Journal of Teaching and Learning with Technology, Vol. 2, No. 2, December 2013, pp. 79 – 89.

Human patient simulation to teach medical physiology concepts: A model evolved during eight years

Gabi N. Waite[1], Ellen F. Hughes[2], Roy W. Geib[3] and Taihung Duong[4]

Abstract: Worldwide, the use of human patient simulators in medical education has expanded rapidly as a means of enhancing the clinical and emergency response skills of health care students in a risk-free environment. The use of patient simulation for teaching of medical basic science concepts, however, is still in its infancy. At our medical school, ten years ago we had relatively inexpensive access to a high fidelity patient simulator which we used for teaching in the following courses: anatomy, medical immunology, and medical physiology. When this situation changed five years ago with the building of an education simulation center, the cost-to-benefit ratio for the use of simulators during the physiology class had to be reevaluated (anatomy and medical immunology discontinued simulation teaching after three years). This Best Practice paper presents our use and learning outcomes of low and high fidelity simulation for the past four years as part of a flipped physiology learning model and discusses its potential for widespread adoption for medical science teaching.

Keywords: human patient simulation, medical school, physiology, cardiovascular, basic science teaching

I. Introduction.

Medical education is increasingly adopting integrative learning curricula, which aim at teaching traditionally separated subjects such as basic sciences and clinical competency in a comprehensive way. Information on which teaching tools effectively provide such integration is, however, still sparse. While the efficacy of human patient simulation as a teaching tool to train and assess *clinical* competency has been well accepted (Grenvik, Schaefer, DeVita, & Rogers, 2004; Naik & Brien, 2013), there are only a few institutions worldwide that use patient simulators for *medical science* teaching (Euliano, 2001; Gordon, Brown, & Armstrong, 2006). In our view, its widespread use in the latter context is hampered mainly by three factors: First, it is challenging to achieve clinically correlated science teaching objectives with medical students in their early stage of training since they do not yet have sufficient clinical knowledge. Second, basic science educators often do not feel comfortable providing ad hoc clinical realism in a medical scenario. And third, as is true in general for simulation training, it requires expensive technology, faculty competence and time-intensive repeats with multiple student groups.

[1] Associate Professor, Department of Cellular and Integrative Physiology, Indiana University School of Medicine; Associate Professor of Life Sciences, Indiana State University; and Research Professor of Applied Biology and Biomedical Engineering, Rose-Hulman Institute of Technology, gnindl@iupui.edu
[2] Teaching Associate, Department of Microbiology and Immunology, Indiana State University, ehughes@medicine.indstate.edu
[3] Professor of Pathology and Laboratory Medicine, Indiana University School of Medicine and Professor, Department of Biology, Indiana State University, rgeib@iupui.edu
[4] Associate Dean and Director, Indiana University School of Medicine, Terre Haute, IN, USA, tduong@iupui.edu

We use human patient simulation for teaching of medical physiology since 2006 and arrived in 2010 at a 'Flipped Learning Classroom' (Hamdan, McKnight, McKnight, & Arfstrom, 2013). In the flipped learning paradigm, students are asked to prepare for the content of the scenarios ahead of time, leaving class time for the simulation exercises which consist of role play and discussion. This serves to reinforce and conceptualize physiological principles and to illustrate the clinical relevance of the basic science information. This is different from the patient simulation teaching paradigm for advanced learners, which tests the students' clinical competence in unknown situations and minimally disrupts the flow of action during the simulation by directing any discussion to the wrap-up session. This Best Practice paper describes our flipped learning simulation teaching model, presents its efficacy over the past four years for learning physiology, and discusses its relevance for widespread adoption of patient simulation for medical science teaching.

II. Patient Simulation for Teaching of Medical Physiology.

A. Motivation and Program Development.

Indiana University School of Medicine-Terre Haute (IUSM-TH) is one of eight regional campuses of the Indiana University School of Medicine, which has its main campus in Indianapolis. One advantage of the regional campuses is the small class size (24 students per entering class at IUSM-TH), which allows for experimentation with new teaching modalities and ease of interdisciplinary communication with instructors in other courses. The patient simulation activities described here were conducted as part of two spring semester courses in the first year of medical school: Medical Physiology and Clinical Problem Solving (CPS). Medical Physiology is a 7 credit hour, CPS a one credit hour course.

