Implementation of Virtual Reality for Teaching Auscultation to 3rd Year Medical Students

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Abstract

Background.

Auscultation is one of the fundamental skills of a doctor in the physical examination of the patient. Virtual reality (VR) training has been used last several years in medical education. The aim of the project is to compare the effectiveness of lung and heart auscultation training using traditional teaching methods and virtual reality technology.

Methods.

The study was conducted the Belarusian State Medical University. 77 students of 3rd year studying clinical medicine were divided into 2 groups: a group of students who studied in virtual reality (VR protocol, n = 28), and a comparison group - students who studied without using virtual technology (classic scenario, CS protocol, n = 49). VR auscultation was taught using the Oculus Quest 2 headset with software that allows auscultation of the heart and lungs. The study continued throughout the semester.

Results.

When listening to the control records of lung sounds after the end of training, it turned out that VR group students recognized sounds somewhat better than the students of the CS group (54.5 vs 38.3%), p = 0.010. Heart sound recognition in the VR group was slightly better compared to the CS group (44.6% vs 37.0%), p-0.232. At the final control of testing the knowledge retained on auscultation, which was carried out 3 months after the end of the study of auscultation, it turned out that long-term results were better in the VR group. In recognizing lung sounds, students on the CS protocol performed slightly better (41.7% versus 36.9% for the VR protocol). On cardiac auscultation, the situation was reversed: the VR protocol group recognized sounds in 56.1% of cases, versus 25.4% in the CS protocol group. In all, VR group recognized 47.6% respiratory and heart sounds versus 33.4% in C group, p-0.003.

Conclusion.

Our data suggest that VR technologies are quite superior in learning efficiency as compared to traditional teaching methods of auscultation and can be used as a supplementary form of teaching.

Highlights

- Virtual reality technology can be used to teach auscultation to medical students.
- Students are highly enthusiastic about learning in virtual reality.

- The results of virtual reality learning of lung and heart auscultation are comparable or superior to the results of learning according to the classical method and can be used as supplementary form of teaching.

1. Background

1.1. Medical Simulation Technology

Throughout history medical simulation technology has played a vital role in not only medicine, but medical education as well. According to G. Alinier [1], the level of its development today is characterized by the presence of interactions between the operator and the simulation device. Such interactions can be achieved by the use of digital technologies and can be implemented in several ways.

Firstly, (when a computer program is commanded to respond to the user's input) rigidly focused on executing the specific commands in a material carrier-matrix: for example, mannequins that resemble certain parts of the human body and respond to a limited range of operator manipulations.

The second way, which has been improved over the past decade, is virtual reality simulators. Virtual reality training is used in anatomy [2], communication with patients [3], taking an objective structured clinical exam [4], etc.

Which approach is better? - it is impossible to say for sure. Thus, the use of simulators based on a material carrier (dummy) gives the trainee the "effect' of presence, when the operator receives tactile sensations, feeling of a tissue, an organ; this is important when teaching the invasive techniques of interventions. At the same time, due to the rigidity of the software to the mechanical matrix, this vastly hinders the simulators abilities to perform multiple manipulations which limits the capabilities of the simulator by performing one or more manipulations.

Virtual reality technologies, on the other hand, do not offer the feeling of tactile contact and the scope of application is determined only by software. In addition, virtual reality technology significantly reduces the space required to house a simulator and, in the long run, is far cheaper. The advantages and disadvantages of using virtual reality in medicine and the educational process are presented in the review [5, 6, 7,8].

Recognition of sounds during auscultation of the lungs and heart is one of the fundamental skills of the doctor in direct examination of the patient. Learning auscultation skills involve mastering the technique of auscultation, the skills of recognizing the sound and the ability to classify the latter in accordance with the generally accepted nomenclature.

The classical approach to teaching auscultation involves the theoretical material (including work on simulators) before presenting to the patient's bedside.

