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Implementation of a Web-Based Interactive Virtual Patient Case Simulation as a Training and Assessment Tool for Medical Students

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Abstract. Objective Structured Clinical Examinations (OSCE) are resource intensive, not practical as teaching tools, and their reliability depends on evaluators. Computer-based case simulations ("virtual patients", VP) have been advocated as useful and reliable tools for teaching clinical skills and evaluating competence. We have developed an internet-based VP system designed both for practice and assessment of medical students. The system uses interactive dialogue with natural language processing, and is designed for history taking, evaluation of physical examination, including recognition of visual findings and heart and lung sounds, and ordering lab-and imaging tests. The system includes a practice modality that provides feedback, and a computerized OSCE. The reliability of our system was assessed over the last three years by comparing the clinical competence of medical students in similar VP and human OSCE. A total of 262 students were evaluated with both exam modalities. The correlation between the two exams scores was highly significant ($p<0.001$). Alpha Cronbach for the computerized exam was 0.82-0.89 in the 3 years, and was substantially higher than that of the conventional OSCE each year. We conclude that a computerized VP OSCE is a reliable examination tool, with the advantage of providing also a training modality.

Keywords. Virtual patient, OSCE, medical education,

1. Introduction

Clinical medical education is based on a combination of lectures, written literature and "bed-side" teaching during clinical rotations. The latter is obviously the cardinal and most important part of medical education. Unfortunately, bed-side teaching is associated with many practical limitations. It requires a large core of experienced and well trained instructors, is time consuming, and the number of adequate patients available for teaching and the spectrum of diseases are insufficient. Similarly, medical exams based on real patients are known to have unacceptable low reliability, and were usually replaced by OSCE (objective structured clinical examination) simulations by actors or medical staff. However, OSCE's are very resource intensive [1], and judgments made by individual evaluators jeopardize both reliability and validity [2].

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The development of computerized systems has enabled to develop a new level of tuition and evaluation, that can be placed between the book and written exams on the one hand, and bedside teaching and assessment on the other. Over recent years, an increasing number of computer-based simulations of patients have been proposed for both training and assessment in medical education, often referred to as "virtual patients" (VP). Although the use of VP has not yet entered the main stream of medical education and is only currently starting to be integrated into the regular curriculum in few universities, there is no doubt in the potential of VPs to fill significant gaps in the current tuition of medical students. VPs are excellent teaching tools for developing clinical reasoning and decision-making skills and improving clinical competency [3,4]. Clinical reasoning is a process that matures through deliberate practice with multiple and varied clinical cases. VPs are ideally suited to this task, as potential variations in VP design are practically limitless [5]. VPs can incorporate images, sound, videos, lab tests and imaging results, both for early medical students [4], and for later years' courses [3]. Although VPs cannot replace interpersonal communication with real patients, students tend to react similarly to real and simulated patients [6]. Web-based VP software has the most important advantage of providing an interactive "game", enabling practicing patient management in a fast sequence whenever and wherever convenient for the student, providing real-time and accurate feed-back. The same system can be used for exams, providing statistically analyzed results within seconds after the exam. The most advanced VP programs replaced the multiple choice system by natural language processing, designed to enable the student to ask any medical related question via an interactive dialogue with text entry [7,8]. However, due to practical and logistic problems, it appears that despite the obvious theoretical advantages of VPs, few if any university has published its experience with a VP system that was implemented into the curriculum and used for regular exams.

Over the last years we have developed and implemented a web-based VP system that simulates and replaces OSCE with broader scope, and designed for both training and exams. This VP system is currently used by students at the beginning of their clinical year to practice clinical reasoning skills and enlarge the spectrum of diseases evaluated, in parallel with encounters with real patients. The same system was also used over the last 3 years for the final exam of the introductory course, in parallel with a "traditional" OSCE, performed by human assistants, independently but at the same time. The current paper describes our OSCE-based VP system and compares the results of the human and virtual OSCE.

