Singapore Med J 2002 Vol 43(5) : 238-242

Teaching First-Year Medical Students Physiology: Does the Human Patient Simulator Allow for More Effective Teaching?

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ABSTRACT

Background: Although the Human Patient Simulator (HPS) is an effective teaching tool in many medical fields, literature supporting its use in the teaching of physiology to medical students is lacking. This study investigated the effectiveness of HPS-based teaching of cardiovascular physiology to first-year medical students.

Methods: Two hundred and ten first-year medical students were scheduled to our HPS laboratory w ith the purpose of demonstrating "physiology in action". Students were divided into groups of 19-25 each, and attended a lecture followed by a HPS session. Using a theatre-type simulator complete with mannequin, anaesthesia machine and monitors (METI, Sarasota FL), the scenarios of hypovolaemia, sepsis, and cardiac failure were run to demonstrate the physiological changes that occur with changes in preload, afterload, and cardiac contractility. Each student was given a true/false test before, and again after the HPS session, followed by a survey of their learning experience.

Results: There was marked improvement in test scores after the HPS session (82.1% vs. 64.6%, P<0.001). Most of the students felt that HPS was a better teaching tool (94.5%) and raised more questions (76.5%) than lectures. They wanted more topics to be taught this way (96%), as they could apply and re-enforce textbook knowledge, and visualise real-time changes. However, they felt that their experience could have been enhanced with more time and smaller groups.

Discussion: HPS is an excellent teaching tool as it stimulates student curiosity and makes knowledge acquisition and understanding easier. It is highly desirable to be incorporated into the teaching of physiology.

Keywords: Simulation, Physiology, Education, Medical Students

Singapore Med J 2002 Vol 43(5):238-242

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INTRODUCTION

A simulator is a machine that attempts to reproduce or represent the exact or nearly exact phenomenon likely to occur in real life. Simulators have been used successfully and widely since 1930 in a myriad of fields including aviation, military, and civilian industries such as nuclear power plants and maritime transport[1]. However, its use in the field of medicine is still very much in its infancy. The first medical simulator, SIM One, was developed by Denson and Abrahamson in 1969 for learning the skill of endotracheal intubation[2]. Since then, simulator programmes have been designed and successfully used for specialised medical fields including radiology, surgery, cardiology and anaesthesia. Of these, simulators for anaesthesia are perhaps the most widely used.

Simulators for anaesthesia can be classified into computer screen-based or theatre-type simulators[3]. With computer screen-based simulators, a mouse and keyboard are used to navigate through multiple pharmaco-physiological models of the performance of anaesthesia, therefore allowing learning without putting patients at risk. However, it has been criticised for not testing the hands-on skills vital to the conduct of anaesthesia[3]. The use of a theatre-type simulator, more commonly known as the Human Patient Simulator (HPS), addresses some of the shortcomings of the computer screen-based simulators by creating a realistic working environment (a simulated operating theatre) and requiring hands-on intervention. The HPS has several advantages as a teaching tool[4]. Firstly, there is no risk to patients. Second, exercises in routine procedures can be practised intensively. Third, simulation of rare but disastrous scenarios can be practised. Fourth, the HPS allows unlimited and exact repetition of scenarios and procedures for evaluating individual or group performance. Fifth, scenarios can be halted at any time to allow for discussion of management strategies. Lastly, recording, replay and critique of performance are facilitated because there are no issues of patient safety or confidentiality.

The HPS has been shown to be effective in the education, training, and evaluation of anaesthesia

