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Virtual patients as the basis for problem-based learning of cardiologists

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ABSTRACT

Implementation of virtual patients allows avoiding risks for patient safety, using the standardized clinical situations repeatedly, and providing remote access to information. In order to create virtual patients, the project team comprised of specialists competent in the diverse subject areas. Every virtual patient is a structural model for a diagnostic and treatment process of a real patient augmented with textual and multimedia information. A sample comprising of 50 archival clinical charts of patients with typical cardiovascular diseases and rare pathology variants was formed. Textual information from medical records is supplemented with the multimedia results of instrumental and laboratory studies. Created data and knowledge base of virtual patients was designated for a demonstration of complete cardiovascular cases to the trainees in linear trajectory with an option of Web-access. The virtual patient repository will become a factual basis for problem-based distance learning of medical students and physicians.

Key words: virtual patients, case-based technologies, case study, distance learning, standardization, multimedia, Web-service, gamification, repository, database, knowledge base.

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Виртуальные пациенты как база проблемно ориентированной подготовки врачей-кардиологов

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РЕЗЮМЕ

Виртуальные пациенты позволяют избежать рисков в отношении реального больного, неоднократно использовать стандартизованные клинические ситуации, обеспечить удаленный доступ к информации. Для создания виртуальных пациентов в команду проекта включены специалисты с компетенциями в разных предметных областях. Каждый виртуальный пациент является структурированной моделью лечебно-диагностического процесса реального больного, наполненной текстовой и мультимедийной информацией. Сформирована выборка из 50 архивных историй болезни пациентов с типичными сердечно-сосудистыми заболеваниями и редкими вариантами патологии. Текстовая информация из историй болезни дополнена мультимедийными результатами инструментальных и лабораторных исследований. Созданная база данных и знаний о виртуальных пациентах предназначена для демонстрации обучающимся завершенных случаев кардиоваскулярных заболеваний в линейной траектории с возможностью Web-доступа. Репозиторий виртуальных пациентов станет фактологической основой проблемно ориентированного дистанционного обучения студентов и врачей.

Ключевые слова: виртуальные пациенты, case-технологии, анализ прецедента, дистанционное обучение, стандартизация, мультимедиа, Web-сервис, геймификация, репозиторий, база данных, база знаний.

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

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INTRODUCTION

Problem-based learning is viewed as one of the principal approaches in medical education focusing on the development of skills for making clinical and diagnostic decisions [1]. These professional competencies are formed in the very process of solving diverse problems regarding patient health. A trainee should be directly involved in a treatment of the patient to develop the clinical decision making skills, which may not coincide with the desires of real-life patients and have

limitations in terms of medical insurance. The risks of problem-based learning in medical school can be minimized by using the descriptions of complete clinical cases and simulation methods to avoid direct contact with patients.

In this regard, virtual patients are widely implemented in the medical education abroad. The term "virtual patient" has various interpretations including standardized clinical cases performed by actors or volunteers, computerized robots, and multimedia computer models of clinical situations. Virtual patients may serve as a basis for learning based on the case studies and effectively implemented in the clinical disciplines [2–4]. Conceptual cases may be developed based on the clinical charts so the virtual patients are created for further online use [5].

This paper reviews the development of a simulation format that has been used abroad since late 20th century to develop decision making skills of trainees [6–8]. The computerized multimedia simulations for diagnosis and treatment allow avoiding the risks of incorrect or inappropriate actions towards a real patient. The systematic reviews and meta-analyses demonstrate the pedagogic effectiveness of virtual patients as well as the interest of trainees to this educational technology where the interactivity of trainees increases and they get motivation for team work with a certain gamification of clinical training [9–12].

Hereinafter, the term "virtual patient" will be viewed as a computer multimedia interactive simulation of scenarios for the diagnosis and treatment of patients [13]. A virtual patient can have a real depersonalized prototype or be a result of developer imagination, i.e. fully virtual. The use of real scenarios of treatment and diagnostic process is one of the approaches to creating of virtual patients. An incorporation of depersonalized data from the clinical charts and multimedia results of diagnostic studies into this model results in a complete case virtualization and allows ensuring a remote access to this information.