In the latter case, we are faced with a number of problems that make training difficult: the presence of a patient with thematic pathology in the clinic, ethical problems (the patient's consent to examination by a student, a high ratio of students to patients, the short duration of exposure also (may be due to the severity of the patient's condition, or the patient's refusal to cooperate for educational purposes). In addition, to these challenges, the prevalence of COVID-19 has also presented restrictions on the educational process [9].

It is optimal when a student comes to a patient already having very basic skills in recognizing sound so that he can compare the sounds he hears with the collection of sounds that he has in his memory.

The effectiveness of the use of simulation technologies in the preparation of a medical student is being actively studied. For example, a meta-analysis [10] included 13 works where simulations were used as additional training tool with traditional “bedside" methods. The authors conclude that simulation technologies are crucial in the preparation of medical students. However, today we would like to discuss trends towards a higher efficiency of simulation technologies compared to traditional teaching methods.

It should be noted that many studies of the effectiveness of simulation technologies relate to assessing student satisfaction with these technologies [9]. This feedback helps to improve the quality of training students as simulation technologies are introduced [11].

1.2. The aim of the project

The aim of the project is to compare the effectiveness of lung and heart auscultation training using traditional teaching methods and virtual reality technology.

2. Methods

2.1. Virtual reality (VR) technology.

Auscultation was taught using the Oculus Quest 2 headset with software that allows auscultation of the heart and lungs using a virtual stethoscope (Proven Reality, Republic of Belarus, Minsk).

The virtual reality headset "Oculus Quest 2" had the following characteristics: display resolution 1832x1920 for each eye, refresh rate 90 Hz, RAM 6 GB, tracking of the surrounding space and user movements is carried out using cameras with a viewing angle of 100^0. The image adapts to the user's movements (the device independently provides tracking of the user's position in real time on a room scale without external sensors; while using the headset, the user can stand or sit, regardless of the size of the environment). Virtual reality has 360° video technology, the student is completely immersed in the virtual world without any external distractions.

Two touch controllers in virtual reality resemble real hands and are synchronized with the position and the basic movements of the user’s hands in real time (Fig. 1). "Oculus Quest 2" has positional audio, built

directly into the headset.

In the conditions of virtual reality, the conditions of a doctor's office are recreated, with a virtual patient (male or female) present; the student has the opportunity to independently perform the actions necessary when listening to the lungs and heart. Several features that should be noted: (a) the teacher sees the student's actions on the monitor of the central computer and can correct them; (b) the student sees an interactive menu where they can select a specific sound with help information; (c) students work in pairs - one student is engaged in the actual auscultation, the second one ensures the safety of the operator's movement around the room; (d) the software provides the ability to work in study mode and in exam mode, in which the teacher sets the working conditions.

2.2. Research design.

The study was conducted at the Department of Propaedeutics of Internal Diseases of the Belarusian State Medical University by 77 students of 3rd year studying clinical medicine. The students were divided into 2 groups: a group of students who studied in virtual reality (VR Protocol, virtual reality, n = 28), and a comparison group - students who studied without using virtual technologies (CS Protocol, classic scenario, n = 49) (Table.1). The study continued throughout the semester.

All participants gave informed consent to participate in the experiment. In accordance with the Program, 14 hours were allotted for studying auscultation of the lungs, and 14 hours for auscultation of the heart.

Table 1
Contents of the Training Protocols

class No	Duration, hours	VR Protocol	CS Protocol
		Lesson content*	
1	3.5	Theoretical foundations of lung auscultation. Technique for working in virtual reality	Theoretical foundations of lung auscultation. Simulation technique
2	3.5	Lung auscultation study in virtual reality	Learning auscultation of the lungs on simulators
3	3.5	Lung auscultation study in virtual reality	Study of lung auscultation on bedside simulators
4	3.5	Checked by	Checked by

Note. * - also, the VR Protocol and the CS Protocol were applied for training in cardiac auscultation.

Naturally, in the beginning, students needed time to familiarize themselves with the technology of the oculus system (which often took less times than for the professors). By the second lesson, students were more comfortable and had easily adapted to the headset.

Pulmonary sounds were classified according to [12], heart sounds according to [13]. Lung and heart sounds were included in both the VR and CS protocols, respectively, after an assessment by 3 independent experts (Table.2).