In 2004, IUSM-TH joined with Indiana State University and Union Hospital to build the Landsbaum Center for Health Education (LCHE), an educational facility designed to house the training of nurses, medical students and family practice resident physicians in close proximity. The LCHE purchased a high fidelity human patient simulator from METI (Medical Education Technologies Inc.), and several faculty and staff underwent the certification training offered by the manufacturer.

In 2006, IUSM-TH's medical physiology instructor used the simulator for the first time during the medical physiology course, resulting in overwhelmingly positive student feedback. Students were fascinated by the clinical relevance that the new teaching tool provided during their first year of medical education, but also voiced concern that they were lost and overwhelmed by the new clinical information provided at the simulated bedside. The following years were used to modify the simulation activities in order to improve student learning and satisfaction. By 2010, we had developed an effective teaching method that is presented here.

By 2012, through a continuing collaboration (Rural Health Innovation Collaborative – RHIC) with other educational facilities and health organizations, the simulation teaching room with one simulator had evolved into an 8000 square foot Simulation Center with a wide variety of high and low fidelity simulators (RHIC Simulation Center, 2013). While the creation of the RHIC Simulation Center indicates enormous progress for patient simulation teaching at IUSM in general, the ease of access to the use of simulators by medical school faculty decreased due to scheduling conflicts and increased administrative barriers related to the growth of the RHIC Simulation Center. This triggered at IUSM-TH the development of a "longitudinal simulation curriculum." Most of the medical school physiology simulation exercises used in the first year are conducted inside the physiology classroom using a non-computerized manikin along with physiology software that projects 'patient information' on a screen at the front of the classroom. The culminating simulation exercises conducted at the end of the first year and those conducted during second, third and fourth year of medical school take place at the Simulation Center. These later activities aim at training and assessing clinical competency and follow established clinical teaching models (Orledge, Philipps, Murray, & Lerant, 2012). Figure 1 outlines the transition from guided patient simulations, which aim at applying physiology knowledge, to open simulations, which aim at formative assessment of medical competency in a risk-free environment.

Courses:	Bloom's Taxonomy Goals:	Educational Objectives:	Teaching Method:	Assessment:
Basic Science Courses (e.g. Physiology) Clinical Problem Solving (CPS)	Cognitive: knowledge, understanding, application, thinking skills	Apply physiology knowledge in clinical context	Pre-session lecture Self preparation Didactic session Wrap-up Post-session lecture	Focus on formative feedback & comprehension evaluation
End of semester Clinical Courses & Electives Years 2, 3 and 4	Psychomotor: motor skills, organization skills Affective: emotions, attitudes, values	Acquire problem-solving, clinical, organizational and communication skills, Demonstrate self-perception, values and professionalism	Skill training Team Training Patient Care Leadership training Professionalism	Focus on summative feedback & performance evaluation

Figure 1. Longitudinal patient simulation curriculum.

B. Resources.

An adult sized manikin, the Human Patient Simulator® (HPS, Medical Education Technologies Inc.), which was part of the Landsbaum Center for Health Education, was used through 2011. This HPS system was maintained by the building's Information Technology personnel who underwent special training. Simulation programs were created by faculty and staff by adapting scenarios provided by the manufacturer. The manikin was operated by staff from a side room, separated from the simulation room that housed the learners and facilitators by a one-way mirror. Figure 2A shows the HPS manikin, six medical students, the physiology instructor at the end of the bedside, and educational staff on the left side facing a table with demonstration material.

The SimMan®3G system (Laerdal Medical Inc.) was used for the simulation exercise in the RHIC Simulation Center. The Center is managed by a Simulation Specialist and a Technical Support Specialist who help with the design, programming and execution of the simulation exercises. The Center is operated by a Memorandum of Understanding between various educational health organizations, which facilitates interprofessional activities. Figure 2B shows two respiratory therapists, one nursing student and two medical students working together for the first time as a Rapid Response Team. In 2013, the costs for use of the Center for 0-4 hours were ~$ 350 per student.

