INTRODUCTION

The difficulties of providing comprehensive medical education represent a never-ending challenge for basic science professors, clinical educators, and medical school administrators alike. There is a continuous need for self-reflection, as well as reevaluation of curricular structure and pedagogical content. The necessity to maintain certain educational standards creates fertile ground for the development and implementation of innovative teaching strategies and curricula modifications that will adequately prepare future clinicians to serve as competent healthcare providers. Consequently, medical education in the United States and abroad has changed dramatically in the past several years since the focus has shifted to employing more dynamic patient-oriented instructional methods (8, 10, 12, 16, 17). Most medical school programs, which once employed lecture-based curricula techniques as the primary method of disseminating information, have modified the nonclinical phase of medical education to include more independent study paradigms, problem-based strategies, and small-group learning approaches. Such teaching methodologies facilitate the early integration of basic and clinical sciences before any formal clerkships and hospital rotations that customarily occur during the latter clinical phase of medical school. A 2011 survey, conducted by the American Association for Medical Colleges (AAMC), suggests that, while simulation technology in medical education is not new, the use of simulation is underutilized as an instructional tool, especially during the initial years of medical education.

Although human patient simulation (HPS) began more than a decade ago, substantial evidence argues for increased use of simulation in teaching basic science courses, such as physiology and the full integration of simulation into medical school curricula so as to benefit both educators and learners (7, 12, 15, 19, 21). The introduction and application of simulation in medical education is considered to be one of the most important steps in curriculum development. One of the main concerns with widespread use of simulation during the nonclinical phase curricula is the prerequisite for highly trained simulationists and dedicated facilities capable of supporting the development and implementation of conceptualized scenarios emulating human physiology (11). Many consider basic science physiology as the foundation of medicine, in that knowledge of normal human function is required for diagnosis of pathophysiological conditions that physicians manage in clinical settings. Findings have revealed several advantages of introducing clinical skills during the nonclinical phase as an integral component of the early basic science curricula. Most notably, simulation has a positive impact on ensuring that students make the connection between classroom instruction and real patient care in the hospital (13, 21). As a result, simulation is a valuable, evidence-based teaching method employed in medical education to teach, evaluate, and remediate the fundamental clinical skills competencies of students. To that end, simulation is becoming more widely accepted in medical education as a means of linking fundamental physiological mechanisms, taught in didactic courses, with the clinical skills used at the bedside.

The patient-centered approach has many advantages and benefits for the learner, the educational entity, and the global health community. Identified benefits include improvement of patient care, reduction in medical errors, enhancement of provider skills essential for patient management, facilitation of teamwork building, communication improvement, and leadership development (1). From a clinical perspective, the ultimate goal of simulation is to increase patient safety and reduce medical errors. At Howard University College of Medicine (HUCM), physiologists, clinicians, and simulationists recently implemented a case-based simulation for first-year medical students (MDY1) enrolled in a structure and function (S&F) basic science anatomy and physiology course. From the pedagogical point of view, simulation was employed as a means of linking didactic lecture objectives with specific clinical skills used for cardiorespiratory clinical evaluation. Traditionally, curriculum models emphasize clinical skills training predominantly in third-year clerkships (1, 14). However, in this case, MDY1 learners had an opportunity to tackle one of the greatest challenges for medical students: developing a conceptual and practical connection between founding principles of basic science physiology and the clinical skills suitable for the assessment of medical conditions.

We focused on interdisciplinary integration employing medical simulation as a complementary teaching tool for medical
physiology and correlation of clinical skills germane to patient assessment. Subsequently, MDY1 students played an essential role in the constructive critique and evaluation of the cardiorespiratory exercises, thereby providing educators with information regarding their perceived effectiveness of the simulations. Here, we summarize voluntary feedback for each of the five simulation evaluation categories obtained from MDY1 students, where we hypothesized that students would view the simulations as an effective teaching tool for the integration of didactic lecture objectives with clinical skills, and an acceptable pedagogical approach for MDY1 learners.

