code consists of approximately 9,700 lines of JavaScript (ECMAScript 2020 standard) without the use of third-party libraries or frameworks; the total size of the application is approximately 2 MB. The implementation consists of a single HTML file hosted on the author's website (URL: https://babab.ru/demo-programmator.html). Once the page loads, all computations are performed locally in the browser without transmitting data over the network.

A key feature of the development is its bilingual interface — Russian and English. This allows students to learn the parameters and functions in their native language while simultaneously becoming familiar with the English terminology they will encounter when working with a real programmer.

Implemented functional blocks of the simulator:

- a replica of the Boston Scientific Latitude defibrillator interface, including device parameter panels, electrocardiogram displays, settings menus, an arrhythmia episode log, and reports;
- Live rendering of electrocardiograms on four channels (Lead I, atrial channel, ventricular channel, left ventricular channel) with continuous, integrated phase calculation — without jumps when changing the lower frequency limit (LRL), the upper synchronization frequency limit (MTR), and the Exercise mode;
- Correct atrioventricular dissociation on the surface ECG in VVI mode with preserved sinus rhythm; realistic atrial fibrillation oscillations with deterministic noise;
- MRI Mode master with switching to DOO, VOO, and AOO modes and automatic return to default settings after 6 hours;
- Implementation of the device's responses to a magnet (Magnet Response) and to noise (Noise Response);
- Temporary bradycardic pacing mode (Temp Brady) with the option to revert to previous settings.
- Electrophysiological tests (EP Tests): programmed burst pacing, induction of ventricular tachycardia and atrial tachyarrhythmia;
- Lead tests with automatic verification of sensitivity margin (rule: ≥ 2 times the threshold) and pacing margin (ratio of programmed amplitude to threshold);
- Battery life prediction based on the percentage of ventricular pacing;
- Full Undo/Redo functionality (Ctrl+Z) for all parameter changes;
- Generation of a printable visit report (Visit Summary) in PDF format.

Clinical Demo Scenarios. The simulator includes 13 detailed demo patients covering the main categories of implantable antiarrhythmic devices and typical clinical situations:

Single-chamber pacemakers:

1. VVIR ESSENTIO MRI L110 — persistent atrial fibrillation with bradycardia.

Dual-chamber pacemakers:

2. DDDR ESSENTIO MRI L111 — third-degree complete atrioventricular block, episodes of pacemaker-mediated tachycardia (PMT), low atrial sensitivity reserve.
3. DDDR ESSENTIO MRI L111 — sick sinus syndrome, ventricular lead integrity failure with multiple increases in impedance and 47 episodes of falsely recorded non-sustained ventricular tachycardia due to oversensing.
4. DDDR ESSENTIO MRI L111 — recurrent episodes of PMT (endless-loop tachycardia) against a background of short PVARP.
5. DDDR ESSENTIO MRI L111 — sick sinus syndrome with paroxysmal atrial fibrillation, frequent Atrial Tachy Response (ATR) triggers, and an increasing AF burden.
6. DDDR ESSENTIO MRI L111 — classic pacemaker-induced cardiomyopathy (PICM) with long-term right ventricular pacing, progressive decrease in ejection fraction.
7. DDDR ESSENTIO MRI L111 — exit block with a progressive increase in the ventricular pacing threshold while electrode impedance remains stable.
8. ALTRUA 2 DR S702 — Elective Replacement Indicator (ERI) status on the power source replacement indicator.

Implantable cardioverter-defibrillators:

9 RESONATE D424 single-chamber ICD — ischemic cardiomyopathy, primary prevention of sudden cardiac death.

10. INOGEN D040 dual-chamber ICD — idiopathic dilated cardiomyopathy, secondary prevention following resuscitation, paroxysmal atrial fibrillation.