Figure 2. Medical physiology learning using human patient simulation. A: Six medical students plus two facilitators using a high fidelity simulator. B: Respiratory therapist, nursing students and medical students acting as a Rapid Response Team. C: Two medical students using a manikin and physiology software in the classroom. D: Material from handouts and textbooks displayed in the classroom for content discussions.

For the simulation exercise in the physiology classroom we used a life-sized inexpensive manikin (Amazon.com, Inc.) that was outfitted with wigs, makeup and wardrobe. It was placed on the floor, on an examination table, or in a wheelchair to suit the clinical case. The computer simulation program Müse™ was used and displayed on the projector screen. It is designed as an interface for METI products but was operated in the classroom on its own. Other physiology or clinical software could have been used instead. Figure 2C shows two medical students reviewing physiological principles by plotting simulated patient data from the projector screen on the white board. Handouts from lecture and clinical information new to first-year medical students were posted on the chalk board of the classroom (Figure 2D).

At the beginning of the course, we use patient simulation exercises in which the facilitator guides the students through history, physical, diagnosis and treatment while relating the case to physiology core principles. An example of such a facilitator-guided case is presented in the following section. Then, throughout the course, as the students gain familiarity with the teaching tool and the learning objective of applying physiology to a patient encounter, we gradually transition to more traditional simulation exercises. For the traditional exercises, the students work through the patient scenario with minimal interruption and the discussion is postponed until the debriefing session.

C. Example of A Facilitator-Guided Exercise.

I. TITLE: Early stage hypovolemic shock

II. AUDIENCE: First year medical students at the end of the cardiovascular physiology section, in groups of 4-23.

III. STUDENT PREPARATION: Review of cardiovascular physiology and handout with three short cases of cardiogenic, septic and severe hypovolemic shock containing questions on the cardiovascular and hemodynamic parameters of the patients before and after treatment.

III: MAJOR LEARNING OBJECTIVES:

- Each student should achieve an introductory understanding of hypovolemic shock and how it compares to cardiogenic and septic shock.
- Each student should understand the relationship between the simulation case and the following physiological principles: Preload/afterload; Stroke volume and cardiac work; Frank Starling relationship and Starling forces; Cardiac autonomic regulation.
- Each student should develop an insight into emergency care.

IV. ENVIRONMENT:

Classroom: The manikin will be in front of the computer projector screen, in close proximity to a writing board. Students gather around the manikin or sit in close proximity to it. Each student should easily reach the board.

Manikin: A life-sized manikin is used. Hair and clothes are of a young 17-year old man. A bruise is painted on the skin above the spleen. At the beginning, there are no leads, lines or tubes. The computer is blank.

Audiovisual: A two-monitor set-up will be used. One screen is used to display cardiovascular/ respiratory/ hemodynamic monitoring from programmable software. The second screen is used to show educational slides and laboratory studies. The latter information can also be printed and displayed, and/or made available on students' portable devices.

Preparation: The following will be available: Blood pressure cuff, pulse oximeter, supplemental oxygen by facemask, ambulance blanket, hospital bed sheet, various gauge needles, catheter tubing, IV pole, empty IV bags, adhesive tape, scissors, calculator, colored markers. Optional: Swan-Ganz catheter, rapid-infuser device, Foley catheter.

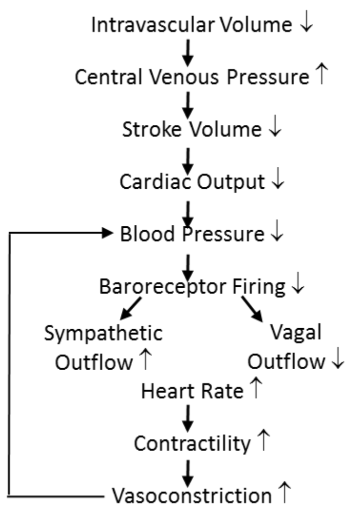
Learners: Students will act as emergency medical technicians and as emergency medicine or critical care physicians. All students will participate in discussion, interpret data, answer questions, and assume miscellaneous roles such as nurses and support staff.