Ethical considerations. The Howard University Institutional Review Board for Human Subjects reviewed and approved the study protocol and determined that an informed consent exemption was appropriate. This project was provided exempt status based on 45 CFR 46.101(b)(4) and involves minimal risk (IRB-17-CAS-42).

MATERIALS AND METHODS

As a component of the MDY1 S&F course, we employed three simulation modalities to directly link physiology lecture objectives to clinical skills used in the assessment of cardiac performance, blood flow in the heart, cardiorespiratory auscultation, and respiratory mechanics. We used human simulation as a teaching tool to assist with making the connection between textbook information and diagnostic assessments for cardiorespiratory function. The simulation exercises were structured so that students had ample time to complete a sequence of clinical skills activities that facilitated learning through hands-on training and case-based evaluation.

The basic science faculty and medical staff who facilitated the clinical skills activities completed professional training to ensure the standardization of the information. Training included a theoretical overview of congestive heart failure (CHF) and the clinical correlations germane to specific physiology learning objectives to be emphasized when debriefing discussion points. Instruction was provided for three simulators: SAMII (student auscultation manikin part-task trainer); Vimedix transthoracic echocardiography (TTE) training platform; and SimMan3G, the human patient simulator. Clinical personnel became familiar with operating the computer software program used to control the acoustic output to the SimMan3G and SAMII to ensure proper placement of the stethoscope for accurate auscultation.

Correlating learning objectives and clinical skills. The two simulation exercises were strategically designed to highlight cardiorespiratory symptoms of CHF. During the cardiovascular simulation, students reinforced the relationship between the physiological significance of the cardiac action potential, muscle contractility, and the electrocardiogram (ECG). Standard learning objectives for the cardiovascular auscultation component consisted of activities where students learned proper thoracic auscultation techniques and related heart sounds to normal cardiac function (i.e., sounds correlate to valve opening and closure as well as unidirectional blood flow through the heart). The SAM II allowed for comparisons of audible heart sounds (exaggerated heart sounds) characteristically heard during CHF compared with normal physiological auscultations. Participants used the ECG recordings and Vimedix to observe normal rhythm and calculate the heart rate and the mean ventricular axis of the CHF patient, respectively. The ECG simulation component also demonstrated normal excitation and contraction as well as cardiac arrhythmias that could result in reduced contractility and subsequent reductions in ejection fraction.

For the pulmonary simulation exercise, students focused on auscultation as a correlate to mechanics of the airway. For example, pulmonary mechanics lecture objectives focused on airflow throughout the respiratory tract and how changes in bronchial diameter can influence the production of pulmonary sounds. Students also considered mechanisms involved in airway mucus production and inflammation development as it related to turbulent airflow and wheezing, often observed during an acute asthma attack or chronic obstructive pulmonary disease. Because many pulmonary diseases produce similar audible resonances within the various regions of the thorax, students were required to auscultate during normal respiration and pathological conditions. To observe the effects of a narrowed and inflamed airway, students compared breath sounds during normal respiration and those heard during an asthma attack and wheezing. Coarse vs. fine pulmonary crackles commonly observed during pulmonary edema and CHF were also available for auscultation demonstration.

SAMII for individualized training. Crackle and wheezing sounds characteristically associated with CHF due to pulmonary edema were auscultated via preprogrammed respiratory and cardiovascular sounds on SAMII. The first clinical skills activity focused on physiological and pathophysiological cardiac and respiratory sounds, where MDY1 students were taught proper technique of cardiorespiratory auscultation. SAMII was used to reinforce topics, including respiratory mechanics, airway patency, valvular control of unidirectional blood flow, and pathological sounds produced when obstructions occur in the airway and blood vessels. During the ~25-min session, clinicians directed students (3–4 at a time) to auscultate directly on the thorax of SAMII while completing preprogrammed modules for normal cardiorespiratory sounds, as well as sounds characteristically heard in patients with CHF [i.e., exaggerated heart sound (S1), fine and coarse crackles, wheezing, etc.]. Basic electrophysiology of the heart, ECG, was displayed in synchrony with the auscultated sounds for normal sinus rhythm, as well as heart failure and cardiac arrhythmias. Similarly, learners reexamined mechanical and airways dynamics associated with CHF while listening to normal breath sounds via direct auscultation of anterior and posterior lung regions, where crackles are most commonly observed. At the conclusion of the skills activity component, clinicians then projected sounds overhead to ensure learners detected key features of each module studied during the individualized auscultation components.

