Active learning strategies to teach renal-cardiovascular integration with high student-to-teacher ratios

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Brands MW, Schumacher L. Active learning strategies to teach renal-cardiovascular integration with high student-to-teacher ratios. Adv Physiol Educ 33: 282–285, 2009; doi:10.1152/advan.00055.2009.—To address the challenge of increasing opportunities for active learning into a medical physiology course with ~190 students enrolled, we chose an integrated approach. This was facilitated by the availability of a patient simulator facility at the School of Nursing at the Medical College of Georgia, and an ~20-min simulation of acute hemorrhage on the simulators comprised the first of three components in our approach. The second component was a small-group problem-solving session that each group conducted immediately after their patient simulator session. It brought in the more complex physiological responses to acute hemorrhage using an exercise we designed using free downloadable simulation software from the Department of Physiology and Biophysics at the University of Mississippi Medical Center. The third component was a student worksheet exercise that was built around data collected from 12 students who volunteered to collect a 24-h urine sample and have blood pressure measured after 3 days on either high or low salt intake. The worksheet was completed independently, and the answers and student data formed the basis for a classroom lecture. The approach has met with increasingly positive reviews due to testing the first two components on second-year medical student volunteers before its implementation, keeping the first component as simple as possible, keeping the second component to <30 min, and continued revision of the third component to increase clinical context of the study questions. An integrated active learning approach can enhance student interest in integrating cardiovascular-renal physiology, particularly if faculty members are willing to revise the approach in response to student feedback.

simulation; medical physiology; tutorial

ONE OF THE MORE CHALLENGING ASPECTS of teaching large classes is finding ways to engage them actively in the process. Whether the objective is making lectures a more interactive activity, supplementing lectures with other activities, or replacing lectures, implementation is complicated when class size increases. At the Medical College of Georgia (MCG) in Augusta, GA, ~190 students matriculate into the School of Medicine each year, and in the cardiovascular portion of the Medical Physiology course, we have been working for the past 3 yr to develop a combined approach to infusing more active learning methods into the course. The relevance of this effort to this Refresher Course in renal physiology lies in the third component of our approach, which integrates renal physiology with the cardiovascular material.

There are many potential approaches for shifting from a purely passive lecture-based course to a more active-learning course. One of those is an audience response system, often referred to as “clickers.” Students armed with remote devices are able to respond to questions on a PowerPoint slide, for example, by selecting the correct answer choice (answers A–E). They gain immediate feedback about their answer as well as the overall response of the class. This can be an effective tool, but that effectiveness is dependent, to a large extent, on the proficiency of the instructor at keeping the presentation flowing. Issues about attendance also arise if used in a school that does not require attendance, particularly if points are awarded. Laboratory exercises in anesthetized animals or with computer simulation are excellent supplemental approaches, but limitations include space, cost, and animal rights issues for the former and heavy reliance on a sufficient number of knowledgeable faculty members for both. Small-group problem-solving exercises also work well but are dependent similarly on having sufficient faculty discussion facilitators. Worksheets that are completed independently and then discussed in class are an alternative workaround for the limitation for small groups, but it is challenging to keep the assignment from being perceived as “busy work,” which also is a potential detractor from the use of computer simulations. By using a combined approach in the cardiovascular block, we hoped that the variety would enable us to increase active learning significantly while minimizing the risk that apathy would result from excessive use of one method in the same portion of the course.

APPROACH

Our combination approach was composed of the following: 1) a patient simulator exercise, 2) small group problem solving with the computer simulation, and 3) a worksheet plus classroom discussion.

Patient simulator exercise. Through a collaborative arrangement with the Interdisciplinary Simulation Center at the School of Nursing at MCG, we developed a laboratory exercise on hemorrhage using three of their adult patient simulators. Our primary challenges were to make it relevant to the course and capitalize on students’ excitement, balance rigor with simplicity, and schedule all 190 students within a 5-day period using only 1 faculty member. The patient simulators have many capabilities, but to satisfy the scheduling demands (running groups at 1-h intervals requires rapid resetting of the patient and the room) and ensure an error-free experience, we opted for a very simple exercise.

After exploring the patient simulator, students (in groups of 4) worked as a team to collect baseline data (Fig. 1). The data collected were 1) blood pressure and hemoglobin saturation from the patient monitor (Fig. 2), 2) heart rate and ventilation rate (direct measures by students), 3) the presence or absence of peripheral pulses (palpation of the patient by students), and
4) hematocrit (given by the instructor as laboratory data). The patients are instrumented with sphygomonanometers, and most students take advantage of this, because it is usually their first opportunity to use their stethoscopes to measure blood pressure. However, for the sake of time and consideration of potential equipment failure, blood pressure data for the exercise are obtained from the patient monitor.