Table 2
Respiratory and heart sounds in VR and CS protocols.

Sounds	Number of options
Respiratory sounds	
Vesicular breathing	3
Bronchial breathing	2
Crepitus	2
Crackles	3
Wheezing	2
Rhonchi	2
Pleural Friction Rub	2
Heart sounds	
Normal sounds* Apex/Aorta	2/2
Additional sounds*	2/2
Systolic murmur** Apex/Aorta	2/2
Diastolic murmur** Apex/Aorta	2/2

Note. * - recognition of the listening point; ** - only murmur recognition was taken into account, regardless of the listening point.

2.3. Checkpoints.

The assessment of effectivity of this learning approach technology was performed by having the students recognize different heart and lung sound audio recordings.

To assess auscultation of the lungs and heart 5 audio tracks were recorded which contained 4 different respiratory and heart sounds each. For the final control, 5 sound were recorded, each of which contained 6 different sounds: 3 respiratory sounds and 3 heart sounds. The students were asked to identify the

sounds they heard after listening to the recordings twice. All control audio tracks played were randomized to prevent the dissemination of information, since testing was not carried out at the same time.

Checkpoints: 1) after training; 2) 3 months after training.

The study was conducted during the COVID-19 pandemic. A number of students and project participants, needed to self-isolate at the time of passing the sound recognition checkpoints. Therefore, results were not taken into account. The participants used headphones connected to a laptop to hear the sounds.

2.4. Questioning students.

The students were asked several questions to assess their feedback towards the virtual reality method. Responses were assessed on a modified Likert scale (1–10), from "completely dissatisfied" to "completely satisfied":

1) Have you used VR goggles before?

2) How satisfied are you with VR training?

3) How easy was it to start learning during the first lesson?

2.5. Statistical analysis.

Statistical processing was carried out using the program "Statistica 10". When analyzing data with a non-normal distribution, the median (Me) and the inter-quartile interval [Q25; Q75], non-parametric statistical methods were used to compare data. Data differences were considered statistically significant at $p < 0.05$.

3. Results

3.1. Auscultation of the lungs. When listening to the control records of lung sounds immediately after the end of training, it turned out (Table. 3) that students trained in virtual reality recognized sounds somewhat better than students trained in conventional technologies (54.8% vs. 38.3%). At the same time, crackles in the VR group were recognized significantly worse.
Table 3. Respiratory sound control

Sound	VR Protocol (n=26)			CS protocol (n=45)			p
	R*	NR	% recognition	R	NR	% recognition	
Vesicular breathing	5	15	**25.0**	8	30	**21.1**	0.991
Bronchial breathing	10	4	**71.4**	12	14	**46.1**	0.230
Crackles	5	14	**26.3**	18	17	**51.4**	0.135
Wheezing	18	5	**78.3**	11	19	**36.6**	0,006
Rhonchi	5	3	**62.5**	6	9	**40.0**	0.555
Pleural friction rub	6	4	**60.0**	6	14	**30.0**	0.236
Crepitus	8	2	**80.0**	8	8	**50.0**	0.265
Total	57	47	**54.8**	69	111	**38.3**	0.010

Key. R – recognized; NR - did not recognize

3.2. Auscultation of the heart.

The efficiency of recognition of heart sounds immediately after training is presented in Table. 4. Overall, sound recognition in the VR protocol group was slightly better compared to the CS protocol group (44.6% vs. 37.0%). At the same time, the efficiency of recognition of individual pathological sounds (murmurs) in the VR protocol group was slightly lower.

