Combining simulated patients and simulators: pilot study of hybrid simulation in teaching cardiac auscultation

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The general conditions of inpatient care have changed substantially. The duration of hospitalization has decreased, and there is increasingly less time available to adequately educate students and doctors. This conflict between necessary education and the lack of practical training can be balanced by simulation of various aspects of clinical practice. For such purposes, simulated patients (SPs; i.e., actors playing patients) and simulators (i.e., technical models such as body parts) have been used to perform practical, invasive techniques. In addition, situations are simulated in patient rooms or artificial accident scenarios.

Students worldwide are currently trained using auscultation torsos, and various models are available. For position-dependent auscultation (e.g., the third heart sound), the patient should be placed in a left lateral position (21) and positioned upright to exclude functional systolic murmur (1). Auscultation torsos are of limited value in such cases. Overall, auscultation using auscultation torsos is a rather unrealistic model.

One part of the auscultation curriculum since the winter term of 2008–2009 at the Medical Faculty of Muenster has included mannequins with an identical auscultation technology in addition to auscultation torsos (Life/form Auscultation Trainer and Smartscope, Nasco, Fort Atkinson, WI) to teach auscultation of position-dependent heart sounds and murmurs. These mannequins can be examined in a supine position with the upper body elevated and can be turned to the side and positioned upright. A remote control is used to adapt the auscultation findings to the mannequin’s position. Therefore, a realistic training situation is created. This method is widely accepted among students. Nevertheless, only a few innovative approaches have been used to teach auscultation. The only change since the introduction of auscultation mannequins in the 1970s has been in the presentation of the findings, which were formerly presented using audio cassettes and vinyl records instead of digital technology (22).

SPs are defined as medical laypersons trained to portray a patient with a special medical condition (2). They have been a part of the medical teaching tradition for decades and are now used worldwide. Because of the good results SPs have achieved in medical education, we evaluated a new approach to teaching auscultation. Teaching pathological findings in cardiac auscultation of a healthy SP is difficult; thus, SP were equipped with the hardware and software of the auscultation mannequins (hereafter termed “hybridization”; Fig. 1) with the aim of presenting pathological findings that could previously only be taught with auscultation torsos. Thus, using these hybrid models, the best elements of auscultation torsos or whole body mannequins can be combined with SPs and thus provide an interactive teaching environment presenting students with highly clinically relevant challenges.
METHODS

The present study was carried out in the spring term of 2009 at the Medical Faculty of Muenster. Subjects comprised 143 students in their second preclinical year who participated in the practical part of the course entitled “General Clinical Examination” at the simulation center “Studienhospital Münster.” This course is divided into both theoretical and practical aspects such as taking a medical history and performing a physical examination. Participants are taught the basics of a clinical examination in six sessions. The whole curriculum comprises 24 h, 18 h of which are dedicated to practical training. Because cardiac auscultation is an important topic taught in this course, this part of the clinical examination lasts for 2 full-course days. The content of these 2 days includes both a theoretical background and the practical implementation of the auscultation of physiological heart sounds and murmurs. Students are trained in a systematic approach to evaluating the third heart sound and the functional systolic murmur because these are common findings in healthy patients.

Study Design and Materials

For this study, students were randomly assigned to a control group and an intervention group. Students were taught using either auscultation mannequins (whole body mannequins in the control group) or hybrid models (SPs in the intervention group) for auscultation of position-dependent heart sounds and murmurs (Fig. 2). In contrast to auscultation torsos, the auscultation mannequins were whole body models with arms, legs, and clothing. The hybrid model was a human being that was electronically outfitted to produce pathological heart sounds. To prepare the hybrid models, the electronic chips were removed from the auscultation torsos (Life/form Auscultation Trainer and Smartscope, Nasco) and then glued to the anatomically correct auscultation positions of the SP. SPs wore skin-colored bodies to hide the electronic chips. The heart sounds could then be auscultated when special stethoscopes were held on the correct auscultation positions. The types of auscultation sounds were controlled via an infrared remote control. The natural heartbeat of the SP was not detectable because of the special stethoscopes; thus, students only heard the heart sounds generated via the mannequin’s excised hardware.

After the course, various aspects of this teaching intervention were assessed in a questionnaire. Besides providing information on age and sex, students were asked to complete a self-assessment using a visual analog scale between 1 (“very poor” or “no, only a little”) and 100 (“very good” or “yes, very much”) regarding the following items: 1) How do you evaluate the following parts of the course? Plenary lecture, physical examination involving auscultation on the upper-body model (torso), physical examination involving auscultation on the whole body model (actor in the intervention group or mannequin in the control group), and physical examination involving teaching by tutors; and 2) Did this course help you at all?

The wording corresponded to the faculty-wide evaluation of all courses, which is always focused on the “value to learning.” We obtained oral informed consent for participation in the study from all participants. In light of the aforementioned study design, the Ethics Committee of the Chamber of Physicians Westfalen-Lippe and the Medical Faculty of the Westphalian Wilhelm University Muenster waived the requirements for an ethical approval procedure. This study adhered to all ethical principles.