Cardiac Resynchronization Therapy Devices:

11. CRT-P VALITUDE X4 U125 — responder: increase in ejection fraction from 25% to 40% with biventricular pacing.
12. CRT-D AUTOGEN X4 G177 — ischemic cardiomyopathy with persistent atrial fibrillation, BiV pacing 98%, episodes of sustained ventricular tachycardia with successful antitachycardia pacing and one defibrillator shock, quadripolar left ventricular lead.
13. CRT-D DYNAGEN X4 G172 — non-responder: no increase in ejection fraction over two years, suboptimal percentage of biventricular pacing (88%) due to competition with intrinsic AV conduction.

Quality Control and Validation. During the development phase, 762 automated tests were implemented, covering the clinical validation of parameters (verification of acceptable ranges in accordance with age-based guidelines), the correct display of electrograms, the behavior of the MRI mode and the temporary bradycardia mode (mutual exclusion of these modes from the magnet/interference response mode), as well as rendering on high-pixel-density displays (Hi-DPI Canvas).

Use of the Simulator in the Educational Process. From September 2025 to May 2026, training was provided to

25 participants at the Kushchevskaya Central District Hospital (a state budgetary healthcare institution) under the Ministry of Health of the Krasnodar Region, as well as through extracurricular sessions and remotely via the author's website. The majority of the trainees were residents (about 80%); medical interns (about 10%) and senior medical students (about 10%) also participated.

Training was organized in both individual and group formats (groups of two to four people). A training cycle for a single student consisted of three to four sessions, each lasting 1.5 hours. During the sessions, students progressively learned the programmer interface, basic operations (changing the mode, frequency limits, and stimulation amplitude), interpretation of electrograms and the arrhythmia log, and practice with diagnostic algorithms for common problems — electrode integrity issues, power source depletion, and PMT episodes.

Effectiveness Assessment. For each trainee, a pre-test was administered to assess their baseline knowledge of using the simulator, a post-test was conducted upon completion of the training cycle, and an anonymous survey was administered to evaluate the user-friendliness of the interface, the realism of the clinical scenarios, and the subjective usefulness of the simulator.

Results

Between September 2025 and May 2026, 25 individuals (20 residents, 3 medical interns, and 2 senior medical students) completed the training course using the simulator. All trainees completed the planned course of sessions and took part in the final assessment.

Mastering the basic functions of the programmer. Based on the results of preliminary testing, the trainees' initial level of knowledge regarding the Boston Scientific programmer interface was low: most participants had no experience working independently with the programmer and were unfamiliar with the English terminology used for the device's parameters. Upon completion of the training course, all trainees were able to independently perform basic operations with the simulator: initiate a device interrogation, change the pacing mode, adjust the rate limits and pacing parameters, interpret the arrhythmia log, and generate a printed visit report.

Diagnosis of highly complex clinical scenarios. During the final assessment, participants independently identified the following clinical situations presented in the demo patients: PMT episodes, electrode integrity failure with oversensing, an ERI status on the scheduled replacement indicator, and a suboptimal biventricular pacing fraction in a patient with a CRT-D. Most trainees correctly formulated management strategies for each scenario and proposed appropriate parameter adjustments.

Students' subjective assessment. According to an anonymous survey, participants cited the following as the simulator's strengths: realistic reproduction of the original programmer's interface, Russian-language prompts, the ability to operate offline, the absence of risk to patients when practicing non-standard solutions, and the opportunity for independent practice outside of clinical settings. As areas for improvement, the students suggested expanding the set of clinical demo scenarios and adding support for devices from other manufacturers.

Applicability in a peripheral medical and preventive care facility. The use of the simulator in a central district hospital providing primary care demonstrated the possibility of training cardiologists and residents without the need for additional equipment, specialized simulation centers, or reliance on the manufacturer's external training programs.

Discussion

The results confirm that a browser-based programmer simulator can be effectively used as a training tool for the training of cardiologists and residents when access to the manufacturer's original training programs is limited. A training program involving 25 participants at a central district primary care hospital demonstrated that simulation training can be conducted using only a personal computer or mobile device, without specialized simulation equipment.