Table 4. Heart sound control

Sound	VR protocol (n=28)			CS protocol (n=48)			p
	R*	NR	% recognition	R	NR	% recognition	
Normal sounds	35	45	**43.7**	43	95	**31.2**	0.085
Additional sounds	1	3	**25.0**	2	4	**33.3**	0.673
Systolic murmur	10	7	**58.8**	18	12	**60.0**	0.818
Diastolic murmur	4	7	**36.4**	8	10	**44.4**	0.968
Total	50	62	**44.6**	71	121	**37.0**	0.232

Key. R – recognized; NR - did not recognize

3.3. Preservation of sound recognition after 3 months.

At the final control of the knowledge retention on auscultation of the heart and lungs, which was carried out 3 months after the end of the study of auscultation, it turned out that long-term results were better in the virtual auscultation group (Table 5). It is necessary to pay attention to the low level of sound recognition - almost 50% and below. We believe that this is due to the lack of daily auscultatory training among students: the auscultatory skill requires daily training: even for experienced doctors, after a long absence from the clinic, it can take some time to recover these abilities.

In recognizing respiratory sounds, students on the CS protocol performed slightly better (41.7% versus 36.9% for the VR protocol). However, vesicular breathing was poorly recognized, with the VR protocol group performing significantly worse at perceiving normal vesicular breathing - only 9.1% of students, as compared to the CS protocol group – 25.9%. A similar situation was observed in regard to recognition of crepitus. Bronchial breathing and crackles were comprehended and appreciated more by the students of the VR protocol.

On cardiac auscultation, the results were reversed: the VR protocol group recognized sounds in 56.1% of cases, versus 25.4% in the CS protocol group.

Interestingly, if the recognition of control heart sounds immediately after training was comparable in both groups, then after 3 months, students in the VR protocol were considerably better at recognizing heart sounds and were often 2 times better than in the CS protocol group.

Thus, in general, 3 months after the auscultation training, the students of the VR group recognized the sounds of the heart and lungs better than the students trained by conventional methods. It is important to note that some sounds are appreciated better after training in VR, while others are heard better after training with conventional technology. On the other hand, such "heterogeneity" may be due to a small sample size of students.

Table 5
Control of respiratory and heart sounds

Sound	VR protocol (n = 28)			Protocol CS (n = 48)			p
	R*	NR	% recognition	R	NR	% recognition	
Respiratory sounds							
Vesicular breathing	1	10	**9.1**	7	20	**25.9**	0.430
Bronchial breathing	5	6	**45.5**	8	13	**38.1**	0.112
Crackles	8	6	**57.1**	12	15	**44.4**	0.103
Wheezing	10	14	**41.6**	15	14	**51.7**	0.650
Rhonchi	2	4	**33.3**	5	6	**45.6**	0.976
Pleural friction rub	4	8	**33.3**	6	11	**35.3**	0.297
Crepitus	1	5	**16.7**	7	5	**58.3**	0.034
Total respiratory sounds	31	53	**36.9**	60	84	**41.7**	0.570
Heart sounds							
Normal sounds	24	4	**85.7**	20	28	**41.7**	<0.001
Additional sounds	12	6	**66.7**	7	23	**23.3**	0.005
Systolic murmur	7	11	**38.9**	6	24	**20.0**	0.276
Diastolic murmur	6	14	**30.0**	3	33	**8.3**	0.083
Total heart sounds	49	35	**56.1**	36	108	**25.4**	<0.001
TOTAL	80	88	**47.6**	96	192	**33.43**	0.003

Key. R – recognized; NR - did not recognize

3.4. Student survey

We surveyed 28 students who used virtual reality in the process of learning auscultation of the lungs and heart. Students showed high interest and motivation when working in virtual glasses. Previously, 18 out of 28 (64.3%) students had no experience with virtual reality headsets, the remaining 10 (35.7%) students were experienced with this technology. At the same time, none of the students mentioned any significant difficulties in using the equipment: most of the students did not have any questions with using the technology, 16 people (57.1%) each scored 9 and 10. Most students (n = 15, 53.6%) needed only one lesson to master the device before the Protocol. 10 students (35.7%) needed two sessions, only 3 students (10.7%) needed more than two sessions.

The average value of satisfaction (on a 10-point scale) with virtual reality technology was high – 8.74, the minimum value of satisfaction was 5, the maximum satisfaction rate was observed in 10 students (32.1%).