Vimedix TTE training platform. Failing cardiac performance evidenced as a reduced ejection fraction was reinforced with the Vimedix cardiac echo simulator. Clinicians used the Vimedix TTE simulator to review the functional anatomy of the heart and visualize the aorta and vascular blood flow in relation to cardiac performance (e.g., cardiac chamber pumping actions), as well as demonstrate valvular functions governing unidirectional flow through the heart to the pulmonary circulation. Valvular dysfunction (stenosis or regurgitation) was also demonstrated when students/clinicians guided a handheld probe over the region of interest. The system uses high-fidelity sonography with calibrated three-dimensional color imaging that provided students with clearly discernable structures within a dilated myocardium characteristic of CHF. Students observed a reduced contractility and cardiac ejection fraction to reflect what is anticipated in a CHF patient. An additional key point involved students' ability to reconsider the patient's case history regarding cardiac performance and ejection fraction during the presentation of severe CHF to correlate the development of pulmonary edema with failing heart function. This activity was very important in correlating normal cardiac function with images depicting the heart's pumping action and valvular functions during clinical pathologies such as CHF.

SimMan3G “Howard” human patient simulator. SimMan3G was presented in monge with symptoms of CHF to provide full integration of the interdisciplinary mechanisms. SimMan3G displayed a radial artery/wrist pulse, heartbeat, respiratory movements, and eye flippers to indicate an arousal-alert state, presenting in distress with CHF symptoms, including jugular vein distention, pitting edema in lower extremities, and altered S3 heart/respiratory sounds. Critical interdisciplinary integration of cardiorespiratory physiology lecture objectives was discussed at the bedside during physical diagnosis. Students practiced newly acquired auscultation skills, and clinicians...
used this segment of the simulation to direct learners’ attention to simulated physiological readings on monitors (i.e., ECG, chest X-ray of cardiomegaly and severe pulmonary edema) to pose discussion questions that reiterated clinical correlations with basic science lecture objectives.

Participants, prerequisites, and simulation structure. Two consecutive simulations were implemented for the MDY1 (n = 120) and graduate (n = 2) students enrolled in S&F. Twelve groups, comprised of 10–14 students, participated in the simulations following both the cardiovascular and respiratory lectures. Each simulation was 1–1.5 h, thereby allowing student groups ~20–30 min per clinical skills activity. Students were provided prerequisite instructional information and videos, as well as the CHF cases, before each simulation exercise. The basic structure for simulations consisted of an initial didactic/instructional segment lead by the cardiovascular or respiratory basic science faculty, clinical skills activity training and debriefing lead by clinicians, followed by evaluation.

Simulation evaluation by Likert scale survey and data analysis. Summary data utilized in this study were obtained from students who provided voluntary responses on a 21-question Likert scale survey completed at the end of the cardiovascular and respiratory simulation exercises. No student identifiers were included on the survey documents to ensure that responses remained completely anonymous. Participants selected choices from the 5-point Likert scale survey, ranging from agree, strongly agree, neutral, disagree, or strongly disagree. The simulations consisted of an initial didactic/instructional segment lead by the cardiovascular or respiratory basic science faculty, clinical skills activity training and debriefing lead by clinicians, followed by evaluation. For the didactic/session instructions component of the survey, questions focused on an assessment of the basic science faculty member’s ability to introduce the simulation exercise, inform students about expectations for lecture objective mastery, and usefulness of instructional videos used to orient learners. For the cardiovascular didactic components, 94–97% of the participants agreed that physiology professors adequately explained the purpose and objectives of the simulation exercises. Learners also agreed that the instructional videos were informative and helpful. Approximately 1–5% of the participants remained neutral or replied disagree, suggesting that the didactic component was inadequate (Table 1). The vast majority (97–99%) of MDY1 learners participating in the respiratory simulation agreed that the simulations would impact their ability in the future when functioning as a healthcare provider in a clinical setting.