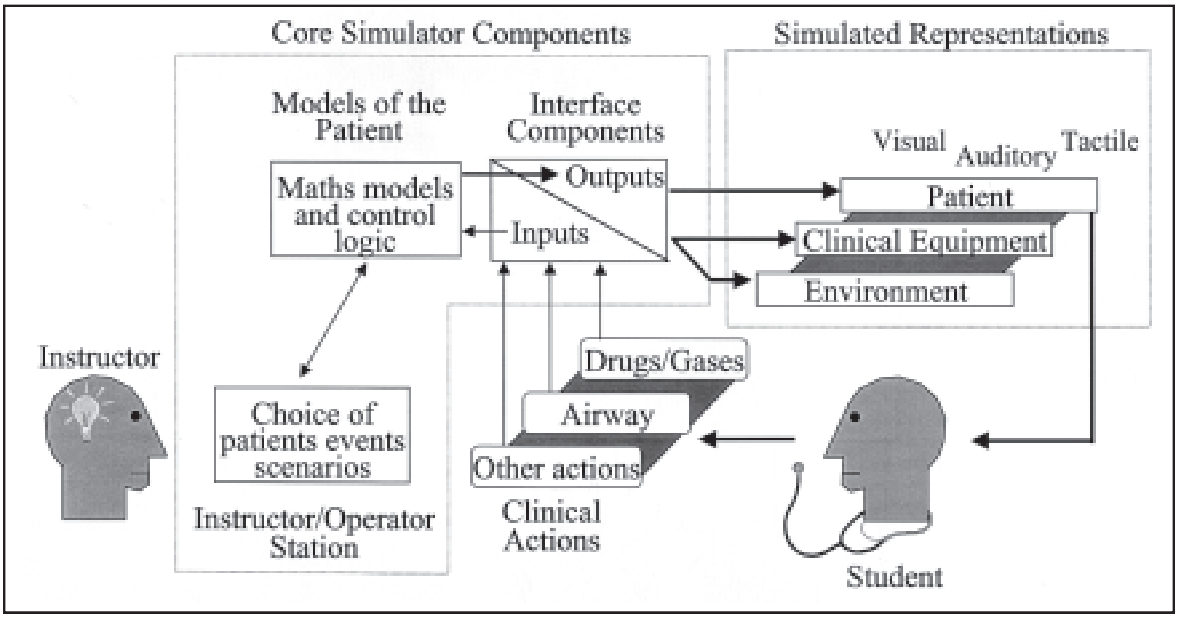

Fig. 1 Cartoon illustrating the set-up of the anaesthesia-based Human Patient Simulator (HPS). The above modified from Gaba DM, Human Work Environment and Simulators; Chapter 80: anaesthesia fifth edition pg. 2650 (Ed. Miller RD).

residents and specialists[5-7]. This has resulted in the integration of simulators in the teaching of anaesthesia to residents/medical officers in many institutions worldwide. In contrast, the use of HPS as an educational adjunct in the medical school curriculum is not commonplace as yet. Published studies on the use of HPS for teaching medical students have been largely limited to those in clinical postings in sub-specialities such as anaesthesia and critical care[8-10], or as an assessment tool[11]. We believe that with an anaesthesia-based HPS, its use can be extended to the teaching of pre-clinical subjects, given the close relationship of anaesthesia to physiology, pharmacology and anatomy. Therefore, this study was conducted to examine the effectiveness of using an anaesthesia-based HPS for the teaching of cardiovascular (CVS) physiology to first-year medical students.

METHODS

Two hundred and ten first-year medical students from the National University of Singapore (NUS) were scheduled to spend a day learning CVS physiology at the Department of Anaesthesia, National University Hospital (NUH). They were in their fourth month of medical school and had just completed their CVS and respiratory physiology modules. The aim of the anaesthesia attachment was to demonstrate "physiology in action" for a better understanding of, and to stimulate interest in, the subject.

The class was divided into 10 groups of 19-25 students in alphabetical order. In turn, each group attended a 20-minute didactic lecture on the physiological responses to hypotension and shock. At the end of this lecture, a true/false test (pre-HPS) was administered on the topic. This test consisted of four questions with five stems each (Table I). There was no penalty for a wrong answer. The students were told that this test would not count towards any examination scores. This was followed by a 20-minute HPS session in the HPS laboratory in NUH.