A key methodological feature of this development is its bilingual interface — Russian and English. This approach addresses two objectives simultaneously: it reduces the initial language barrier for Russian-speaking students while gradually helping them become familiar with the English terminology they will encounter when working with a real programmer. In our view, this is particularly relevant for the Russian system of training cardiologists, since alternative training conducted exclusively via the original English-language interface significantly increases the time it takes for a substantial portion of students to master basic functions.

The use of clinically valid simulation scenarios — including complex ones such as pacemaker-induced tachycardia, electrode integrity failure with episodes of falsely recorded ventricular tachycardia, and planned battery replacement — is consistent with modern principles of highly realistic simulation in medical education [9]. Practicing diagnostic decisions in such situations on a real patient is impossible without significant risk (or their rarity makes it unlikely that one will encounter each of them during routine training), which makes the simulation approach particularly valuable.

Meta-analyses of technology-enhanced simulation-based training in medicine have demonstrated the positive impact of this approach on the acquisition of clinical knowledge and skills [7]. Our data from the pilot use of the simulator in the educational process are consistent with this conclusion and support the possibility of incorporating such solutions into continuing professional education programs in cardiology.

Limitations of the Study. This pilot study is limited to a sample consisting of a single primary-care medical and preventive care facility and a single author-instructor; the number of trainees (25) is insufficient for a rigorous statistical assessment of the training's effectiveness compared to a control group that did not use the simulator. The assessment of skill mastery was limited to testing within the simulator environment and a survey of the trainees and did not include a long-term evaluation of the transfer of skills to working with a real programmer. Furthermore, the simulator covers a programmer from only one manufacturer (Boston Scientific), which does not reflect the full range of implantable devices a physician may encounter in clinical practice.

Future Development Plans. Expanding the range of clinical demo scenarios; developing modules that simulate programmers from other manufacturers (Medtronic, Abbott, Biotronik); conducting a multicenter study on the effectiveness of the simulator at involving several simulation centers and educational institutions; developing a standalone version of the program for use without an Internet connection; examining the issue of state registration of the computer program with Rospatent.

Conclusion

A Russian-language training simulator for Boston Scientific's implantable antiarrhythmic device programmer has been developed. It is implemented as a standalone browser-based application that runs locally without transmitting data over a network. The simulator features a realistic reproduction of the original programmer's interface, 13 clinical demo scenarios, and a set of training tools. A pilot study involving 25 residents, interns, and medical students at a central district primary care hospital demonstrated the tool's effectiveness in practicing both basic and complex clinical scenarios without risk to patients and without the need for access to an actual programmer. The simulator can be recommended for use in training programs for cardiologists, given the limited availability of training programs offered by manufacturers of implantable devices within the Russian Federation.

Author's contribution: sole author — software concept and design, implementation, organization and delivery of training, data collection and processing, and drafting of the manuscript.

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OphthalmoSIM, simulator for adult and pediatric ophthalmoscopy

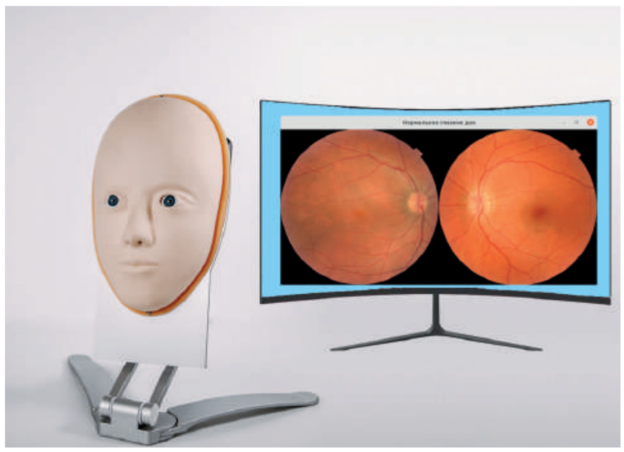
Ophthalmoscopy is the basic eye examination technique. OphthalmoSIM has been designed to enhance training in ophthalmoscopy examination in adults and infants, as well as accreditation of medical specialists.