RESULTS

The five components assessed for each of the simulation exercises included the following: didactic/session instructions, session experience, postsession, faculty/instructor, and the simulation center. The results for the procedural and technical skill Likert evaluation were used to independently assess the cardiorespiratory simulation sessions. Categorical results are shown for both cardiovascular (Table 1) and respiratory (Table 2) simulation sessions, and values are presented as the percentage of participants who replied agree/strongly agree, neutral, or disagree/strongly disagree.

Didactic/session instructions. For the didactic/session instructions component of the survey, questions focused on an assessment of the basic science faculty member’s ability to introduce the simulation exercise, inform students about expectations for lecture objective mastery, and usefulness of instructional videos used to orient learners. For the cardiovascular didactic components, 94–97% of the participants agreed that physiology professors adequately explained the purpose and objectives of the simulation exercises. Learners also agreed that the instructional videos were informative and helpful. Approximately 1–5% of the participants remained neutral or replied disagree, suggesting that the didactic component was inadequate (Table 1).

Table 1. Cardiovascular student evaluation results

| Survey Questions by Category | Agree/Strongly Agree | Neutral | Disagree/Strongly Disagree |
|------------------------------|---------------------|--------|---------------------------|
| Didactic/session instructions |                     |        |                           |
| Q1. The orientation helped me to understand the purpose and goal for the simulation activity. | 97.4 | 0.9 | 1.7 |
| Q2. I understood the objectives before the session. | 94.6 | 3.6 | 1.8 |
| Q3. The didactic before the session was helpful and informative. | 97.3 | 0.89 | 0.9 |
| Q4. The videos presented before the session were helpful and informative. | 93.8 | 4.5 | 1.8 |
| Session experience |                     |        |                           |
| Q1. The faculty/instructor provided me with guidance during the session. | 95.5 | 0.9 | 3.6 |
| Q2. The amount of time for the hands-on practice was appropriate for the skill being taught. | 95.5 | 3.57 | 2.7 |
| Q3. The session length was appropriate. | 97.3 | 0.9 | 1.8 |
| Postsession experience |                     |        |                           |
| Q1. I am more confident to practice in an actual clinical environment. | 96.5 | 1.8 | 1.8 |
| Q2. Future procedural and technical skills training sessions would improve my clinical practice. | 97.3 | 0.9 | 1.8 |
| Q3. What I learned today will help to improve patient outcomes. | 95.5 | 2.68 | 1.8 |
| Q4. The commercial vendor inclusion in the session was beneficial and valuable. | 97.3 | 1.3 | 2.6 |
| Q5. The hands-on skill development with real clinical equipment was valuable. | 96.2 | 1.35 | 2.6 |
| Faculty instructor |                     |        |                           |
| Q1. The faculty/instructor set the stage for an engaging learning experience. | 97.3 | 0.9 | 1.8 |
| Q2. The faculty/instructor was able to answer my questions. | 96.4 | 1.8 | 1.8 |
| Q3. The faculty/instructor helped me see how to improve or how to sustain good performance. | 95.5 | 2.7 | 1.8 |
| Simulation center |                     |        |                           |
| Q1. The simulation team provided a safety overview before the start of the procedural and technical skills session. | 97.2 | 0.0 | 1.9 |
| Q2. The simulation team provided adequate orientation on the simulator, equipment, and supplies before the start of session. | 98.2 | 0.0 | 1.8 |
| Q3. The simulation center environment was a safe place for learning to take place. | 98.2 | 0.0 | 1.8 |