Facilitators: The physiology faculty manages the overall flow of the case by prompting necessary actions, referring to provided background information, asking questions, and providing feedback. A second person controls the software and adjusts the patient's clinical values upon signal to pre-defined, clinically realistic numbers. The person may also help with adjusting the scenario environment, explaining the use of the clinical equipment, and being the voice of the manikin.

V CASE NARRATIVE:

In the Rural Ambulance

The case starts with a 911 dispatch: All-terrain vehicle accident in Vermillion County near St. Bernice on County Road 9505, ½ mile east of Route 71. One adult male possibly injured. Another adult male is with him.



Initial assessment by the Emergency medical technician of the responding ambulance reveals: Alert and oriented times 3, Respiratory rate 18, Heart rate 100, Weak peripheral pulses, Slightly cool and clammy skin, Capillary refill delayed, Blood pressure 118/78, Oxygen saturation 96 percent, No obvious external bleeding, Bruise on abdomen, no clear tenderness or distention. Students discuss how the information is obtained and what it means. They discuss potential hemorrhage by comparing the patient's information with provided information on the four stages of hemorrhage. The values and signs best fit to Class II hemorrhage with mild blood loss.

Students are to discuss the physiological responses to mild blood loss including the patient's stable blood pressure. A flow diagram as shown on the left can be developed or provided without arrows. Students are asked to indicate on the diagram the principles of Preload and Afterload, the presence of beta-1 and alpha-1 autonomic receptors, and their cell signaling when activated. The roles and response times of the following may be discussed: chemoreceptor reflex, the activation of the thirst mechanism, the renin-angiotensin-aldosterone system, and hemopoiesis. Three treatments are initiated: 1) An ambulance blanket is used to keep the patient warm, 2) Supplemental oxygen is intermittently provided by face mask, 3) A peripheral intravenous line is laid into the antecubital vein.

For the IV line, the students are to select a large bore needle from a variety of choices. A student will write on the board Poiseuille's flow equation that explains the use of a large diameter, short length catheter.

The students are to select saline as the fluid replacement from the choices of crystalloid, colloid and type O blood and discuss their relevance for maintaining oncotic pressure and oxygen saturation.

Dispatch information:
- Age and sex of patient
- Cause of injury
- Vital signs
- Injuries noted
- Any care you have provided
- Estimated time of arrival

A student role-plays the dispatch from the rural ambulance to the emergency room staff guided by the information provided in the box on the right.

In the Rural Clinic

As shown in the following, a wide range of cardiovascular physiology principles can be tied to the case. The sequence in which they are discussed and the time required for discussing the principles is flexible and should be adjusted to the individual class circumstances:

A quick History and Physical exam reveals no information relevant to the case, except for an increasingly tender abdomen. Following blood tests are ordered for Mr. Frank R. Starling, the name of the patient: CBC, PT, aPTT, BUN, Cr, Ca, Mg, serum lactate, ECG, blood typing and cross matching. A clinically used form to request laboratory tests may be available for students to fill out.

The students simulate laying an arterial line, a urinary catheter and a central venous line and discuss their purpose. It is important for the facilitator to point out that the central venous line allows continuous monitoring of fluid balance, but is not routinely used due to the risks involved.

In the simulated case, use of the central venous line allows discussion of additional cardiovascular physiological concepts.
The physiology software is started and the computer monitor shows blood pressure (BP), heart rate (HR), central venous pressure (CVP) and cardiac output (CO). Students fill out the first row of the table below and calculate stroke volume (SV) and mean arterial pressure (MAP).

	BP (mmHg)	HR (BPM)	CVP (mmHg)	CO (L/min)	SV (ml)	MAP (mmHg)
Admission	*100/85*	*102*	*-1*	*4.6*	*45*	*90*
+ 1 liter	*106/82*	*81*	*2*	*5.7*	*70*	*90*
+2 liter	*112/80*	*74*	*6*	*5.8*	*78*	*90*

