DEVELOPMENT OF SIMULATION METHODS IN BIOMEDICAL SCIENCES - FROM PHANTOMS TO VIRTUAL PATIENTS

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RAZVOJ SIMULACIONIH METODA U BIOMEDICINSKIM NAUKAMA - OD FANTOMA DO VIRTUELNOG PACIJENTA

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Received/Primljen: 03.05.2020.

Accepted/Prihvaćen: 26.08.2020.

ABSTRACT

Simulation is an imitation of the operation of a real process or system over time that is applied for a variety of purposes, including entertainment, education, training, system evaluation, and research. Medical simulation is an artificial presentation of real clinical situations, which is applied in education. Medical simulation allows the acquisition of clinical skills without the risk of harming the patient. Medical simulations have been developed and refined over the years- simulation models, cadavers, actors and robots have found wide application in medical training. Of more sophisticated simulation technologies, Virtual and Augmented Realities are used. The presence of science in the digital world is necessary in order to market the proven knowledge acquired in an adequate manner. The traditional teaching process, despite serious and thorough research, seems non-inspirational, and it is important that educators and teachers keep up with the times and provide students with the latest teaching and work methods.

Keywords: Simulation, medicine, dentistry.

SAŽETAK

Simulacija je imitacija rada realnog procesa ili sistema tokom vremena koja se primenjuje u razne svrhe, uključujući zabavu, obrazovanje, obuku i istraživanje. Medicinska simulacija je prezentacija stvarnih kliničkih situacija koja se primenjuje u obrazovanju. Medicinska simulacija omogućava sticanje kliničkih veština bez rizika od nanošenja štete pacijentu. Razvijane su i usavršavane tokom godina - simulacijski modeli, leševi, akteri i roboti pronašli su široku primenu u medicinskoj obrazovanju. Od sofisticiranijih tehnologija simulacije primenjuju se Virtuelna Realnost i Proširena Realnost. Prisustvo nauke u digitalnom svetu je neophodno kako bi se dokazana znanja stečena na odgovarajući način plasirala. Tradicionalni nastavni proces, uprkos ozbiljnom i temeljnom istraživanju, deluje neinspirativno i važno je da nastavnici i saradnici idu u korak sa vremenom i učenicima pruže najnovije metode učenja.

Ključne reči: simulacija, medicina, stomatologija.

INTRODUCTION

Simulation is an imitation of the operation of a real process or system over time. Today, simulation is used for a variety of purposes, including entertainment, education, training, system evaluation and research. It is commonly used in areas where people need to manipulate or control complex systems, including aviation, healthcare, power plant operations, and the like. The effective use of simulators in aerospace industry provided the basis for their application in other industries (1).

Medical simulation is an artificial presentation of real clinical situations. Medical simulation allows the acquisition of clinical skills without the risk of harming the patient. It can be used both for individual learning and practice as well as for *multidisciplinary team working* (2). The goal of simulation-based medical training is to provide an optimal relationship between knowledge acquisition and patient safety (3). In addition, medical simulation has the potential to simulate a scenario that happens less often in practice, such as urgent, critical, and life-threatening conditions. Medical simulation can be applied both in graduate and postgraduate studies, as well as in continuing medical education to reconstruct critical situations and emergencies that occur in natural disasters and war (Figure 1).

Figure 1. Development of simulation methods: Phantoms, cadavers, actors, robotics, computers and mobile devices, Virtual Reality and Augmented Reality

Simulation models

Phantom / manikins based simulators represent a patient with different levels of physiological and anatomical detail. They may represent age groups (eg newborn, baby, child and adult) or organ parts (4). Today, manikins are used in almost all aspects of medical education, from the anatomy of the human body to surgical simulation scenarios. Manikins help students to involve in assessing the patient's condition, by being able to reproduce vital signs, and thus to develop better clinical skills, cognitive thinking, and communication in a professional healthy environment. In order to create a more

realistic image of the patient, certain props are often added to them, such as wigs or clothes, and the environment in which the doll is used is of exceptional importance for the entire simulation course. (5). In dental practice, Oswald Fergus introduced the first 'Phantom head' in 1894, thus laying the cornerstone of dental education (6). This type of simulation is still prevalent in everyday preclinical dental practice (Figure 2A) (7). The main limitation of the preclinical model for exercise is the poor presentation of soft tissues, thus making the learning of more complex realistic clinical procedures difficult. Moreover, students cannot practice without limitations, among other things due to material costs.