Values are in percent for each answer option, which is denoted: Agree/Strongly Agree, Neutral, Disagree/Strongly Disagree. Q1–Q5, questions 1–5, respectively. *For Q1, all students checked Not Applicable. †For Q2, one student checked Not Applicable.
Table 2. Respiratory student evaluation results

| Survey Questions by Category | Agree/Strongly Agree | Neutral | Disagree/Strongly Disagree |
|------------------------------|----------------------|---------|---------------------------|
| Didactic/session instructions |                      |         |                           |
| Q2. I understood the objectives before the session. | 97.3 | 1.4 | 1.4 |
| Q3. The didactic before the sessions was helpful and informative. | 98.7 | 1.3 | 0 |
| Q4. The videos presented before the session were helpful and informative. | 98.8 | 1.25 | 0 |
| Session experience |                      |         |                           |
| Q1. The faculty/instructor provided me with guidance during the session. | 96.3 | 2.5 | 1.2 |
| Q2. The amount of time for the hands-on practice was appropriate for the skill being taught. | 95.10 | 3.7 | 1.2 |
| Q3. The session length was appropriate. | 98.8 | 1.2 | 0 |
| Postsession experience |                      |         |                           |
| Q1. I am more confident to practice in an actual clinical environment. | 98.75 | 1.3 | 0 |
| Q2. Future procedural and technical skills training sessions would improve my clinical practice. | 98.73 | 1.27 | 0 |
| Q3. What I learned today will help to improve patient outcomes. | 98.8 | 1.23 | 0 |
| Q4. The commercial vendor inclusion in the session was beneficial and valuable. | 98.8 | 1.2 | 0 |
| Q5. The hands-on skill development with real clinical equipment was valuable. | 100 | | |
| Faculty instructor |                      |         |                           |
| Q1. The faculty/instructor set the stage for an engaging learning experience. | 100 | | |
| Q2. The faculty/instructor was able to answer my questions. | 100 | | |
| Q3. The faculty/instructor helped me see how to improve or how to sustain good performance. | 100 | | |
| Simulation center |                      |         |                           |
| Q1. The simulation team provided a safety overview before the start of the procedural and technical skills session. | 98.7 | 1.3 | 0 |
| Q2. The simulation team provided adequate orientation on the simulator, equipment, and supplies before the start of session. | 100 | | |
| Q3. The simulation center environment was a safe place for learning to take place. | 100 | | |
| Q4. Overall, I was satisfied with the service provided by the simulation center staff. | 100 | | |

Values are in percent for each answer option, which is denoted: Agree/Strongly Agree, Neutral, Disagree/Strongly Disagree. Q1–Q5, questions 1–5, respectively.

was adequate, whereas <1.4% provided neutral or disagree as their response (Table 2).

Session experience. Three questions were used to assess the appropriateness of the simulation session organization. Students provided feedback regarding faculty guidance during the sessions, as well as suitability of the timing allotted for hands-on practice during each clinical skills activity. The session experience received similar ratings for both the cardiovascular (96–97%) and respiratory (95–99%) exercises, with participants agreeing that appropriate guidance was provided and adequate time was allotted for hands-on interaction. However, only 1–4% of the learners disagreed or remained neutral (Tables 1 and 2).

Postsession experience. The postsession experience provided valuable information regarding students’ confidence level for working in a clinical environment after having completed the simulations exercises. Students were asked to consider potential influence that the clinical skills activities would have on future encounters with real patients. For the cardiovascular simulation, >96% of the participants were confident with their ability to perform in a clinical setting and agreed that additional procedural and technical skills instructions would further enhance their ability. Learners also agreed that the hands-on training with the clinical equipment provided during the simulation exercise would help to improve patient outcomes (Table 1). Nearly all students who participated in the respiratory simulation, >99%, agreed that the postsession experience increased their confidence in their ability to execute clinical skills effectively to promote positive outcomes in hospital settings in the future (Table 2).

