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

Andrey Mikhmel

Kushchevskaya Central District Hospital, Stanitsa Kushchevskaya,
Krasnodar Krai, Russian Federation

ORCID: 0009-0004-9635-2648

andrey@mikhmel.ru

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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.
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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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