The kit includes a newborn baby mannequin or head of an adult patient, an image generation unit and an optical unit that are connected to the user's computer. The original optical system paired with a high-resolution monitor creates high-quality real digital fundus images obtained during the examination of adults and infants with various abnormalities.

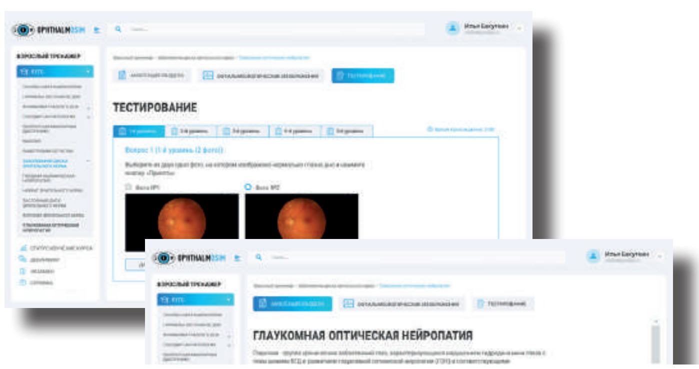
pediatric simulator

Key Features

- The images on the display reproduce normal and pathological conditions of the fundus.
- Detectable red reflex.
- Extensive library of real fundal images featuring various abnormalities.
- Detailed image description and graphical highlighting of the relevant areas.
- Fundus is not visible in case of poor ophthalmoscope positioning.
- Conventional ophthalmoscopes are used for direct and indirect ophthalmoscopy. All training and examination results are presented to both the student and the teacher.
- Standard and customized programs are available. Customized programs can be created at the request depending on the student's level of knowledge.

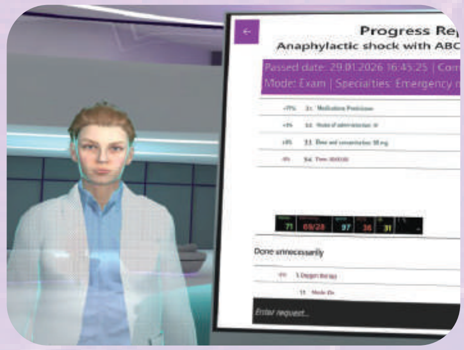


adult simulator



DIMEDUS

Digital Medical Education Systems



Communication with AI-Patients

Interact naturally with virtual patients using unscripted spoken language. The AI-based patients respond in real time, helping develop clinical communication and history-taking skills.

Team Training in VR Multyplayer

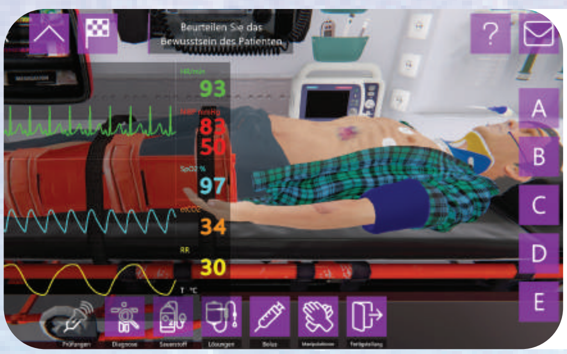
Multiple users join the same virtual case to practice teamwork providing care, clinical decision-reasoning, and communication in a realistic, collaborative environment.

Debriefing Guided by AI-Assistant

After each case, an AI facilitator leads a structured debrief. Choose from common models (GAS, PEARL, etc.) or customize your own prompts to fit specific educational goals.

Immersive Cases for Skills Training

Full interaction for skill training — user performs essential clinical procedures in hybrid immersive or digital environment. Pick up tools, check data, draw medications, examine patients — interact with real objects in VR-hedasets or on portable devices.



Emergency Training in Ambulance

Emergency care training in a mobile ambulance environment – train inside a fully equipped virtual ambulance. Over 10 scenarios of the pre-hospital care and emergency response are simulated in a realistic, confined setting.

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