Course Structure

Each course day began with a plenary presentation. The contents of the first course day included the history of auscultation, the location of auscultation points, the functioning and technical handling of the stethoscope, the approach to the assessment of auscultation, and the identification of systole and diastole. This was followed by a repetition of the aforementioned topics as well as a pathophysiological explanation and onomatopoeic presentation of the third heart sound and functional systolic murmur on the second course day. Each teaching session lasted ~45 min. Students were subsequently divided into groups of six in small seminar rooms. This setting allowed for interactive teaching and good practical instruction; the students’ knowledge was deepened by practical exercises in the second part of the study. Students were taught in classrooms equipped with three examination tables. Two students shared one examination table to perform the exercises. On the second course day, in addition to a repetition of the first and second heart sounds, the third heart sound and a functional systolic murmur were introduced and practiced with the tutor using the auscultation torsos. The auscultation was followed by all students via loudspeakers. These exercises were repeated using the whole body models (auscultation mannequins or new hybrid models). Two case scenarios of thorough investigations using these exercises are presented below.

Case Scenarios

Case scenario 1: mesosystolic murmur. A 53-yr-old patient presented to the emergency department because of vague abdominal
briefed peer tutors. All peers were medical students who had success-
fully passed the course a few semesters earlier. To ensure that variability did not confound the feedback data obtained from the two groups, all peer tutors were similarly trained to demonstrate the cardiac examination by an experienced physician based on learning objectives that had been clearly defined in advance. The cost of the course, including all 24 scenarios played by the SPs and the additional preparation, was €200 ($260 United States dollars (USD)). The computer chips that required removal from the torsos were added to this cost. Because one torso contained sufficient chips for two SPs, only one torso had to be disassembled ($2,725 USD according to the manufacturer).

### Statistical Analysis

The collected data were analyzed using the statistical software R (version 3.0.1, R Core Team). Because the distributions of the assessment variables and age were rather skewed in the control and intervention groups, nonparametric methods were used to describe and compare the data. Thus, medians are given to summarize the data. Mann-Whitney U-tests were performed to compare the assessment variables between the control and intervention groups. Sex was checked for balance over the control and intervention groups using Fisher’s exact test. Another point of interest was the paired comparison of the assessment of the auscultation torso with the whole body model within the intervention and control groups, for which analogous Wilcoxon signed-rank tests were performed. The local significance level was set at 0.05 and was two sided for every test. No adjustment for multiple testing was performed; therefore, the results must be interpreted accordingly.

### RESULTS

In total, 142 of 143 questionnaires were collected after the course, for a return rate of 99.3%. All questionnaires were analyzed. Student tutors gave positive verbal feedback about the SPs; they described a higher level of attention and seriousness during the class in the group that was taught with the hybrid model than in the group taught with the auscultation mannequins. The SPs also responded positively and felt accepted and respected.

The median age of the students in both the control and intervention group was 21 yr old ($P = 0.863$). In total, 67.1% of the students in the control group and 58.3% in the intervention group were women; 33.9% of the students in the control group and 42.7% in the intervention group were men ($P = 0.302$). Thus, age and sex were distributed similarly between the control and treatment groups.

Figure 3 shows the data for the five assessment variables separated between the control and intervention groups. These results show that, overall, students of both groups evaluated the different aspects of the auscultation course positively (the overall benefit of the course was evaluated with a median of 87 and 88 points in the control and intervention groups, respectively). However, the evaluation results of the auscultation mannequin in the control group differed. We found no significant differences in any aspects of evaluation between the control and intervention groups (plenary lecture: median of control/intervention = 78.5/77.5, $P = 0.579$; torso: median of control/intervention = 79.0/79.0, $P = 0.784$; tutor: median of control/intervention = 77.5/80.0, $P = 0.569$; and benefit: median of control/intervention = 87.0/88.0, $P = 0.646$). Students in the intervention group evaluated the hybrid model to be significantly better than the students in the control group evaluated the auscultation mannequin (median of

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**Fig. 2. Study design.**

**Resources**

Sessions for both the intervention and control groups were led by briefed peer tutors. All peers were medical students who had success-

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**Fig. 3. Study design.**

**Evaluation**

- auscultation-torso (total 25 minutes)
  - demonstration and training 1st and 2nd heart sound
  - demonstration and training 3rd heart sound
  - demonstration and training mesosystolic murmur

- auscultation-manikins (each 10 minutes)
  - case scenario 1 (see text)
  - case scenario 2 (see text)

- hybrid-models (each 10 minutes)
  - case scenario 1 (see text)
  - case scenario 2 (see text)

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complaints. After auscultation, the physician mentioned a nonmorbid heart murmur. However, the patient became concerned and asked the “family doctor” (the student) for clarification. No other abnormal findings were observed during the examination in the emergency department, and the abdominal problems are no longer present.

**Case scenario 2: third heart sound.** A 63-yr-old patient presented to the emergency department because of dizziness. After auscultation, the physician mentioned a nonmorbid heart murmur. However, the patient became concerned and asked the “family doctor” (the student) for clarification. No other abnormal findings were observed during the examination in the emergency department, but a systematic inquiry revealed symptoms of heart failure. The medical history in this case was presented by either the tutor (auscultation mannequin group) or SP (hybrid model group). This training required ~45 min; thus, the entire course required 2 academic hours.