The HPS laboratory was set up to simulate an operating theatre, complete with an anaesthesia machine (Narkomed 4, North American Drager, Telford PA) and anaesthesia monitor (Hewlett Packard, Boise ID) with a six-channel display (electrocardiograph, intra-arterial waveform, central venous waveform, pulmonary arterial waveform, oxygen saturation and temperature). A life-size mannequin [HPS-001, version 5.55, Medical Education Technologies, Inc. (METI), Sarasota FL] was hooked up to a computer containing standard clinical scenarios, which was manipulated to suit our needs (Fig. 1). This mannequin had features that made it exceptionally suited for the teaching of CVS physiology. In addition to the vital signs displayed on the monitors as mentioned above, the change in the pressure waveform as a pulmonary artery catheter is floated towards the pulmonary arteriole could be demonstrated. Cardiac output could be measured with the thermal dilution technique, and indices such as systemic vascular resistance derived from it. Pulses (radial, brachial, femoral or carotid) could be palpated, and would differ in quality (thready or bounding) according to the clinical situation; heart and breath sounds could be auscultated, and when appropriate, be manipulated to have different characteristics (eg. gallop rhythm or

Table I. Questions of the true/false test.

Question	Stems
1. The pulmonary artery catheter	Can measure right ventricular preload Can measure left ventricular preload Is inserted through a systemic artery Passes through the tricuspid valve Wavwform is used to guide its placement
2. When a person loses blood acutely	He responds with an increased heart rate Drowsiness is a late sign of hypoperfusion His skin temperature is maintained He compensates with a parasympathetic response His pulse will feel stronger
3. In heart failure	Volume replacement always improves blood pressure Central venous pressure rises Pulmonary arterywedge pressure rises There may be crepitations in the lungs Heart rate will increase initially
4. In Patients with reduced afterload	There is a decrease in the systemic vascular resistance Pulses may be bounding They respond with a tachycardia Their blood pressure will always rise Central venous pressure will fall

Question three stem four was excluded from analysis because not all the students had the opportunity to auscultate the Human Patient Simulator (see text).

Table II. Survey Form.

Question
1. Is this a better way to learn physiology than books or lectures?
2. Would you like to learn other subjects like antomy and pharmacology using the Human Patient Simulators?
3. Did the simulator raise questions you wanted to look up?
4. What was the best part of the simulator experience?
5. What was the worst part of the simulator experience?

Questions one to three were in the form of yes or no answers, while questions four and five required text answers.

Table III. Answers to survey questions four and five.

What was the best part of the simulator experience?	What was the worst part of the simulator experience?
• Able to see realistic changes in physiology in real time	• No hands-on
• Easier to grasp concept	• Some of the changes occurred too fast to comprehend
• Application of theoretical knowledge	• Inadequate time
• Reinforce theoretical knowledge	• Too big a group and thus cannot see the monitor screen well

The four most common answers to survey questions four and five are represented in this table.

crepitations in heart failure). Peripheral perfusion could be assessed by urine output, and the presence of a core-skin temperature gradient could be shown. The mannequin breathes in room air and exhales carbon dioxide, allowing it to respond appropriately to oxygen therapy. Conversely, putting a plastic bag over its head will cause it to suffocate and die.

The HPS sessions were conducted in two parts. The students were initially shown the physiological changes that occur when the factors affecting blood pressure (systemic vascular resistance, afterload, venous return and cardiac contractility) were manipulated. Then, three clinical scenarios were used to demonstrate these changes. All three scenarios had hypotension as a common denominator. The first scenario involved a patient who was involved in a road traffic accident, and was actively bleeding with subsequent hypovolaemic hypotension. The changes observed in the HPS were tachycardia, a drop in central venous and pulmonary arterial pressures, and weak and thready pulse with eventual loss of consciousness. The above would be reversed when adequate fluid loading was given. The second scenario was that of a patient in congestive heart failure where the differences seen were that of raised central venous and pulmonary arterial pressures, decreased cardiac output, and these responded to initiation of inotropes. There was also a presence of crepitations for the simulation of pulmonary oedema. The last scenario was that of a septic patient. This time there was a drop in central venous pressure but an initial rise in the cardiac output, and hyperthermia.