Simulators were programmed to hemorrhage 1,800 ml over 30 min, and the 30-min hemorrhage was broken into three 10-min segments, with each segment taking 2 min of real time to be simulated. The program paused after each segment so data could be collected again. After the simulated 30 min, the students hung a 500-ml saline bag and connected the infusion set to a patient catheter, the software then simulated the response, and final data were collected. The total time in the patient room was 30 min, and each student had a data sheet (see the Simulation Experience Datasheet in the Supplemental Material) that they kept for their reference. This exercise and the computer simulation below were tested twice on four second-year medical student volunteers before implementing it our first year.

Small group problem solving with the computer simulation. To add more physiological depth to the hemorrhage exercise, the patient simulator was coupled with small-group sessions. After leaving the patient simulator, students moved down the hall to a study room where three laptop computers had been set up to run simulation software developed by the University of Mississippi Medical Center’s Department of Physiology and Biophysics [Quantitative Circulatory Physiology (QCP), http://physiology.umc.edu/themodelingworkshop/index.htm; see the QCP screenshot in the Supplemental Material]. A patient was also set up in that software to hemorrhage 1,800 ml over 30 min, and the students worked in their same groups of four to move through a worksheet (see the Mr. McG: Patient Simulator Followup Datasheet in the Supplemental Material) that required them to collect hormone data (e.g., plasma catecholamines, angiotensin II, and vasopressin), record carotid baroreceptor and low-pressure receptor firing rates, and record body fluid volumes and cardiac output. The saline treatment was also simulated, and the students had to repeat the simulation with a patient that had chronic α1-adrenergic receptor blockade. A list of study questions asked for explanations for the various responses, and they had the option of doing those later, on their own time, if they chose. They were not required to hand in the worksheet. The total time for this exercise was ~30 min.

Division of hypertension worksheet and discussion. Ten to twelve student volunteers were recruited during the lecture to be part of either a low- or high-salt intake group and provide a 24-h urine sample after 3 days on their respective diet. Instructions on general dietary guidelines and precautions, how to

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**Fig. 1.** First-year medical students checking heart and respiration rates, the presence of peripheral pulses, and laboratory data on a patient simulator during simulated hemorrhage.

**Fig. 2.** Screenshot of the patient monitor in the simulator room. ABP, arterial blood pressure from an arterial line; SpO2, percent saturation of hemoglobin; NIBP, noninvasive blood pressure.

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1 Supplemental Material for this article is available online at the Advances in Physiology Education website.
correctly collect a timed sample, and how their sodium excretion and blood pressure measurements would be taken were given in front of the whole class so that everyone knew what was happening. The volunteers were given standard 3-liter graduated urine specimen containers. On the assigned turn-in day, the volunteers met in my laboratory, provided the total volume and actual collection time, and were issued gloves and a test tube and sent to the restroom to obtain a small sample and dispose of the remaining urine. Students had their blood pressure taken in an adjoining room, and samples were analyzed later for sodium and potassium concentrations. Several days earlier, all students had been given a worksheet (see the Worksheet in the Supplemental Material) that contained renal and cardiovascular study questions and required them to plot chronic pressure natriuresis curves (1) using sample patient data, and, during the lecture that day, the subject data were presented and discussed in the context of the study questions. Data were kept anonymous, and the only requirement from the MCG Human Assurance Committee was that we only would assay for urine electrolytes and subsequently dispose of the samples.

RESULTS

Patient simulator exercise. A persistent concern is that the patient simulator exercise will bore the students because of its simplicity, but through our dry-run testing before implementation we learned that 1) the keen interest in exploring the simulator and its capabilities is good for at least 10 min, 2) the simulation session per se must be kept to ~15 min, and 3) attempting a complicated simulation without ample resources and personnel in each room is a tremendous risk. No points were awarded the first year we tried this exercise, yet there were only 6 absences of 180 students, even though all time slots were afternoons from 1 to 5 PM. A technical staff person was in each room, with the faculty member rotating among the three rooms, and most students wanted to interact with these people to ask about the simulator itself, its capabilities, and the responses measured during the exercise. Most students were also very interested in learning the procedure for opening the saline bag, inserting the infusion set, and properly configuring the stopcock. The students could see that we diverted the patient’s intravenous catheter to a reservoir under the bed, reinforcing that the effect of saline treatment is only being simulated, but the physiological responses and starting the saline infusion were interesting to them nonetheless. Students continue to enjoy this, and invariably ask if they will be able to do more simulations later in their training.