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control/intervention: 64/83, \( P < 0.001 \). Another interesting finding is that students in the intervention group evaluated the hybrid model significantly better than the torso model (median of hybrid model/torso: \( 83/79, P = 0.011 \)), whereas students in the control group evaluated the auscultation mannequin significantly worse than the torso (median of mannequin/torso: \( 64/79, P < 0.001 \)).

**DISCUSSION**

Because there was no difference in the age and sex distribution of the students in the intervention and control groups, the two groups were comparable. The positive assessment of the hybrid models in contrast to the auscultation mannequins in the questionnaires confirmed the immediate verbal feedback after the course. Our study shows that the use of hybrid models was evaluated as a more superior teaching method than auscultation mannequins. This is even more noticeable due to the fact that there were no differences in these two groups in their evaluation of the value of the plenary lecture, the auscultation torso, the tutors, or the course overall. Thus, the significantly higher evaluation of the hybrid model over the mannequin was related to the hybrid model itself and not to ancillary factors. Kneebone et al. (8) described the combination of training models and SPs to “practice technical and communication skills in realistic clinical scenarios using simulated tissue connected to SP to create a ‘safe zone.’” His research group (8) combined SPs with wound care pads or a model for the insertion of a urinary catheter. According to Kneebone et al., this simulation method is helpful to teach practical skills as well as doctor-patient interactions. The patient’s privacy and well-being can be ensured at the same time.

In addition to theoretical instruction, students are traditionally trained to identify pathological findings during cardiac auscultation using various types of auscultation models before working with real patients. The use of SPs presented in this study represent a gradual transition derived from the previous use of SPs. As early as 1985, Norman et al. (17) showed that there are no differences in taking patient history between real patients and SPs. This is why SPs are also used in the final examinations of physicians (19). Accordingly, McGraw and O’Connor (16) showed that there were no differences in acquiring the basic practical clinical skills, as assessed by objective structured clinical examinations, between students who were trained with real patients and those who were trained with SPs. Not surprisingly, May et al. (14) concluded in a 10-yr review (1996–2005) in which most authors considered the use of SPs in training to be valuable. Diseases and clinical problems can be presented in training even when no real patients are available. The complexity of the cases can be gradually increased and thus be adapted to the educational level of the student. A further major advantage of SPs over auscultation mannequins is the personal interactions in the practice sessions. The SPs can provide information about their medical history and interact emotionally with students. Lewin et al. (9) confirmed in a review that training in patient-centered treatment improved communication with patients, clarified patients’ concerns, and improved patients’ satisfaction with the treatment. Doering et al. (3) demonstrated that teaching with SPs significantly increases students’ empathy.

Based on previous relevant research on simulation-based medical education, we have identified two important elements that improve student performance and have determined that these elements must be integrated into medical education: feedback and the opportunity to repeat training (15). Medical students have confirmed this viewpoint. The relevance of simulators in a Best Evidence Medical Education review (6) was confirmed in a qualitative study of students’ assessment of simulation. Among other factors, students identified feedback and realistic involvement in the clinical context in this qualitative study (18). In our course, students received feedback about the proper localization of auscultation points by the reproduction of heart sounds and murmurs through loudspeakers and by the interpretation of the findings of the group.
possible cause of the lower evaluation of auscultation mannequins compared with torsos might be that, especially when moving the auscultation mannequins (e.g., into the left lateral position), they appeared to be very artificial and were more difficult to handle because they were much larger than the torsos.

In medical education, the outcome of a mixture of teaching methods (e.g., lectures) and interactive elements (e.g., role playing and practical exercises) in a single education model is superior to that of solitary didactic and interactive teaching models in terms of resultant competence and performance. There was mild evidence of positive patient outcomes using this mixed didactic and interactive approach (4). In contrast, purely didactic formats increased the theoretical competence of the learners but did not affect their performance, as demonstrated in a review by Davis et al. (2). Students’ appreciation of these didactic and interactive course models was demonstrated in the overall assessment of the usefulness of the course regardless of whether auscultation mannequins or hybrid models were used.

Certainly, a disadvantage of the SP is the high cost. Although the €20/h cost of the SP in the Studienhospital Muenster is much lower than the costs of other practical training methods, one must add the followup costs. The training of the SP, which is mostly performed by medical trainers, as well as the training of the instructors for the simulation training is quite costly. Furthermore, we emphasize that simulation is merely an addition to training in the clinical setting, but cannot replace it (5).

Conclusion and Prospects

The positive feedback from both tutors and SPs suggests a high acceptance of this new teaching model, and the results of the self-assessment of students in this teaching method are encouraging. The heart murmurs were controlled very well via remote control so that position-dependent findings could be presented. This project expands the repertoire of SPs by the presentation of pathological heart murmurs. It simplifies teaching cardiac auscultation in a clinical context. An extension of the method described herein seems possible but will require implementation of this training in the curriculum according to needs assessment (7). Further studies are required to evaluate the impact on students’ performance.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS


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