Faculty instructor. Assessment of the faculty/clinical staff’s performance was considered throughout the entire simulation exercise and scored. Faculty served a critical role for the simulation exercises, and participants assessed the effectiveness of the faculty facilitator’s influence and guidance during the sessions. For the cardiovascular (97%) and respiratory sessions (100%), students indicated that the faculty set the stage for an engaging learning experience and were capable of answering students’ questions related to the simulations, 96% and 100%, respectively. Additionally, learners for the cardiovascular (96%) and respiratory (100%) simulations agreed that instructors advised them as to how they could sustain and/or improve performance (Tables 1 and 2).

Simulation center. The final component of the survey involved a critique of the simulation center (hereafter referred to as the center) and simulation staff. Students provided feedback regarding an introductory safety overview, orientation for use of simulation equipment, and the environment as a safe place to learn. Participants (97–100%) agreed that the center and its staff met their expectations and adequately performed their duties regarding the simulation exercises (Tables 1 and 2).

DISCUSSION

Simulation in medical education is now more widely accepted and required for accreditation of United States medical schools because it provides a safe, controlled, and nonjudgmental environment for students to acquire knowledge, practice, and demonstrate newly learned skills. Simulation provides the correct attitude and skills among medical students to cope.
with real-life critical situations competently. The use of simulation as a core component of medical physiology education allows students to transition from the old school of thought where the rule was “see one, do one, teach one,” to a modern era model where learners “see one, practice many, do one” (2). This prototypical approach protects the ethical and legal rights of patients.

At HUCM and in collaboration with the center, physiology basic science faculty, clinicians, and simulationists implemented case-based simulation exercises directly related to the fundamental principles of cardiovascular and respiratory physiology. Many institutions have utilized simulation for teaching basic physiology and various functions of the cardiorespiratory system (5, 9, 18, 22). According to the 2011 AAMC Survey that reflected responses obtained from 90 medical schools and 64 teaching hospitals in the U.S., medical simulation education is used in medical schools during the first year. However, the most common content was for clinical skills/doctoring, introduction to clinical medicine, and physical diagnosis. Forty percent of medical schools indicated physiology as a preclinical content area that is addressed during MDY1.

Our pedagogical goals for using simulation were critical to the reinforcement of basic science lecture objectives and afforded MDY1 learners the opportunity to explore a disease model that correlated normal physiology and clinical skills needed to assess the patient’s status at the bedside. This alternative teaching strategy incorporated the use of several technologies, including screen-based computer modules, task trainers, and human patient simulators to create realism during the exercises. The use of high-fidelity human simulators in the environmental setting of the center was reminiscent of a professional clinical setting. In addition, the disease model provided an ideal opportunity to discuss the interdisciplinary relationship of the cardiorespiratory systems and underlying physiological principles of CHF. Students gained a greater appreciation for cardiorespiratory auscultation, cardiac performance, ECG interpretation, and respiratory mechanics, as described during their S&F course lectures.

Simulations were an integrated component of the S&F course required for MDY1 students. Assessments of information mastery were encompassed in the objective examination for content presented during the simulations and the entire lecture series for both cardiovascular and respiratory physiology. The introduction of HPS as a new pedagogical approach appears to have “done no harm,” since the MDY1 class obtained a passing average for both the cardiovascular and respiratory didactic exams.

Simulation has been shown to have the potential to revolutionize health care and nonclinical medical physiology education and address the patient safety issues, if appropriately utilized and fully integrated into the educational and organizational improvement processes that allow educators to determine outcomes and benchmarks (6). The underutilization of functional physiology model simulators for basic science instruction remains; however, simulation is increasingly being used as an effective tool that fosters retention of learned skills and receives high ratings for learner satisfaction (3). The implementation of computer-assisted instruction systems has traditionally been conducted in advanced training settings for the purpose of introducing novel technology resulting from new developments in science. Some of the first simulation centers included Harvard University, which originally established training for anesthesia residents and academic anesthesiology faculty members, and are still in use (20). Others have used simulation for the purposes of team building in medical settings, where multiple departmental entities come together to accomplish a common goal (i.e., surgical teams). In this study, a different approach was considered. Educational and clinical skills training simulations were designed for novice MDY1 students in an effort to offer early clinical exposure to multidisciplinary skills and solidify the understanding of rudimentary concepts of cardiorespiratory physiology.