"How can cardiac output be obtained?" becomes the next topic of discussion. Discussion should include the thermodilution method with the help of a Swan-Ganz catheter and the Fick principle with the help of a spirometer and blood oxygen sensors. Detailed discussion of commonly used non-invasive methods is postponed to the wrap-up.
Two liters of saline are sequentially administered by a rapid-infuser device and students record the resulting new patient values in rows two and three of the table above. Students discuss the rate of fluid replacement and its physiological limitations. They review the body's fluid compartments (60-40-20 rule) and estimate the amount of fluid that remains inside the patient's blood vessels.
Students are asked to plot a Frank-Starling curve based on the tabulated patient's values over time. SV versus CVP should be plotted.
Students are asked to expand the plot of this cardiac function curve with a vascular function curve and indicate its change with increased blood volume.
Reviewing the principle of how blood volume relates to end-diastolic cardiac muscle fiber length and ventricular pressure, the students are asked to sketch a left ventricular pressure volume curve of a cardiac cycle and its changes with increased vascular fluid volume.
An arterial pulse curve may be shown and students demonstrate the expected changes in systolic and diastolic pressure with stage II-IV hemorrhage.
Last, it is discussed how vascular fluid changes affect capillary Starling forces and how the accumulation of metabolites and hypoxia may affect compensatory mechanisms.
At this point, the results of the blood tests become available and can be discussed. Normal results of the 12-lead ECG are shown and may be discussed.
After stabilization, the patient undergoes Focused Abdominal Sonography for Trauma (FAST), which is explained using slides or a short video. The patient's results are shown and reveal a damaged spleen. Treatments are discussed.

VI WRAP-UP: Physiologist and clinician

- The physiological principles of the case are recalled in the order that they were studied throughout the cardiovascular section and the order they appear in the textbook.
- The students' answers to the questions presented in the paper cases are discussed, and a summary is created showing the similarities and differences between hypovolemic, cardiogenic, and septic shock.
- The simulated case is reviewed from the clinical perspective. The following are examples of clinical questions that can be discussed: Who staffs a rural ambulance? What are the major sources of trauma morbidity in a rural setting? How would the case be different with a 70-year old patient? How do clinicians work with nurses to monitor the status of a recovering

patient? What role does a Frank Starling curve play in the clinic? What role does cardiac output play in the clinic, and how is it obtained?

III. Evaluation.

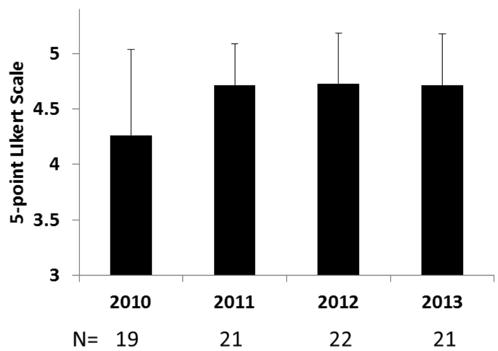


Figure 3. Four-year Likert scale student evaluation scores of the hypovolemic shock simulation exercise.

The hypovolemic shock simulation was conducted in 2010 and 2011 with a high-fidelity simulator in groups of 6 students. In the following two years it was conducted with a non-computerized manikin and physiology software, in 2012 in groups of 6 students and in 2013 with the whole class of 23 students.

Voluntary student feedback was collected immediately after each exercise using a mixed-type questionnaire with Likert scale and open-ended questions. Question one asked to “provide a rating for this exercise,” followed by a 5-point Likert scale, with 5 indicating the highest rating. Figure 3 shows the results of the past four years from the hypovolemic shock exercise. Average ratings are 4.3 in 2010 and 4.7 in the following three years, indicating high student satisfaction. Average questionnaire response rate was 93 percent, with a standard deviation of 6.2. This response rate was significantly higher than the average response rate of laboratory activities without patient simulation, such as a nutrition-related activity, indicating a higher student interest in the simulation exercise.

In addition, question one encouraged students to explain “what made you choose this rating” by writing in the space provided below the question. This open question format was chosen to obtain formative feedback which otherwise is difficult to obtain when collecting identifiable information throughout the course. The answers were analyzed using NVivo10 (QRS International Inc.). The analysis revealed six categories that are shown in Figure 4. Out of a total of 110 comments, 29 percent commented on the clinical context of the learning experience, followed by 25 percent expressing that they liked the teaching method. Some form of learning enjoyment was expressed in the vast majority of all answers, often using a single word or a short phrase such as ‘awesome,’ ‘was fun,’ or ‘good experience’ as an introduction. Twenty-one percent expressed that the simulation exercise helped them understand physiological principles. Sixteen percent of the answers mentioned benefitting from the debriefing session. A few students commented on educational objectives such as ‘problem-solving’ and ‘team work,’ which become the focus of more advanced simulation exercises. Three comments were disapproving and expressed thoughts of disinterest (1), feeling rushed (1), and using up too much time (1).