At the end of the session, the students participated in the true/false test again. The purpose of the retest (post-HPS) was to examine if they had gained knowledge from the HPS session. They had been informed that the marks from these questions do not count towards any of their examinations. They were also asked to fill up a survey form with regards to their learning experience at the end of their anaesthesia attachment (Table II).

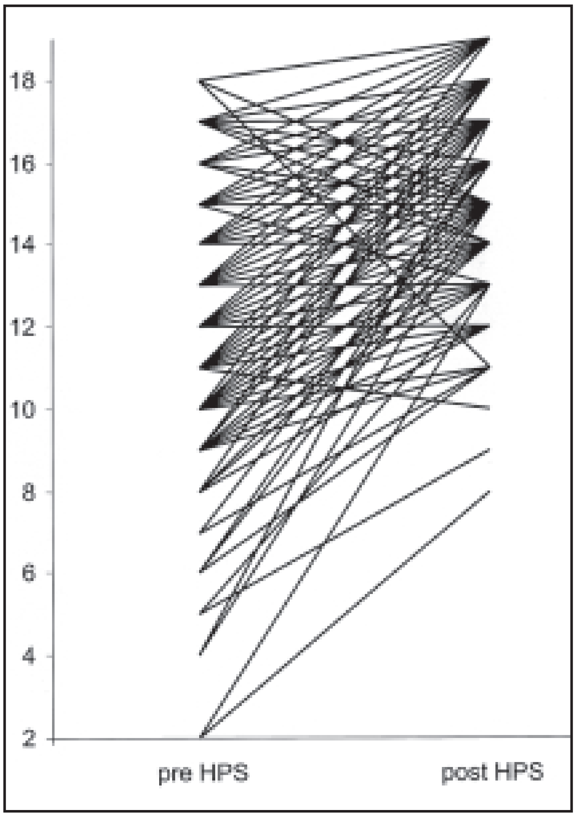

Fig. 2 Line chart showing the pre-HPS and post-HPS test scores of individual medical students. Y-axis represents the raw scores, ranging from two to 19 (minimum score possible = 0; maximum score possible = 19). HPS refers to Human Patient Simulator.

STATISTICS

Test scores for each individual were tabulated and analysed using a statistical software package (SPSS 9.05, Chicago IL). Pre-HPS and post-HPS test scores were compared with the paired sample T-test. The level of statistical significance was taken as $P<0.05$.

RESULTS

All 210 students completed the test paper, while there were 200 returns for the survey form. Of the 210 test returns, one student misunderstood the instructions and instead of answering true/false for each stem, chose the "best answer" from the five stems of each question. This student's response was therefore eliminated from analysis. The test and retest were designed such that the maximum score was 20. However, due to physical constraints, there was not enough time to allow each and every student to appreciate the presence of crepitations during the heart failure scenario and as a result, the answer to question three, stem four was disregarded. The maximum final score was therefore changed to 19.

The majority of the students performed better in the test after the HPS session (Fig. 2). Their scores improved by 27% (15.60±2.02 vs. 12.27±3.08, $P<0.001$). In the survey after the HPS session, the students overwhelmingly found that it was a better way to learn physiology (94.5%), would like to learn other subjects (like anatomy and pharmacology) with the HPS (96%), and that it raised further questions that they wanted to look up (76.5%). Among the common answers given, when asked what the best part of the HPS experience was, were that they were able to see realistic changes and that the HPS made grasping of concepts easier (Table III). They were of the opinion that the worse parts of the HPS experience were that some of them did not get hands-on experience, some of the changes occurred too fast to comprehend, that there was inadequate time, and difficulty in seeing the monitor (Table III).

DISCUSSION

In 1998, the Masterplan for IT in Education was revealed by the Government of Singapore[10]. This served as a blueprint for the integration of information technology (IT) in education, and was a strategy to meet the challenges of the 21st century. The goals of the masterplan were to encourage creative thinking, lifelong learning and social responsibility. It was envisioned that students would develop competencies in accessing, analysing and applying information, and develop habits of independent learning. The Ministry of Education has been active in increasing the use of IT as a teaching and learning tool in our schools. Its target was to use IT to conduct 30% of lessons in all schools by the year 2002.