Our study lends support to existing evidence indicating that HPS, computer-assisted instruction, and advanced technologies have tremendous potential when meticulously linked to basic science learning objectives, thereby making simulation an attractive and effective teaching approach, especially for MDY1 learners. For testing purposes, faculty used higher ordered questions to assess student performance. As in previous years, questions were designed to promote critical-thinking skills and to evaluate how well students analyzed and applied information from lecture objective materials. With the addition of clinical skills simulations to the MDY1 curriculum, the clinical perspectives afforded students additional insight, in addition to simple factual recall.

In conclusion, the blended expertise of physiologists, simulationists, and clinicians facilitated the presentation of a medical case with a remarkable degree of realism to simulate cardiorespiratory physiology and pathophysiology expected in patients with CHF. The multifaceted approach offered a new paradigm for teaching MDY1 students basic science physiology lecture objectives. The cardiorespiratory case-based CHF disease model immersed students, “textbook to the bedside,” and learners offered high approval ratings overall. We conclude that medical curricular modifications that employ innovative use of simulation to teach basic science physiology will serve as an efficacious alternative for correlating didactic lecture objectives and clinical skills for MDY1 students.

ACKNOWLEDGMENTS

The authors acknowledge the contributions of physiology basic science faculty (Dr. Georges Haddad, Department of Physiology and Biophysics), Medical Director of the Howard University Clinical Skills and Simulation Center (Dr. Debra H. Ford), Howard University Hospital cardiology fellows (Drs. Mark Larralde and Jemina Udeogu), and internal medicine residents (Drs. Raka Amin, Adebayo Atanda, Osigbemhe Iyalomhe, Onyinyechukwu Ochi, and Oluwakemi Owoyemi), the Howard University Clinical Skills and Simulation Center staff (Catherine Wright and Anthony Slack), and Howard University Hospital, Office of Graduate Medical Education.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

S.M.J., T.L.O., and J.N.O. conceived and designed research; S.M.J. and J.N.O. performed experiments; S.M.J. and J.N.O. analyzed data; S.M.J. and J.N.O. interpreted results of experiments; S.M.J., T.L.O., and J.N.O. drafted manuscript; S.M.J., T.L.O., and J.N.O. edited and revised manuscript; S.M.J. and J.N.O. approved final version of manuscript.

REFERENCES

1. Banerjee A, Slagle JM, Mericaldo ND, Booker R, Miller A, France DJ, Rawn L, Weinger MB. A simulation-based curriculum to introduce key teamwork principles to entering medical students. BMC Med Educ 16: 295, 2016. doi:10.1186/s12909-016-0808-9.
USE OF HUMAN PATIENT SIMULATION TO MAKE CLINICAL CONNECTIONS

2. Datta R, Upadhyay K, Jaideep C. Simulation and its role in medical education. Med J Armed Forces India 68: 167–172, 2012. doi:10.1016/S0377-1237(12)60040-9.

3. Eason MP. The use of simulation in teaching the basic sciences. Curr Opin Anaesthesiol 26: 721–725, 2013. doi:10.1097/ACO.0000000000000008.

4. Euliano TY. Teaching respiratory physiology: clinical correlation with a human patient simulator. J Clin Monit Comput 16: 465–470, 2000. doi:10.1023/A:10141011887.

5. Gaba DM. The future vision of simulation in health care. Qual Saf Health Care 13, Suppl 1: 12–10, 2004. doi:10.1136/qshc.2004.009878.

6. Ginzburg SB, Brenner J, Cassara M, Kwiatkowski T, Willey JM. Contextualizing the relevance of basic sciences: small-group simulation with debrief for first- and second-year medical students in an integrated curriculum. Adv Med Educ Pract 7: 79–84, 2017. doi:10.2147/AMEP.S124851.