Figure 2. A) Dental phantom for exercise in restorative dentistry (6); B) Use of cadaver to learn the anatomy of the head (7)

Cadavers

The tradition of using cadavers originated in ancient Greece in the third century B.C. Through the centuries, it has

become an important method that has given students a 3D view of human anatomy. In addition to formalin embalming, Thiel's (Walter Thiel) embalming method (8) has been successfully used to demonstrate a number of oral surgery techniques (9) (Figure 2B). Performing these procedures on a cadaver may enhance students' confidence prior to operating on their first patients and reduce the incidence of complications (10). Cadavers allow surgeons to practice procedures in a realistic environment, where they can make mistakes without endangering the patient's life (11). Today, due to traditional customs and culture, cadavers for medical education are rarely donated.

Actors

To make the simulation flow as realistic as possible, 'simulated patients' have also been employed in medical education. These are trained performers – actors, who simulate different clinical conditions and diseases and interact with students relying on medical history and specific segments of physical examination (12). Simulated patients can also be instructors and thus can give feedback to students on communication, technical and non-technical skills (5).

Robotics

This scientific branch is focused on the development of robots for automation of operations, and one of the main areas of robotic systems and artificial intelligence applications in the modern medical field. Tmsuk R&D Inc. and Tottori University Hospital of Yonago have jointly developed a Mikoto robot for medical training. This robot is specifically designed for endotracheal intubation, endoscopy and aspiration (13). In dental education, a Hanako robot (Hanako - Dentaroid, Nissin, Netherland) is being applied today, designed to simulate a patient with anatomical and physiological characteristics that the instructor can control at a touch of the panel interface on the controller (14) (Figure 3). The application of robots in medical branches gives high accuracy and can reduce the probability of making a mistake during the operation. Also, it can affect better diagnosis and thus better treatment of the disease. So, the main purpose of the development of medical robotics is to increase the efficiency of treatment, to reduce the risk and harm to human health, but from the financial aspect, it is still not widely applied in everyday education (15).

Computer-Aided Learning / mLearning

By introducing computers in the curriculum of health sciences (Computer-Aided Learning), the acceptance has been achieved, both by teachers and students. Computers effectively complement conventional learning and help students to acquire specific knowledge and to develop problem-solving skills. They can facilitate problem-based learning, by using realistic, risk-free clinical simulations and providing student-centered instructions under the control of the educator. This can result in a more enjoyable learning experience that encourages users to try to understand better and to use learning resources more often (16). With the

development of mobile devices, smartphones have been increasingly used in the educational process (Mobile-Aided Learning, mLearning).

Figure 3. Robotics in dentistry
(Hanako - Dentaroid, Nissin, Netherland)

Undoubtedly, the use of mobile devices pervades the field of biomedical education in the form of simulation models, complementing conventional teaching. Numerous mobile applications can transform the medical environment and positively impact student education while also allowing students to learn at their own pace (17-20). The usage of computers and mobile learning devices usually requires students to follow the content without direct or indirect supervision of teachers, and occupies a special place in distance learning, both in the transfer of knowledge in remote areas and during emergencies and pandemics (21). Obstacles to success are mainly technical and practical and can be overcome through cooperation between institutions (22).