Categories of Student Answers	Answer Percentages	Representative Student Comment
Appreciated clinical application of knowledge	29	"Made me think of what I would really do in a real situation & how the principles we learned in class apply to the situation."
Liked teaching method	25	"It was awesome…I enjoyed talking through the case with a working example on the table."
Learned physiology concepts	21	"The case was interesting and helped to better understand a lot of principles."
Wrap-up tied things together	16	"… answered remaining questions effectively and strengthened understanding."
Practiced problem-solving	3	The cases were challenging and required a great deal of thought to explain.
Recognized relevance of team approach	3	"It is important to work as a team to make decisions."

Figure 4. Evaluation comments of the hypovolemic shock simulation exercise.

Figure 5 shows the average score for each year of the Physiology Only Examination from the National Board of Medical Examiners (NBME) Subject Examination Program. This examination is administered as an end-of-course assessment. A high score on the NBME test indicates that the student has acquired the core principles of Medical Physiology. By 2010, the NBME grading scale had changed. Therefore, to allow comparison, the data of Figure 3 are shown as percent above national average. The IUSM-TH scores (solid line) were consistently above national average, and after 2011 they increased to a level higher than the average scores of students of the other eight educational IUSM sites (broken line). The scores transferred into percentiles between 59 and 83, dependent on the difficulty of the test (not shown). Since the NBME Physiology Subject Examination is designed to test the students' application of physiological principles, it is reasonable to assume that practice of this skill via patient simulation contributed to the high scores.

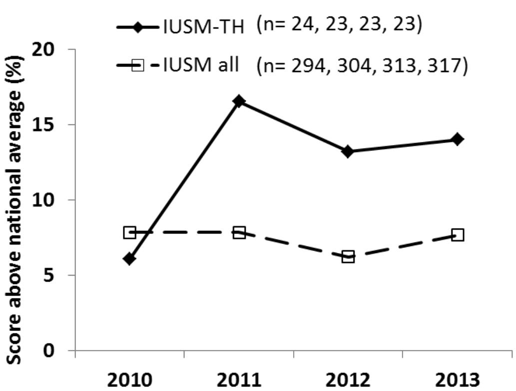


Figure 5. Four-year grades of the Physiology Only Examination from the National Board of Medical Examiners Subject Examination Program. For details, see text.

To evaluate whether the use of patient simulations for the teaching of medical physiology facilitates the students' ability to achieve the learning objectives of more advanced simulation exercises, further data have to be collected. For instance, data are currently being collected for the mid-term exam of the fourth year emergency medicine clerkship, which is a simulation exercise during which students are individually evaluated for clinical competency in the emergency room. For now, we only have sporadic evidence from unsolicited contacts of advanced students with the physiology instructor, in which these students refer to "Mr. Frank Starling, the young man with hypovolemic shock," or "Ms. Carrot, the elderly lady with a hypoglycemic episode," indicating that the simulation exercises remain memorable as early 'patients' of their education.

IV. Discussion and Conclusion.

It is well accepted that human patient simulation training helps ensure competence of physicians by allowing medical students and experienced clinicians to practice procedures in a realistic setting (Orledge, et al., 2012). It is less clear if simulated patient encounters in the first year of medical school can also facilitate basic science learning and if the investment of time and expenses related with such simulation exercises is justifiable.

At our institution, several years ago, we had easy and relatively inexpensive access to the use of a high-fidelity human patient simulator for re-emphasizing medical physiology concepts. First-year medical students enthusiastically embraced the active learning mode. When the simulator was moved to a Simulation Center, which meant increased costs and more limited access, it became time to re-evaluate the usefulness of patient simulation for physiology learning.