Small group problem solving with the computer simulation. This was revised following our dry-run testing and also after each of the first 2 yr to make sure that the students could finish the exercise in well under 30 min. Remarkably, most students stayed to answer the study questions even when the exercise ran long. The faculty member checks in while rotating among the patient simulator rooms, and the students prefer to engage in group discussion without being led by an instructor. There is surprisingly little copying of answers from earlier groups or leaving early, and many groups will want to get faculty feedback on their answers after they have completed the exercise. Keys to success of this exercise are having directions that enable students to run the simulator without error and without help (this was tested and revised numerous times), to complete it in <30 min, avoid repetition (for example, students initially were asked to repeat the hemorrhage under α1-adrenergic receptor, β1-adrenergic receptor, and angiotensin type 1 receptor blockade, but now do only α1-adrenergic receptor blockade), and make it relevant to the lecture material.

Division of hypertension worksheet and discussion. Our first Worksheet effort was an assigned heart failure simulation on QCP. Students were familiar with the software by that time, so a worksheet was provided that required them to run simulations, collect data, and answer questions. This failed miserably, because the simulation and data collection were perceived as busy work. One experience with QCP as part of the simulation exercise was accepted without much negative commentary, but additional simulations were not tolerated well at all. The next year, all data were provided, and there was a page of renal and circulatory data followed by study questions on a worksheet. This was better, but not much, because the questions focused on physiological relationships without obvious clinical application. The division of hypertension exercise has worked better, although the study questions must be revised to place them in a more clinical context. There are other important lessons that the students enjoy, however, such as 1) hearing the volunteers describe the experience of trying to collect a 24-h urine sample, 2) seeing how successful (or not) students were at achieving a low salt intake and how that compared with the 100 mmol/day recommended guideline, 3) what foods were eaten to result in the various sodium intakes, and 4) how far off were students’ estimations of their intake compared with what their excretion data showed.

DISCUSSION

Although we have no quantitative data on how these exercises affect student performance on exams, our attendance data support the students’ interest in the patient simulator and the associated computer simulation. Student evaluations continue to guide us in developing a worksheet + classroom discussion exercise that is interesting and clinically relevant for the students, and the student volunteer and “real data” elements of the division of hypertension exercise appear to be heading in the right direction.

Patient simulators are an exciting alternative to live animal laboratory exercises that clearly are intriguing to the students. The exercise is one of their first opportunities to work in a clinical setting, there is no risk of committing errors in front of a human patient or clinical preceptor, and it helps show clinical relevance of the physiology. Short, simple, and preimplementation testing are keys to success. A major complication in implementing the patient simulator at many institutions will be the cost and space requirements. However, from our experience, it does not appear that simulating hemorrhage (or another pathophysiological condition) is totally dependent on being coupled to the patient simulator to be useful or successful.

Without the lead-in from the patient simulator, there would need to be a well-developed lead-in from a lecture that presented the basic physiology and posed the open and important questions in order for students to see value in a standalone QCP simulation. Followup discussion of the answers in class would enhance this, but that is difficult because logistics usually will
require the student groups to run the exercise over a several-day period, making it difficult to coordinate with the lecture. However, as long as the simulation is short and simple, can be run without errors and restarting, and has a knowledgeable faculty member on hand, this should be able to be run at least once in the course, and perhaps once in the cardiovascular block and once in the renal block, with good reviews from students. Testing this on second-year medical students for frank critique and suggestions before implementation is critical.

Our attempt to assign QCP simulations on the students‘ own time, as a way to collect data for a worksheet assignment, was cause for great unrest among the class. There was a minority of students who had trouble downloading the free software or actually running the assigned simulation, and the main source of unrest simply was having to gather the data. Addressing this by providing the data the next year did not help much, and it is clear that, after getting the basic physiology in lecture, hand-outs, and the textbook, the students want to answer questions when this material is placed in a clinical context. The heart failure worksheet assignment we tried first had considerable data and questions on variables such as free water clearance, creatinine clearance versus creatinine excretion and balance, and tubular fluid-to-plasma ratios in addition to the circulatory variables. Although the material certainly is clinically relevant, the students would have preferred a series of multiple-choice questions about those data rather than questions that required them to write a short answer. That preference often runs afoul of a devout physiologist, but the realization that these are first-year clinical trainees rather than advanced PhD students in renal physiology, and that a goal of these approaches is to generate interest in the material and the course, helps to shift the emphasis in that direction. Switching to the urine collection and blood pressure exercise has helped make our worksheet and classroom discussion exercise more popular. The study questions still need work, but the use of student volunteers helps overcome weaknesses that tend to diminish student interest.

In summary, a combination of approaches has helped increase active-learning opportunities in the course without causing student interest to wane. Overuse of computer simulations or worksheets can have rapid, negative consequences on student interest in the course, but the worksheet effectiveness and perceived utility is enhanced if the study questions are board-style, multiple-choice clinical questions. Keeping the exercises simple, focused, and relevant to the course are critical, as is testing any technological exercise before implementation. Finally, even though the students enjoy their first encounter with the patient simulators using the simple hemorrhage exercise, feedback has shown very clearly that any subsequent simulator exercise would need to be much more rigorous, clinically focused, and engaging.

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REFERENCES