2. Methods

The web-based VP system described was developed by our group, and was designed for medical students at their clinical years, to resemble a realistic patient encounter, covering medical history, physical examination (H&P) and laboratory and imaging tests. The primary goal was to teach the student how to evaluate patients with specific, common clinical conditions. Accordingly, similar to the methodology used in OSCE, the student is encountered with the main complaint and vital signs of a VP, and should know the mandatory questions needed to be asked, specific signs that need to be looked for during physical examination, and tests that need to be ordered, based on the answers and findings. The student conducts an open dialog with the VP, writing medically relevant questions in free wording, and the VP "understands" the question and replies a pre-programmed reply. The ability to conduct a free dialog is based on natural language processing, with a lexicon of keywords. Obviously, the number of questions the VP can answer is much larger than the limited number of questions considered as mandatory. The student asks, in writing, for findings in physical examination, and may get a written reply (like for palpation findings), picture (for findings that can be seen), or audio-video clips of heart and lung sounds. Based on the H&P, the student has to order initial laboratory and imaging tests from a computerized order list similar to lists used in hospitals and other medical agencies..

Our VP system was designed for both exercise and exams. Accordingly, the student can practice solving medical problems and get a grade during exercises conducted at home. Mandatory items are based primarily on the ability of the student to apply the relevant differential diagnosis of the main complaint to H&P and the initial tests. During exercise, the student can pause anytime and ask to see all the relevant questions/findings/tests considered as mandatory, and the lists, ordered in groups of asked or not-asked (or incorrectly identified) items, provide a practical feedback (not shown during exams). A large number of training VP cases is available on the VP website for all students and instructors. Few cases were practiced in small groups with the instructors, but the students were encouraged to practice all cases repeatedly on their own, the same way as preparing for exams from books.

A major shortcoming of VPs is the difficulty in preparing new cases, particularly when natural language recognition is used. To facilitate this task, complex visual modalities were avoided, and multiple mechanisms were introduced to enable simple creation of new cases, particularly when a basic prototype of a specific complaint or finding was already created. Before implementation into the teaching and exam curriculum, 25 clinical prototypes (like chest pain, anemia etc.) with several case scenarios for each were prepared (for example: for chronic diarrhea, a patient with Crohn's disease, a patient with celiac etc.). In addition, a "learning modality" for the VP was created, to add words and items asked by the students, that the VP did not recognize.

The exam is conducted with the same system in the computer center of the faculty. Several cases are presented sequentially, with time limitation for each case and a limitation to the number of tests that can be ordered. The test results, including analysis of the difficulty of each item, the ability of each item to discriminate between "better" and "poorer" students (point-biserial correlation), and the reliability of the whole exam (Cronbach's alpha), are produced automatically at the end of the exam.

Over 2 years before implementation, the VP-OSCE exams were offered to the students on a voluntary basis. Experience gained in these exams was used to improve the system to the level that enabled implementation. Over the next 3 years, on the day of the exam, the students were divided randomly into two groups, the one underwent conventional OSCE with 5 positions/clinical cases, and the other was examined with the VP system on equal number of different cases. During the VP exam, instructors were available to help the students with questions the VP did not "understand". No explanations were permitted, and the instructors only provided adequate wording if the question was relevant, but inadequately worded or misspelled. The human and VP OSCEs ended at the same time, and the groups were switched, each one taking the different OSCE. Hence, every student evaluated on the day of the exam 10 different clinical cases, half performed with actors and half with VPs. The grade in each OSCE modality was calculated equally, as the percent of mandatory items the student knew.

The OSCEs performed over the last 3 years are the subject of the current paper, and were considered as a randomized, crossover, prospective non-inferiority study. To compare the human- and VP-OSCEs, we correlated the individual grades of the students achieved with both types of OSCE (Pearson correlation). Cronbach's alpha was calculated separately for every OSCE each year.