The aim of this paper is to describe the method for creation of virtual patients as a model of treatment and diagnostic process of patients with cardiovascular diseases.

MATERIALS AND METHODS

Project team for creation of virtual patients comprised of the physicians, specialists in radiology and functional diagnostics, software programmers, and analysts. The virtual patient was a compilation of textual and multimedia diagnostic and clinical information. The creation of every virtual patient involved descriptions of a real clinical case. Analytical work allowed to determine the common structure for information representation and to develop the user interface and scenarios for presenting information about virtual patient to the trainees.

The information basis of project consisted of 50 depersonalized archival medical records of cardiovascular patients and multimedia results of studies stored in the corresponding databases. Apart from the texts of complete cases, the test results and medical conclusions regarding electrocardiograms (ECG), Holter monitoring, echocardiography, ultrasound examinations of carotid, femoral, and renal arteries, pleural cavity, and pericardium, multi-slice computed tomography, magnetic resonance imaging, angiography, X-ray examination, laboratory diagnostics, and treatment tactics were used.

Completeness and consistency of depersonalized information in each clinical case was evaluated by the experienced clinical teachers. After expert evaluation, information was transferred to the analysts in the form of approved textual prototypes and files. They were systematically named to be posted in the tables carried out in the PostgreSQL database management system. Multimedia information model of virtual patients was developed using Web technologies: Java Script (framework Vue.js) and Twitter bootstrap. Database was hosted on a server with an option of remote access to the information. Successful implementation of the project was pre-defined by the fact that the specialists of the team were competent in diverse subject areas.

RESULTS

In order to create virtual patients, the team of developers had to answer several essential questions regarding the content:

- Where can the required information be obtained from?
- Which structure would ensure the creation of integral image of a virtual patient?
- What are the trajectories of virtual patient presentation to users?

Two diagnostic categories were considered while establishing the sample of archival cases. The first category comprised typical, most frequently occurring cases of cardiovascular diseases. Several cases with distinct comorbidities and treatments were selected within each clinical entity. One part of clinical charts represented standard cases, which were essential for training

of medical residents and inexperienced physicians. The other part provided an opportunity to demonstrate creative approach to physicians and was of interest to the specialists advancing their qualification.

The second subgroup of clinical records represented the rare occurring variants of cardiovascular pathology potentially leading to serious consequences for a patient. The most interesting cases with rare clinical manifestation were included, which could hardly be demonstrated to the trainees in real life. All medical records in the sample were depersonalized.

The next stage was the analysis of a large pool of textual information present in medical records. Descriptions of anamnesis vitae, past medical history, and pharmacological anamnesis were edited and introduced into the tables of virtual patient database. However, every clinical chart contains a fraction of information which does not play an essential role to clinical decision making. If the results of diagnostic studies do not provide any new information pivotal for establishing diagnosis, they may be omitted from the virtual patient structure.

On the contrary, if a patient has not been investigated for some reason, though study results could be potentially informative, the results may be extracted from record of another patient with similar clinical manifestation, anatomy, and demographic characteristics. Therefore, the necessary multimedia images and recordings (echocardiography, ultrasound, ECG, coronary angiography, MRI, angiography, etc.) were accumulated as a result of a team work of analysts and medical personnel.

It was decided to withdraw from using the patient animations, essentially gamifying the training. Information model of a treatment and diagnostic process, i.e. a superposition of interrelated data on its dynamics in the textual and multimedia formats, is primarily necessary to form and improve the skills of clinical and diagnostic decision making. This superposition is the information image of virtual patient.

A real process of patient treatment in the hospital settings involves periodic contacts with the medical personnel and paraclinical services, periodic laboratory and instrumental studies, periodic treatment correction, and modification of plans for the future. This predetermines discretion of the created multimedia computer model of treatment and diagnostic process.