Some of the advantages of using virtual reality noted by student were the possibility of using it during epidemics, when access to patients is difficult (14.3%), the comprehension of the material studied was easier due to the "reality" of the conditions (14.3%); 7 students (25.0%) noted that there are no issues compared to working with a real patient and there was ample time for auscultation of each student.

4. Discussion

Auscultation is considered to be a difficult physical examination skill: even trained physicians with clinical experience face significant challenges in this field. When assessing the recognition of heart auscultation sounds by doctors from different countries, on average, 20–26% of the presented sounds were recognized [14]. According to SL Kobal et al. [15], board-certified cardiologists were only able to recognize systolic murmurs in 62% of patients and in 16% of patients with diastolic murmurs.
The clinical effectiveness of auscultation largely depends on the apprehension of the course material (university) and constant training during practical work, throughout life. Our data shows that the time allotted for undergraduate students to study auscultation is clearly not enough. The same opinion is shared by researchers from other universities. Thus, 3rd year students were able to recognize only 11% of heart sounds, however, after training on simulator dummies, the frequency of recognition of heart sounds increased sharply - up to 72% [16]. When listening to pulmonary sounds by students, the recognition rate on average did not exceed 30%; only for wheezing and stridor did it exceed 50% [17]. In this aspect, virtual reality technologies cannot change the situation. Of course, the technology is improving day by day and with further updates we may see substantial improvements and better results in assessing pulmonary sounds.

Nevertheless, our data suggest that VR technologies are quite superior in learning efficiency as compared to traditional methods alone. The advantages of virtual reality are the ability to imitate the environment of a doctor's office, its equipment, the doctor's actions during a physical examination, etc., as much as possible. In other words, the student gets the opportunity to recognize sounds not only with an auditory analyzer, but also with a visual and tactile one, which makes it possible to increase the degree of memorization of sounds. In addition, virtual reality technology has a large amount of support and interest by students. A significant advantage of VR technologies is the ergonomics of the equipment: the station can be deployed in almost any room; the only condition is to have silence in the room.

An important feature of virtual technology is their flexible nature. At our request, we can not only add or change some sounds, but also expand the scope of the virtual model without additional equipment.

Virtual auscultation still has some limitations. Among the disadvantages of the technology at this stage, one can note the difficulties of working in virtual reality glasses for a person who has visual impairments and uses prescription glasses permanently may experience tension or headaches due to the size of the

headset and glasses. For students who wear glasses occasionally, we recommend using contact lenses. The time that an inexperienced person can spend in virtual reality is relatively short (according to our data, students were fatigued after 10–20 minutes, and a change of activity is necessary).

Obviously, the data we obtained should be treated with caution, since the sample size of students was relatively small. We consider this project as a pilot one, which will allow us to conduct a large, well-organized clinical and pedagogical study in the future.

5. Conclusions

Our data suggest that VR technologies are quite superior and comparable to learning efficiency as compared to traditional teaching methods of auscultation and can be used as a supplementary form of teaching.

Declarations

Ethics approval and consent to participate

All methods were carried out in accordance with relevant guidelines and regulations.

All experimental protocols were approved by the Belarusian State Medical University committee (Institutional review board).

All students and professionals who participated in the study gave oral and written consent to participate in the study.

Consent for publication

Not Applicable

Availability of data and materials

With a limited version of the software for the Oculus Quest 2 headset, anyone can familiarize themselves with the link https://sidequestvr.com/app/6197/auscultation-training

For a full version, please contact the author for correspondence by e-mail amorozov@provensolution.com

Competing interests

No competing interest for EAD, MVS, KED, TPN.

AVM, PVM, ASL are employees of the company «Proven solution information technology».

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Authors contributions

EAD, MVS, AVM contributed to the conceptualization and carried out the literature review.

EAD, MVS, KED contributed to the writing of the article and editing of all the drafts. EAD, MVS, TPN conducted work with students and their examination.

AVM, PVM, ASL provided technical support for work with VR equipment and participated in the creation of software.

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Figures

Figure 1

View of the patient in virtual reality. A - The image of the patient, which the student sees; B - Screen of the teacher's monitor with images of 4 access points.