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Virtual patients as a format for simulation learning in continuing medical education (review article)

Karas S.I.

Cardiology Research Institute, Tomsk National Research Medical Centre, Russian Academy of Sciences
111a, Kievskaja Str., Tomsk, 634012, Russian Federation
Siberian State Medical University
2, Moscow Trakt, Tomsk, 634050, Russian Federation

ABSTRACT

The use of virtual patients for students and for advanced training of medical doctors is a definite pedagogic innovation. The computer-based interactive multimedia simulations of scenarios for diagnosis and treatment allow for the avoidance of the risk of improper actions in regard to a real life patient, to repeat the clinical situations an unlimited number of times, and to standardize the tasks and criteria of their completion. Virtual patients represent a factual basis of problem-based learning. This review article focuses on the use of this educational technology for the development of medical decision making skills internationally, on its pedagogical effectiveness, and on the variants of the linear and branching scenarios. Meta-analyses demonstrate the pedagogical effectiveness of virtual patients and an interest of the trainees. An integration of the virtual patients into the learning contributes to clinical training gamification, which inspires the students and medical doctors to engage in interactivity and teamwork. The creation of a repository or a web-service of multimedia virtual patients in the tradition of national clinical school is of great current interest for implementation in the system of higher and continuing medical education.

Key words: case technologies, problem-based learning, gamification, standardization, multimedia, Web-service.

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Виртуальные пациенты как формат симуляционного обучения в непрерывном медицинском образовании (обзор литературы)

Карась С.И.

Научно-исследовательский институт кардиологии, Томский национальный исследовательский медицинский центр (НИМЦ) Российской академии наук
Россия, 634012, г. Томск, ул. Киевская, 111а

✉ *Karas Sergey I.*, e-mail: ksi@cardio-tomsk.ru.

Сибирский государственный медицинский университет (СибГМУ)
Россия, 634050, г. Томск, Московский тракт, 2

РЕЗЮМЕ

Использование виртуальных пациентов для обучения студентов и повышения квалификации врачей в России является определенной педагогической инновацией. Компьютерные мультимедийные интерактивные симуляции сценариев диагностики и лечения позволяют избежать риска неправильных действий в отношении реального больного, повторять клинические ситуации неограниченное количество раз, стандартизовать задания и критерии оценки их выполнения. Виртуальные пациенты являются фактологической основой проблемно-ориентированного обучения.

В обзоре рассмотрены применение этой образовательной технологии для формирования навыков принятия врачебных решений за рубежом, ее педагогическая эффективность, варианты использования линейных и разветвленных сценариев. В метаанализах показана педагогическая эффективность виртуальных пациентов и заинтересованность обучающихся. Интеграция виртуальных пациентов в образовательный процесс способствует геймификации клинической подготовки, что стимулирует студентов и врачей к интерактивности и командной работе. Весьма актуально создание репозитория или Web-сервиса мультимедийных виртуальных пациентов в традиции отечественной клинической школы для использования в системе вузовского и непрерывного медицинского образования.

Ключевые слова: case-технологии, проблемноориентированное обучение, геймификация, стандартизация, мультимедиа, Web-сервис.

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INTRODUCTION

One of the main problems of modern medical education is the difficulty of forming decision-making skills among specialists, both when performing manipulations and in clinical and diagnostic setting. In Russian higher medical education and abroad, various formats of simulation learning and virtual modeling are actively used. These educational technologies involve the use of various training devices and simulators that allow the student to play the role of a professional of the healthcare system and to develop manual skills and methods for making medical decisions in a safe situation.

The main incentive for the development of various simulators is to bridge the gap between students' theoretical knowledge and their clinical decisions without risking harm to real patients. The second reason for the introduction of these technologies is the need to standardize the assessment of clinical and diagnostic competencies of doctors and the possibility of repeating the clinical situation as many times as necessary, exploring various strategies and options for action [1–3]. One of the formats of simulation learning is the use of virtual patients (VP).

VIRTUAL PATIENTS IN HIGHER MEDICAL EDUCATION

In the scientific literature, one can find a different understanding of the term "virtual patient": computerized robotic simulators, standardized clinical cases performed by actors, and

computer multimedia simulations of clinical situations.