Not all the records in a medical chart are equally important for an attending physician and, therefore, for the development of medical competencies of trainees. In this context, the analysts made the decision on discreet representation of information in the form of discrete units. They were designated for the trainees as a "visit" and represented information in chronological consequence according to the stages of treatment and diagnostic process of the case. The prototypes of two virtual patients were created as an example of this approach to information presentation. After that, the structure of patient description was redefined, broadened, and approved by the clinical teachers.

The number of visits may differ in virtual patients because not all contacts of the patient with medical personnel generate information useful for the treatment and diagnostic process. The medical records containing new diagnostic and clinically significant data were selected and the list of acceptable formats of textual, graphic, and video information was established for virtual patient. This stage of work resulted in a template where information from the archival medical records and multimedia databases was prepared for all virtual patients. The information units generally corresponded to the traditional sections of a clinical case and served as the basis for the development of relational database tables.

The analytical work with clinical teachers resulted in establishing the prototypes of screen forms, which underwent expertise and, after modification, were implemented as the screen templates for various clinical and diagnostic situations of virtual patients. The screen forms are supplemented with the tab pages containing all information components of the visit; the day of a hospitalization is designated on the tab page to allow an accurate evaluation of the events course by the trainees (Fig. 1). The tab page of the first visit is slightly different because it represents information at the moment of admission (patient anamnesis vitae and case history, results of previous diagnostic studies and physical examination at admission, differential diagnosis, administered symptomatic treatment, and plan of the following diagnostic procedures).

The structure and pattern of information units on the tab pages of follow-up visits do not change, but the volume of information may differ. Anamnesis vitae and case history are available on the pages of all virtual patient visits. However, data regarding the complaints, administered studies, differential diagnosis, prescribed drugs, etc. are specified for the given visit. The number of tab pages (similar to the number of visits) is non-constant; the trainee may shift between tab pages along a free trajectory.

Chronologically, the last tab page of a case corresponds to the situation of patient discharge and ultimately contains the document with epicrisis of a patient stay in hospital (Fig. 2). The images and video recordings of diagnostic examinations are placed on the tab pages for the visits following their administration.

The results of instrumental and laboratory methods are incorporated into the virtual patient structure as the scanned ECG recordings, fragments of video recordings for echocardiography, angiography, and vascular ultrasound, tomography images, and X-ray pictures with the textual medical specialist opinion (Fig. 3 and 4). Based on the current guidelines of the European Society of Cardiology and the Russian Cardiology Society, compendiums of drugs are created with specification of doses and dosage frequency for treatment of a patient.