This paper on best practices of patient simulation for medical science teaching presents the four-year results of student evaluations of a cardiovascular simulation exercise, indicating high student satisfaction and perceived learning benefits in alignment with the learning objectives. Objective summative physiology course evaluations of the students' physiology knowledge are above the national and the school average. Whether simulation itself is responsible for the high scores is unclear and can only be answered with an evaluation tool specifically tailored to answer this question. It is interesting to note that, by comparison, the scores of the IUSM-TH students at the statewide microbiology end-of-course exam are at the school average and did not change over the past five years. Throughout this time, microbiology was taught by the same instructor, using the same teaching methodology.

Interestingly, there was no difference in student outcomes and student satisfaction whether the exercise was performed with a high-fidelity or low-fidelity manikin and whether the learning experience was conducted in small or large groups. A similar lack of a relationship between simulation fidelity and learning has recently been found even for clinical training (Norman, Dore, & Grierson, 2012). These findings point to the possibility for the more frequent use of inexpensive patient simulators in the classroom. Our experience shows that using non-computerized manikins and inexpensive physiology software can also illustrate theoretical concepts in a way that goes beyond classroom demonstrations.

We found it especially helpful to use facilitator-guided exercises at the beginning of the physiology course, such as the presented hypovolemic shock case and to gradually transition throughout the course to more traditional simulation exercises. Our plan is to also integrate the traditional exercises into our flipped learning model, so that students will work by themselves through the scenarios while class time is used for debriefing and answering questions by various content experts. That way, the three major concerns that limit widespread use of patient simulation for medical science learning can be addressed. First, students might feel less overwhelmed since they can work through the case at their own pace in order to reach the physiology teaching objectives without being overwhelmed by the clinical aspects of the case. Second, the debriefing session can be conducted by basic science and clinical experts to realistically cover all aspects of a patient encounter. And third, self-directed learning minimizes instructor time and adds flexibility for each individual teaching environment.

Overall, we find the use of patient simulation with preclinical medical students rewarding and beneficial for integrated learning. However, additional analysis of this teaching tool, using a larger student cohort, control groups and robust assessment tools will be necessary to further support widespread global implementation of patient simulation for teaching the basic sciences during medical training.

Acknowledgements

Over the past eight years, many people helped and supported our efforts. We are very thankful to all. J. Jaeger (RHIC), A. Vincent (Indiana State University) and D. Williams (RHIC) helped with the simulation exercises. M. Pantle (ISU) and Drs. E. Bennett (Union Hospital), R. Stevens (IUSM) and P. Tenbrink (Union Hospital) provided their clinical expertise. Thank you also to the Interprofessional RHIC team, the department of nursing at Indiana State University, and the respiratory care program at Ivy Tech Indiana.

References

Euliano, T.Y. (2001). Small group teaching: clinical correlation with a human patient simulator. *Advan Physiol Educ, 25*, 36-43.

Gordon, J.A., Brown, D.F.M. & Armstrong, E.G. (2006). Can a simulated critical care encounter accelerate basic science learning among preclinical medical students? A pilot study. *Simulation in Healthcare, 1,* 13-17.

Grenvik, A., Schaefer, J. III, DeVita, M.A. & Rogers, P. (2004). New aspects of critical care medicine training. *Current Opinion in Critical Care, 10(4)*, 233-237.

Hamdan, N., McKnight, P.E., McKnight, K. & Arfstrom, K.M. (2013). A review of flipped learning. *Flipped Learning Network, George Mason University and Pearson's Center for Educator Effectiveness. http://*www.flippedlearning.org/.

Naik, V.N. & Brien, S.E. (2013). Review article: simulation: a means to address and improve patient safety. *Canadian Journal of Anaesthesia, 60(2)*, 192-200.

Norman, G., Dore, K. & Grierson, L. (2012). The minimal relationship between simulation fidelity and transfer of learning. *Medical Education*, 46(7), 636-647.

Orledge, J., Phillips, W.J., Murray, W.B. & Lerant, A. (2012). The use of simulation in healthcare: from systems issues, to team building, to task training, to education and high stakes examinations. *Current Opinion in Critical Care, 18(4)*, 326-332.

RHIC Simulation Center. *Rural Health Innovation Collaborative*. http://www.rhicsimcenter.org.