Different medical proxy dummies have been used for a long time in medical education. For example, in 1968, the famous Harvey mannequin was designed to develop skills in diagnosing the state of the cardiovascular system. The model reproduced various types of respiration, pulse, blood pressure, murmurs and cardiac sounds corresponding to 25 diseases of the cardiovascular system. In the 1980s an android was created with an integrated model of physiological parameters of the cardiovascular system, controlled by one of the first personal computers with 35 scenarios of clinical situations [4]. Simulation learning centers are being intensively developed all over the world, equipped with mannequins of various levels of complexity, including an information model for the scenario of a clinical case and feedback from the student's actions [5]. The use of actors instead of patients was tested in 1963 as part of a training program for neurologists [4]. Currently, standardized patients are widely used in Europe and the USA to assess the clinical competencies of doctors, including as part of state licensing programs.

The scope of this review is, in a sense, the "polar" format of the simulation, used not for developing manual techniques, but for the formation of clinical thinking and medical decision-making skills. The results of the first attempts to use computer simulations for the training of doctors, nurses and students were published in the 60–70s of the 20th century [6–8]. Since then, these technologies have been applied in different fields of medicine and for different groups of students, but systematic use began in the USA and Western Europe only in the 1990s.

The term "virtual patient" has become widely used in foreign scientific publications after a series of works [2, 9–11]. The literature review [12] discusses the meaning of this term used in 536 articles: 37% of the articles dealt with interactive simulations of treatment and diagnostic process robots, 19% dealt with computer simulations of clinical situations, and 16% dealt with "standardized patients" performed by actors. Continuing this work, the authors analyzed 185 definitions of VP and built a conceptual map of this subject area [13].

In the future, by the term "virtual patient" we will understand the educational technology of the clinical areas of knowledge, namely, computer multimedia interactive simulations of scenarios for diagnosing and treating patients [10, 14].

The process of solving situational problems during the study of individual diseases has always been part of the training of future doctors. In an expanded form, they are cases that contain multimedia data from a patient examination and serve to analyze information when solving medical and diagnostic problems [15, 16]. The case method provides the strength and consistency of knowledge, a process approach to decision making. Important components of the case method are the assessment of the student's actions and the explanation of the mistakes made [17]. It is this approach that is more often mentioned in the domestic scientific literature than the virtual patient, as its factual basis. Educational technologies using clinical cases are considered in a number of domestic works both at the level of conceptual models and practical use [16, 18, 19].

A report by the European Regional Bureau of the World Health Organization (2016) states: "Schools... should make greater use of e-learning in medical education and continuing education for health professionals." Despite the rapid development of Russian e-health over the past 7–8 years, this process has weakly affected the educational medical space. Separate experiences of the development and use of electronic medical history for classroom work and self-preparation of students in clinical disciplines are described. An elective course "Electronic Medical Record" was created at Stavropol Medical University [20]. The concept of developing a training version of a medical information system and the experience of its application in the educational process are described in a number of works. Virtual modeling of professional tasks is used in dental education, teaching of general medicine, and training of surgeons [21–24]. For these purposes, both widespread software products [25] and specially designed software shells [26] can be used. Ways to integrate simulation technologies and techniques into medical education are considered in the article by K.A. Muravyova et al. (2011). It was concluded that the necessary educational and methodical work and experiments in teaching technologies are needed [27]. However, the vast majority of work on the creation of virtual patients and their use in medical education has been carried out abroad.

THE PEDAGOGICAL EFFECTIVENESS OF VIRTUAL PATIENT TECHNOLOGY

Implementing e-learning technologies in clinical medicine is more difficult than in the technical and scientific fields of knowledge, and the virtual patient is the main option for their practical implementation [28]. The use of VP has become one of the few digital technologies that have significantly changed the educational process. As the main component of lectures and seminars, VPs are the basis for training based on case study and problem-oriented learning and can partially replace traditional teaching methods in clinical disciplines [7, 10, 29, 31, 32].