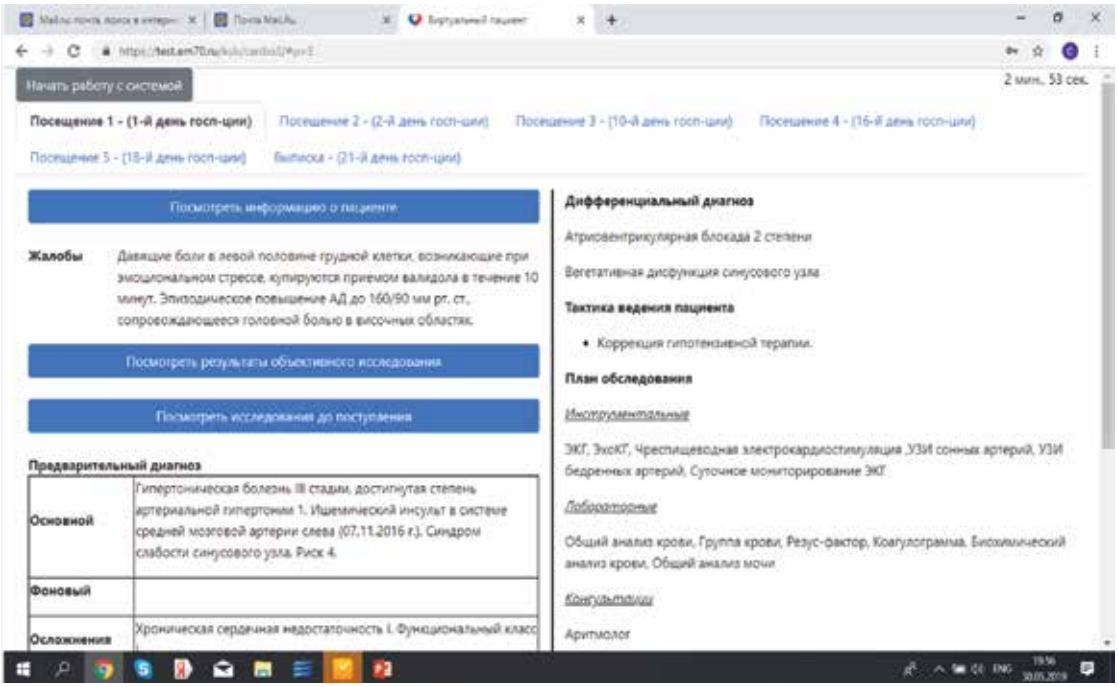

Fig. 1. Organization of the virtual patient interface

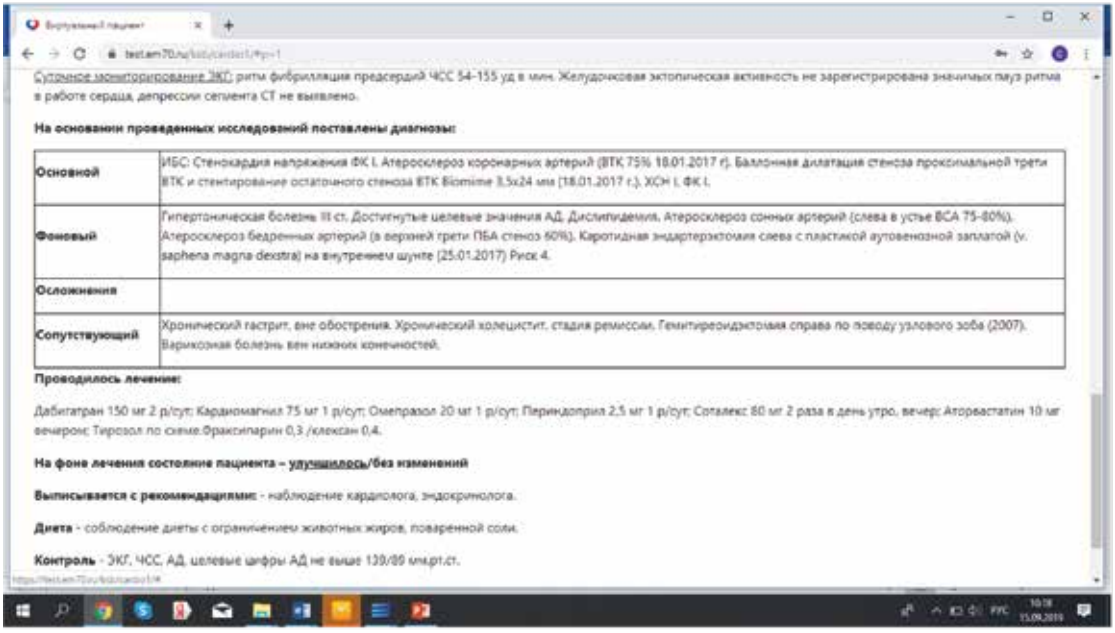

Fig. 2. Epicrisis at the final tab page of virtual patient

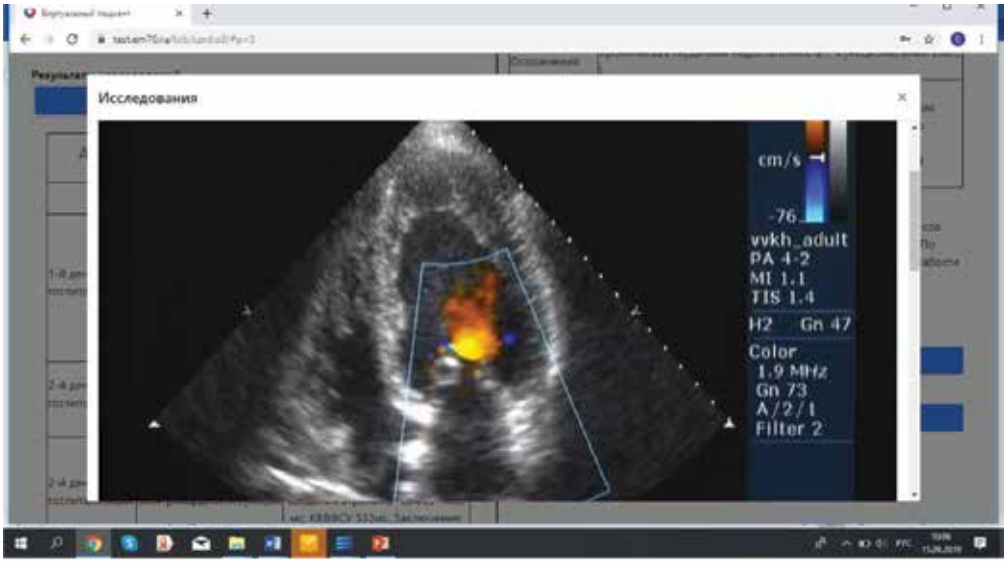

Fig. 3. Presentation of echocardiography results for virtual patient

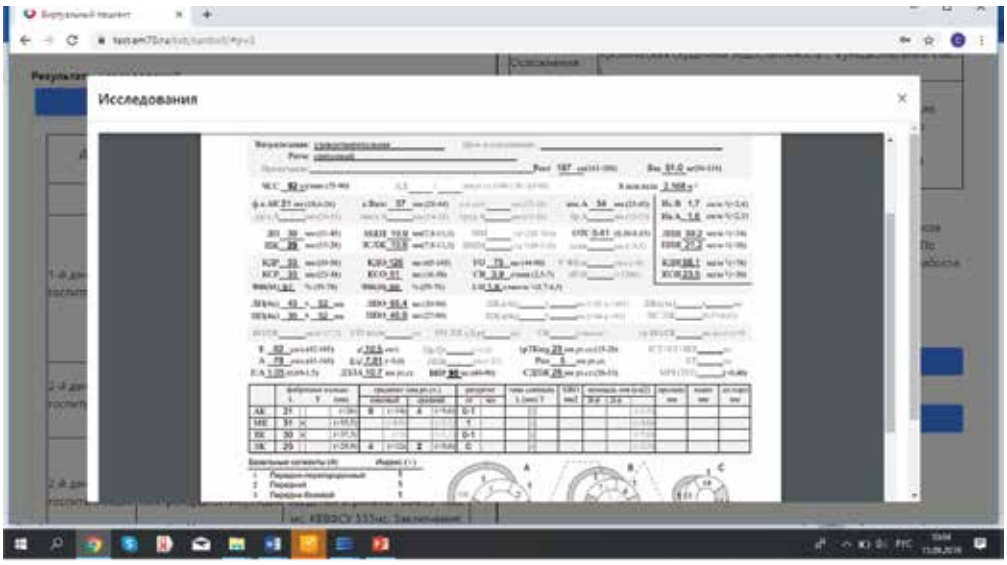

Fig. 4. Presentation of concluding remarks on the results of examination

DISCUSSION

The implementation of virtual patients is a definite innovation for Russian higher medical education. This educational technology has several advantages compared with education requiring contact with real patients or computerized mannequins. It also has some limitations. Considering this debate, one may discuss the optimality of virtual patients for the formation of clinical and diagnostic competencies. In medical education, the patient safety, pedagogic effectiveness, and costs may be considered the most essential characteristics.