The development of IT in the medical school curriculum has not been as dramatic, although there has been considerable progress in web-based teaching and resources, development of the digital library, and improvement in the student-computer ratio. The majority methods of teaching, however, remain the traditional system of lectures, tutorials, laboratory work and bed-side consultations. The development of the HPS presents an ideal opportunity to further the IT revolution in medical teaching. Therefore, in 1999, the teaching of applied physiology with the HPS to first-year medical students was started in NUS.

In this study, we found that HPS-based teaching was an effective and highly satisfactory teaching tool for our medical students. This is in agreement with previous studies on simulator use in medical students. Morgan et al simulated the administration of anaesthesia and the management of intra-operative problems to 143 final-year medical students during their anaesthesia posting. Their students found the HPS sessions to be an excellent learning experience. Gordon et al brought 27 third- and fourth-year medical students who were completing their emergency medicine clerkship through two simulated scenarios.

These were that of a trauma patient with hypovolaemia and tension pneumothorax, and a cardiac patient in ventricular tachycardia. Overall, 85% of their students rated the session as excellent. Gilbart et al randomly divided 139 fourth-year students to HPS-based or seminar-based teaching course on trauma management. Although 100% of the students in the HPS group felt more clinically competent to deal with trauma situations in the hospital, there was no difference in the students' trauma objective structured clinical examination (OSCE) scores.

However, it is clear that the reported successes of the HPS for teaching medical students involved only medical students in their clinical years. The anaesthesia-based HPS we used was designed specifically for the speciality of anaesthesia and simulated the operating theatre. We were worried that as the first-year medical students had never before been in an operating theatre, they may have been intimidated or overwhelmed by the unfamiliar environment. In addition, these students have not been to the wards, and have had minimal, if any, hands-on experience with patients' diseases and problems. We were therefore very concerned that they would be "lost" in the clinically orientated scenarios we ran. Furthermore, the short session meant that these students had to rapidly adapt to the operating room environment, learn to read the monitors and understand the clinical significance of the output. We were pleased that the students' test scores improved despite these inherent barriers.

The main limitation of this study was that the HPS session was held after a didactic lecture, and we cannot discount the possibility that the improved results could have arisen simply from reinforcement. Ideally, the students should be divided into groups either receiving a didactic lecture or HPS session; but because of constraints in the medical school curriculum, this was not possible. Nevertheless, based on the overwhelming endorsement given by the students in the survey, we believe that the HPS truly improves learning, and is an effective teaching tool.

The other limitations of this study were echoed by the students in response to the fifth survey question (Table II). Due to the size of the medical class, and the one-day schedule (time limitation) placed upon us by the medical school curriculum, students had to be divided in relatively large groups. As such, some students did not get hands-on experience on the HPS, while some did not get a clear view of some of the monitor readings. With the time limitation, we could not repeat the scenarios, and some of the students felt that the changes occurred too fast for them to comprehend. We feel that with smaller groups and more time, the efficacy and satisfaction of HPS-based teaching will be even greater.

In conclusion, this study showed that the HPS was an effective and satisfactory method of teaching applied CVS physiology to first-year medical students. It was gratifying that these results were achieved despite not having repetition of scenarios to reinforce learning and adequate hands-on for all students, two of the main strengths of the HPS. However, we feel that in order for students to fully appreciate the changes in the HPS in real-time, especially the more subtle ones, the students must have had some background knowledge of CVS physiology. In this respect, using the HPS as the sole teaching tool might not be ideal. It is perhaps more effective as an adjunct to traditional didactic lectures.

ACKNOWLEDGEMENT

The authors wish to thank the following for their help in the study:

1. Clinical staff of the Department of Anaesthesia, National University Hospital
2. Department of Physiology, National University of Singapore
3. Dr Daphne Pan, Director, Centre for Development of Teaching and Learning, National University of Singapore

This work was presented as a poster-discussion at the annual meeting of the Society of Technology in Anaesthesia 2001, Phoenix AZ.

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