7. Harris JR, Helyer RJ, Lloyd E. Using technology to meet the challenges of medical education. Trans Am Clin Climatol Assoc 126: 260–270, 2015.

8. Gaze PA. Features and uses of high-fidelity medical simulators to teach physiology. Med Educ 45: 1159–1160, 2011. doi:10.1111/j.1365-2923.2011.04105.x.

9. Helyer RJ, Dickens P. Progress in the utilization of high-fidelity simulation in basic science education. Adv Physiol Educ 40: 143–144, 2016. doi:10.1152/advan.00109.2018.

10. Huang GC, Sacks H, Devita M, Reynolds R, Gammon W, Saleh M, Gíva-McConvey G, Owens T, Anderson J, Stillsmoking K, Cantrell N, Passiment M. Characteristics of simulation activities at North American medical schools and teaching hospitals: an AAMC-SSH-ASPE-AACN collaboration. Simul Healthc 7: 329–333, 2012. doi:10.1097/SHH.0b013e318262007e.

11. Issenberg SB, McGaghie WC, Petrusa ER, Lee Gordon D, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. Med Teach 27: 10–28, 2005. doi:10.1080/0142159050046924.

12. Jackson MB, Keen M, Wenrich MD, Schaad DC, Robins L, Goldstein EA. Impact of a pre-clinical clinical skills curriculum on student performance in third-year clerkships. J Gen Intern Med 24: 929–933, 2009. doi:10.1007/s11606-009-1032-7.

13. Lofaso DP, DeBlieux PM, DiCarlo RP, Hilton C, Yang T, Chauvin SW. Design and effectiveness of a required pre-clinical simulation-based curriculum for fundamental clinical skills and procedures. Med Educ Online 16: 7132, 2011. doi:10.3402/meo.v16i0.7132.

14. McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. A critical review of simulation-based medical education research: 2003-2009. Med Educ 44: 50–63, 2010. doi:10.1111/j.1365-2923.2009.03547.x.

15. McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. Revisiting “A critical review of simulation-based medical education research: 2003-2009”. Med Educ 50: 986–991, 2016. doi:10.1111/medu.12795.

16. Motola I, Devine LA, Chung HS, Sullivan JE, Issenberg SB. Simulation in healthcare education: a best evidence practical guide. AMEE Guide No. 82. Med Teach 35: e1511–e1530, 2013. doi:10.3109/0142159X.2013.818632.

17. Pereira D, Gomes P, Faria S, Cruz-Correia R, Coimbra M. Teaching cardiopulmonary auscultation in workshops using a virtual patient simulation— a pilot study. Conf Proc IEEE Eng Med Biol Soc 2016: 3019–3022, 2016.

18. Scalese RJ, Obeso VT, Issenberg SB. Simulation technology for skills training and competency assessment in medical education. J Gen Intern Med 23, Suppl 1: 46–49, 2008. doi:10.1111/j.1527-167W.2007.00283-4.

19. Weinger MB, Banerjee A, Burden AR, McIvor WR, Boulet J, Cooper JB, Steadman R, Shotwell MS, Slagle JM, DeMaria S Jr, Torsher L, Sinz E, Levine AI, Rask J, Davis F, Park C, Gaba DM. Simulation-based assessment of the management of critical events by board-certified anesthesiologists. Anesthesiology 127: 475–489, 2017. doi:10.1097/ALN.0000000000001739.

20. Zafar M, Inayah AT, Shareef MA, Aldalati AM, Afsar NA, Abu-Zaid A, Zafar F, Azouz HJ. Evaluation of a combined approach of clinical skills training utilizing near-peers, in-campus faculty and clinicians: an innovative integrated model. Med Teach 38, Suppl 1: S52–S59, 2016. doi:10.3109/0142159X.2016.1142512.

21. Zvara DA, Olympio MA, MacGregor DA. Teaching cardiovascular physiology using patient simulation. Acad Med 76: 534, 2001. doi:10.1097/00001888-200105000-00072.