First of all, the formation of competencies for decision making and their evaluation using the computer simulations are absolutely safe for the real patients. There is no need to receive patient permission for a trainee to participate in the treatment and diagnostic process; there is no need to wait for a rare in-hospital case; and there is no need to apprehend the sanctions of an insurance company if "something goes wrong".

An opportunity to repeat the same clinical situation indefinite number of times is a very essential aspect of physician training as it is impossible to achieve with real-life patients. The standardization of terms and criteria for evaluation of task performance is the advantageous characteristic of virtual patient education technology, which is hardy achievable in a framework of teaching the clinical disciplines. The presence of real comprehensive results of instrumental studies in

the standardized formats (.dcm, .avi, .jpg, etc.) allows importing them into the computer models of treatment and diagnostic process, i.e. virtual patients.

Pedagogic effectiveness of virtual patients is shown in a significant number of publications. There are not only the developed recommendations for their creation [14], but the certain proposals for the development of virtual patient-based clinical thinking skills [15]. The virtual cases, compared with the traditional medical records on paper, stimulate interaction between the trainees who are actively involved in the process. The branching trajectory makes virtual patient more realistic and useful for trainees, but it complicates the task and increases the frequency of mistakes [16]. All participants of pedagogic process notice the prospects of virtual patients for the medical education, whereas the capabilities of distance learning and decision-making skill testing make this technology unique.

The cost aspect of this educational technology is quite essential. The cost of development for each virtual patient case is one of the limiting factors for their widespread implementation in higher education and constitutes at least $10,000–20,000 abroad [17]. Average prime cost of creating one virtual patient with a linear trajectory of demonstration in this project was less than $1,000 with one-year implementation period.

The limitations of computer simulations in the clinical training include the absence of contact with patients and, as a consequence, the unawareness of patient psychological features and insufficient awareness of other personal characteristics. Even without animation, this educational technology gamifying the learning process, which results in attenuation of essential motivating factors and responsibility level of the trainees for their decision-making.

Upon comparing expected advantages and disadvantages, one may consider the virtual patients an optimal educational technology in clinical disciplines in the distance and face-to-face electronic formats.

The next step of ongoing project will be the development of with branching structure. It would simulate different variants of treatment and diagnostic process with integrated rating system for the evaluation of trainee decisions. The informational basis for the clinical and diagnostic tasks will be the materials from virtual patients. In a framework of branching clinical and diagnostic tasks, there will be an opportunity for changing the trajectory of presenting information to the trainees. The interactivity of educational technology will significantly expand and will consist in making the step-by-step solutions affecting the choice of further trajectory for completing the task.

Linear and branching multimedia models of the treatment and diagnostic process will be included in the repository of virtual patients with access for users in the form of Web-service. This resource will become the factual basis for problem-based technology of distance learning and advanced medical training of physicians.

CONCLUSION

The employed multimedia model of treatment and diagnostic process is designated for demonstration of complete cases of cardiovascular cases to the trainees along a liner trajectory. The interactivity of product is minimal and implies free choice of an information unit visit or (and) multimedia recording depending on the level of knowledge and interest of trainees. The software product complies with the technical design specification developed earlier. It passed the preliminary testing of content quality, clinical and diagnostic information sufficiency, and friendliness of information presentation on screen forms and browsing trajectory of educational content. Web-access to the materials of virtual patient is technologically implemented, which may be used for an in-person electronic learning format and distance advanced professional training of physicians.

As a result of the project competing, 50 virtual patients have been created to date for the higher medical education and postgraduate medical training. This database is hosted on the server at http://virtual.cardio-tomsk.ru as a component of factual basis for the problem-based learning technology and continuous medical education of physicians.

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