3. Results.

Comparison of the grades and reliability of the human and VP-OSCE is given in table 1. The mean grades tended to be higher in the conventional human OSCE, but this difference was statistically not significant. The Cronbach's alpha were substantially higher every year in the VP OSCE. The relationships between individual grades obtained by all students over the 3 years is shown in figure 1.

Table 1. Comparison of grades and α Cronbach obtained in the human and VP OSCEs, and the correlations between grades in both exam modalities. *- $p<0.01$

		Human OSCE		VP OSCE		
Year	***n***	**Grades; mean±SD**	**α Cronbach**	**Grades; mean±SD**	**α Cronbach**	**R**
2008	*87*	78.2±7.3	0.65	78.9±8.2	0.82	0.68*
2009	*76*	83.3±8.0	0.74	78.9±9.6	0.89	0.71*
2010	*99*	85.1±6.9	0.71	80.0±8.8	0.85	0.65*
2008-10	262	82.3±7.9		79.3±8.9		0.70*

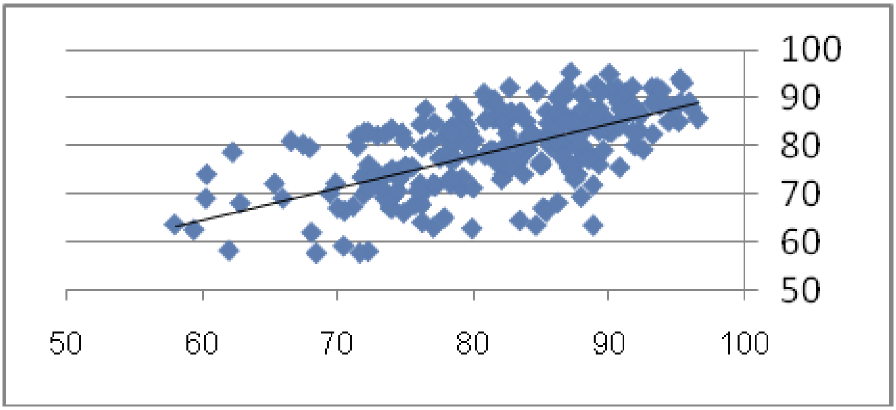

Figure 1. Relationships between grades of the conventional, human OSCE (x-axis) and the VP-OSCE (y-axis), over the 3 years (2008-2010).

4. Discussion

The results of our study indicate that our OSCE-base VP system is well suited to replace the conventional human OSCE. The correlation between the results of the 2 modes of OSCE was similar to the correlation found when the grade of half of a conventional OSCE is compared to the grade of the second half. Also, the reliability of the VP OSCE was consistently higher than that of the conventional OSCE. Most importantly, the VP system can be used as a practice tool both for training and for preparation for this type of examination.

A large number of VP systems have been developed for multiple purposes [9]. The presented system was designed to train and assess students in patient evaluation, based on clinical reasoning and competence. We believe that several lessons can be learned from our experience: First, it is imperative that a VP system should be well designed and assessed in pilot trials before trying to implement it in a regular course. This includes both the development of a high-fidelity, fast response web-based software, and the creation of multiple cases by an experienced physician. Second, we believe that the most important value of our VP system is in its ability to enable students to practice patient evaluation wherever and whenever convenient, in addition to, and in a clinically more relevant fashion than, learning from books. VP should not replace bedside teaching but rather complement it by providing additional cases similar to real patients, but even more by enabling virtual encounters with clinical scenarios not previously encountered. Finally, we believe that in order to motivate students to use the VP training system in their free time and without tutors, it has to be user-friendly, provide real-time feedback, but most of all be directly related to an exam. Even more than other assessment modalities, the students need to be well familiar with the VP system in order to succeed in a VP based exam. The only way to master this exam modality is by practicing many training cases, thereby fulfilling the goal of the VP system. Not surprisingly, almost all entries of our students to the VP site were recorded during the preparation period to the final OSCE examination.

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