Virtual Reality and Augmented Reality

Virtual Reality (VR) is a computer-generated simulation made up of a set of images and sounds that represent a real place or situation, with which the user integrates with special equipment (the basis is VR glasses) (23, 24). Virtual Reality creates a world that man can experience and explore virtually, through his senses. The first application of Virtual Reality in medicine began in the early 1990s due to the need for medical staff to visualize complex medical procedures (25). Many VR systems are available today that allow a more detailed measurement of student performance by looking through precision, accuracy, speed, and error rate. The use of VR in medicine today is an important tool for improving surgical skills and has a positive effect on diagnosis and surgery planning (26) (Figure 4) (27, 28). In addition to surgery, VR has found application in endoscopy (29), neurology (30) and anesthesiology (31). Technological advances have made it possible to incorporate Virtual Reality simulation technology in dental education, and above all in the preclinical restorative dentistry (32, 33). Virtual Reality simulators provide the ability to integrate clinical scenarios into the operating environment and facilitate tactile skills using haptic technology (34). Haptic technology provides tactile feedback in the form of vibrations, movements, and the feeling of touch when applying force. This is very useful in a number of situations, including the ones where surgeons use minimally invasive techniques and manipulate long wires or instruments (35). The main advantage of applying these technologies is that the system regularly and routinely records data on all aspects of operator's performance. These data are not limited to criteria such as "completion time", but they include parameters such as the intensity of the tremor, the force that the instrument exerts on the tissues, the number of movements (5).

Figure 4. Virtual Reality simulation in Maxillofacial Surgery - A) environment sees; B) operator sees over VR glasses (26) (Images reproduced under creative commons)

Augmented Reality (AR) is a simulation of a three-dimensional environment created using hardware and software that provides the user with realistic experiences and ability to interact. Augmented Reality offers an interactive experience and aims to enhance the existing environment by adding virtual elements, rather than replacing it with a completely new environment. The key to using Augmented Reality was the development of personal computer devices, and the advancement of technology has brought augmented reality concepts to mobile devices. The concept of AR has found wide application in the arts, gaming industry, architecture, daily life, industrial design, navigation, auto industry, archeology. With increased need for catheterization and endoscopic interventions, AR has found an important role in many medical disciplines (36) (Figure 5) (37-39). In dental education, it is increasingly used in everyday clinical practice and education. It is most widely used in maxillofacial surgery due to complex clinical procedures, and is increasingly used in implantology, oral surgery and anaesthesia, aesthetics and morphology (Figure 6) (40-46). Augmented Reality shows great potential in facilitating learning, whether it helps in learning anatomy by providing interactive 3D models, improving fine motor skills, or helping students to see interactions from a patient's point of view. This technology provides students with new ways to better understand the complex structures described in textbooks and to apply them in real-world situations (47).

The biggest disadvantage of these sophisticated learning methods is the need for a good knowledge of technology and the concept of work. Contact with these technologies is largely unknown, so training with an educator and practicing is required. As physical contact with virtual objects is not achieved through Augmented Reality and Virtual Reality, it is necessary to work on better user integration in combination with haptic simulators and robotics (48).

Most researchers agree on the significant educational and motivational potential of virtual technologies. These new technologies are constantly advancing, becoming more

affordable, and users also have a positive attitude in implementing them (49).

Figure 5. Usage Augmented reality in operative surgery (36)

Figure 6. Learning local anaesthesia with Augmented Reality mobile simulator (Image by the author)

Martín-Gutiérrez et al (50) identified *four main aspects* regarding the *advantages* of using *virtual* technologies:

- increase student motivation and engagement, and 3D models enhance the learning experience;
- provide better access to learning - students interact with virtual objects, allowing them to explore, experiment and receive feedback;
- available through mobile devices (devices already owned and used by students) and
- Enable greater interaction than traditional teaching aids.

CONCLUSION

The development of clinical competence requires the assimilation of large amounts of knowledge combined with the acquisition of clinical skills and clinical problem-solving

ability. The student should understand the concept of the procedure and develop fine motor skills to perform it. The acquisition of technical skills and the transfer of these skills to clinical practice is of paramount importance. The technological age we live in is greatly shaped by our understanding of space and time. The social circumstances created by the advancement of technology raised the question of adapting to new ways of knowledge transfer (42). The presence of science in the digital world is necessary in order to disseminate acquired knowledge in an adequate manner. In the battle for attention, science has competitors embodied in the entertainment and leisure industries. Standard textbooks, scientific monographs, and the conventional teaching process, despite serious and thorough research, seem uninspiring. The solution to the successful transfer of knowledge is to use new technologies. It is very important that educators and teachers always keep up with the times and provide students with the latest methods of learning and training. In doing so, they acknowledge students' interests and facilitate the learning process.

CONFLICT OF INTEREST

The authors declare no financial or commercial conflict of interest.

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