VPs provide standardization, efficiency, interactive training, and links to evidence-based information sources, contribute to the study of rare cases of the disease, reduce the intensity of the teacher's work and increase student autonomy, and are ideal for developing clinical decision skills that are largely unformalized [14]. A number of reviews, including systematic ones, are devoted to the methodology and technology for developing VP [1, 33, 34].

In their foundational article, J. Bateman et al. (2013) try to answer the question of how the characteristics of VP affect the effectiveness of the formation of clinical competencies of students [35]. The authors developed a model of student interaction with the VP as an educational tool. The model includes three main aspects: clinical (content of the case), pedagogical (sequence and form of presentation of the content, a way to evaluate the student's interaction with the content), digital (the software used, user interface features). Educational experiments were conducted in different institutions; students had different clinical and educational experience and skills, different attitudes to e-learning. During the experiments, the impact of using VP on the students' competencies, their further preferences and motivations was evaluated.

The use of VP in medical education has a significant history: not only have recommendations been developed for their creation [9, 10], but specific proposals have been formulated for the development of clinical thinking skills based on the technology of VP [37]. Experienced educators, in accordance with the recommendations of the MedBiquitous consortium, created two cases of VP verified by six doctors. These cases included a history of life and disease, instrumental and laboratory studies, results of a physical examination of patients, a user-driven tree-like and linear trajectory of providing content, various types of questions, and probabilistic approaches to assessment. Additionally, a demonstration of examples, a list of differential diagnoses, and a help system with the search for pros and cons, and other reference resources were used. Both cases after working with them in an hour-long discussion were evaluated by 46 students of the second and fourth years of study. Students were informed about the experiment, participated voluntarily, without payment; the assessment of VP was carried out according to the recommendations [38]. Compared to traditional methods of presenting cases with paper case histories, virtual patients stimulated interaction between students and their active involvement in the educational process. When using VP, students identify well the key characteristics of the problem; questions for the Bayesian approach to solutions are useful for them. A branching path makes the VP more realistic, but complicates the task and increases the error rate. The solving process is also made more difficult by the interface with scrolling, the lack of audio, video files and feedback from the VP.

A systematic review and meta-analysis of D. Cook et al. (2010) show that the use of virtual patients has a significant educational effect [8]. Comparing the different properties of VP, the authors come to the conclusion about the educational effectiveness of a structured menu system and an interface in a native language for learning; the connection of the text or voice form of presentation of information with the success of training is not so obvious. Thoughtful feedback from the student is undoubtedly important for positive effect, as well as repeated solutions on one VP, although the latter option can cause a negative reaction of students. The long time provided for completing the task using the VP generally reduces the proportion of correct decisions, but this depends on the complexity of the case and the status of the student.

A meta-analysis of 12 randomized controlled trials showed a pronounced positive effect of using VP in learning [39]. The advantages of using the VP in the educational process are not in doubt [40], however, specific methods of integrating the VP with traditional curricula require further research. It is also recommended that fundamental biomedical knowledge be integrated with clinical descriptions of cases of the VP [41].

At the University of St. George (London) a problem-oriented training for medical students is implemented. To use this educational technology on the basis of a "paper" description of completed cases of the disease, conceptual maps of each case were developed, and then virtual interactive patients for on-line work were created in the OpenLabyrinth software application [2]. Ten groups of students worked with five virtual cases in a linear and branched scenario. Both students and teachers note the prospects of this approach, as well as the need for parallel full-time clinical classes.

A study of family medicine knowledge in a group of students who studied in the traditional way (48 people) and using virtual patients (51 people) showed no differences [42]. The authors conclude that the new approach is highly effective, taking into account the absence of risk for real patients. Advice on how to develop the professional competencies of doctors using VP is given by S. Murphy et al. (2016) [43]. Among them are the use of professional nuances in the VP scenario (informed consent, confidentiality, etc.), the need for teamwork predefined by the script, debriefing of the cases worked out and a collective analysis of making stage decisions, taking into account the educational level of students.

VP testing at the University of Bogotб was carried out with the participation of 216 students who noted the positive and systemic impact of VP technology on the individual learning process and the correspondence of the socio-cultural context of clinical practice cases [44]. Testing of acquired skills, from the students' point of view, was qualitatively different from the usual exam and strengthened the motivation for learning. Students consider virtual patients an important educational tool, especially in the field of development of medical logic and decision making.

N. Berman et al. (2009) for 2 years studied the effect of various methods of integrating VP into the clinical disciplines program on the perception and satisfaction of 545 students [32]. The questionnaire was validated; the results were processed by factor analysis. Students rated the effectiveness of VP higher than traditional methods. The integration of VP into the learning process directly affects its effectiveness and student satisfaction, can be combined with the elimination of some traditional educational approaches. However, from the students' point of view, the opposition of e-learning to traditional learning is not constructive; these approaches should complement each other.

A group of students who used typical cases of VP in the study of rheumatology to substantiate medical decisions was studied. Students perceived VP in connection with real patients and the clinical context of training, evaluated them as an integration of biomedical knowledge and clinical experience, as an aid in structuring the available clinical diagnostic information. This integration provided the basis for decision-making in a loosely structured clinical environment in the absence of stress of real actions. Along with this, students lacked emotional interaction with patients and the complexity of real work. The effectiveness of the integration of complex cases of VP into medical education depends both on their technological features and on the clinical situation [45, 46]. Among the adverse effects of the use of VP, it is also worth mentioning the limited control over the distribution of depersonalized clinical diagnostic information, the difficulties of editing the VP, the insufficient validity and reliability of the content [13]. Taking into account the very different implementations of VP, their use does not allow us to evaluate the learner's cognitive skills, as well as to diversify patients according to ethnic and socio-cultural characteristics [47]. Lack of emotional contact and feedback with the virtual patient makes learning difficult [35, 45].

VPs are used to form not only the clinical thinking of students, but also effective laboratory diagnostics [48]. LabCAPS software was used to create eight virtual patients, among which were implemented similar in characteristics, but contrasting in required solutions, which is extremely useful for the formation of recognition of stable clinical and laboratory patterns in students. Students praised the logic of the VP interface, its learning effect, and differentiated cases with confidence.

If the twentieth century was dominated by content learning models, now they are giving way to models of different types of activity of students and teachers. The use of VP implies the active work of the student, which is expected to lead to greater learning efficiency [49]. A number of activities are built into the VP during development (methods for students to obtain information and ensure interactivity); others are associated with the use of VP (work in groups, independent preparation of students, the context of achieving different educational goals), or with the inclusion of VP in the curric-

ulum of the discipline [7]. Evaluation of the role and pedagogical effectiveness of VP technology depends on what activities we are considering. Therefore, the literature discusses not only VP technology, but the roles that these computer simulations can play in the medical education of the future [50].

DIVERSIFICATION OF VIRTUAL PATIENTS

VP scenarios can be divided into those predetermined by a specific completed case and aimed at solving a medical problem as a whole, without a clearly defined sequence of actions [51]. The type of scenario, the amount of data and the form of their presentation, the availability of evidence sources, and the potential for further use of the acquired competencies in the clinic influence the process and the result of learning using VPs. There are different versions of VP models: static and dynamic, linear and branched, with interactivity and without it. Most VP now implements a linear scenario, with the ability for the student to answer questions and make certain decisions [1]. To improve communication skills with patients, static VPs are more often used, while dynamic clinical decision-making skills are used [40]; branched VP scenarios suggest a high level of interactivity with the student [13]. Creation of a computer database of completed cases of the disease for demonstration to students is equivalent to static VP without pronounced interactivity; creation of a computer database of multimedia clinical diagnostic tasks is equivalent to dynamic interactive VPs.

In a number of works by M. Toro-Troconis et al. the process of using VP as a game format for medical education has been studied in detail. From the authors' points of view, the linear VP scenario is more suitable for primary students, and branched scenarios better develop the cognitive skills of future doctors in senior courses [52, 53]. The sex of the student does not affect their attitude to the VP, although this issue needs to be studied in more detail on a large sample of junior students. Students are advised to spend sufficient time daily in this "virtual world", and they are willing to complete tasks, provided that there is time for clinical preparation with real patients.

At the same time, the use of VP in the pedagogical process requires serious methodological support and guidance on the game approach to medical education. The introduction of this format will allow supporting and developing the joint work of various specialists within the framework of one team, including, for example, pharmacists, physiotherapists, and nurses. VPs, as a digital gamified representation of real clinical cases, have a high educational potential for a large number of students, the gain from which significantly exceeds the costs of their development [53].

It was assumed that the relevance of the language in which the virtual patient is presented is of great importance. However, the staff of the medical faculty of the Romanian University did not find statistically significant differences in the students' ability to make a correct diagnosis and make a therapeutic treatment plan for four identical VPs in Romanian (136 students) and in English (144 students). The inclusion of VP in the program of the Romanian medical university in English the authors consider an acceptable and economically viable option for the globalization of medical education [54].

Although the creation of virtual patients requires significant time and financial resources, this technology in terms of cost-effectiveness and educational effectiveness has significant advantages relative to standardized patients and other simulation techniques. The possibilities of the widespread use of VP in the global network, the use in distance and continuing medical education make this approach unique [13, 14].

VIRTUAL PATIENT REPOSITORIES

At the end of the twentieth century virtual patients were included in the USMLE exam program and are used in the educational process in all developed European countries. The effectiveness of VP in medical education was highly appreciated not only by foreign, but also by domestic scientists and teachers [55]. Despite promising characteristics, VPs are slowly being introduced into the curricula of medical universities, although the optimism of teachers and administration remains. The cost of development (the preparation of one case of VP is estimated at 10-50 thousand dollars) is one of the limiting factors; however, the cost of organizing training centers equipped with robotic mannequins is several orders of magnitude higher [1].

To expand the use of virtual patient technology in medical education, it is natural to create VP repositories [44]. The Aquifer Consortium brings together manufacturers of virtual patients; teachers and students using this technology [56]. The users of Aquifer virtual

training courses are most US medical schools and international medical programs. The base of VP of this organization has a multi-parameter search system for virtual patients, depending on the disease, the field of health, and educational tasks. In the 2017–2018 school year, more than 67,000 students accessed the Aquifer VP base about 1.4 million times. The systematic work on introducing VP into practice, including the preparation of a standard for the development and use of VP for educational purposes, is carried out by the Association of American Medical Colleges [57].

The created VP resources are actively used in foreign educational institutions. In particular, the European Commission supported the eViP project aimed at creating a database of virtual patients and clinical diagnostic situational tasks [58]. Universities and medical faculties of Great Britain, Sweden, Germany, Holland, and Romania participate in this project. As part of the project, ClujNapoca University of Medicine and Pharmacy (Romania) and Karolinska University (Sweden) developed computer applications for creating VP in various clinical areas [44, 59]. The basis was the software tool used since 2005 at the University of Bogotб (Spain) for the use of VP in medical education [60]. This Web application allowsthe creation of linear interactive scripts based on real, completed cases.

In 2017, the American Medical Association considered the use of virtual electronic health records (EHR) as a platform for clinical training in medical schools [61]. EHR is used in 90% of medical practices, but students and young doctors are little trained in this technology. The Regenstrief Institute is developing an EHR platform for clinical training. The virtual patient database of this institute includes more than 10,000 real depersonalized cases of the disease and is presented in its own information system [62]. This base is used to develop clinical thinking and decision-making skills in students of more than 30 educational medical institutions in the United States.

CONCLUSION

Currently, a significant positive effect of the technology of virtual patients in medical education and advanced training of doctors has been proved, their economic efficiency has been demonstrated in comparison with simulation centers of robotic mannequins and the use of standardized patients, the possibilities of remote use of VPs for the formation and improvement of competencies in clinical diagnostic decisions are obvious. It is time to create a repository or Web service for multimedia VPs within the framework of domestic clinical schools for use in the system of university and continuing medical education.

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Author information

Karas Sergey I., Dr. Sci. (Med.), Associate Professor, Head of the Department for the Coordination of Scientific and Educational Activities, Cardiology Research Institute, Tomsk National Research Medical Center of the Russian Academy of Sciences; Professor, Department of Medical and Biological Cybernetics, Siberian State Medical University, Tomsk.

(✉) **Karas Sergey I.**, e-mail: ksi@cardio-tomsk.ru.

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