# MERGING OLD SCHOOL METHODS WITH NEW TECHNOLOGY TO IMPROVE SKILLS IN CARDIAC AUSCULTATION

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- *Objective:* Studies continue to document significant deficiencies in cardiac auscultation skills among clinical trainees. The availability of electronic stethoscopes with memory tracks affords the opportunity to practice listening to heart sounds. The objective of this study was to determine whether use of an electronic stethoscope to listen repeatedly to 6 commonly heard cardiac murmurs improves auscultatory proficiency among medical trainees.
- *Design*: Controlled intervention study.
- *Setting and participants*: 40 medical residents at an urban, university-based medical center.
- *Intervention*: Study participants were enrolled prospectively between 1 July 2005 and 1 August 2006 and randomized to 1 of 3 groups: monitored intervention ($n$ = 16), unmonitored intervention ($n$ = 14), or control ($n$ = 10). All participants took an initial proficiency test consisting of 10 human heart murmurs played in random order. The monitored group remained after the pretest for a 2-hour session during which they received electronic stethoscopes containing 6 electronically simulated cardiac murmurs and were instructed to listen to 500 repetitions of each murmur. The unmonitored group left after the pretest with similarly equipped electronic stethoscopes to be used independently over a 1-week period; this group was advised to listen to 500 repetitions of each murmur. The control group did not have access to electronic stethoscopes. All study participants returned 1 week following the pretest for a repeat proficiency test.
- *Results*: Mean test score for the monitored group improved from 26.3% ± 20.6% preintervention to 68.8% ± 25% postintervention ($P < 0.001$). Mean test score for the unmonitored group also improved, from 32.1% ± 13.7% to 70.7% ± 23.4% ($P < 0.001$). The control group had a nonsignificant change in test scores, from 37% ± 17% to 46% ± 23.7% ($P = 0.22$).
- *Conclusion*: Use of an electronic stethoscope to listen repeatedly to common heart murmurs can significantly improve proficiency in cardiac auscultation. This result can be achieved independently by the trainee.


A critical factor in determining whether health care meets the goal of being safe, effective, and efficient [1] is the physician's ability to gather accurate and essential information about the patient from all sources, including the physical examination [2]. Proficiency in clinical examination skills is fundamental to meeting the Accreditation Council for Graduate Medical Education (ACGME) requirement for competency in patient care [2].

A physical examination is not complete without auscultation. Listening to the body through a stethoscope allows the clinician to discover clues to understanding the patient's condition. Unfortunately, physicians are not proficient in accurately detecting abnormal heart sounds. Landmark studies in the 1990s by Mangione et al [3–5] documented alarmingly poor cardiac auscultation skills in clinical trainees. On average, residents correctly identified only 20% of common and clinically important heart sounds, and their proficiency in cardiac auscultation improved little with additional years of training. More recent studies have revealed similarly dismal findings that cardiac examination skills do not improve after the third year of medical school and are low in physicians at all levels of training as well as in practice, including among medical faculty [6,7]. These discouraging reports suggest that most physicians would benefit from more intensive instruction and practice in the skills of cardiac auscultation.

Changes in the clinical training environment over recent decades have likely contributed to the

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widespread deficiencies in cardiac auscultation skills. Increased availability of sophisticated diagnostic technology has led to greater use of these tools, with less reliance on physical examination skills [8]. In addition, pressure to keep hospital stays and clinic visits as brief as possible has meant diminished time for teaching and testing these clinical skills in the course of patient care. As a result, many physicians have entered practice or become attending faculty with poorly developed skills in cardiac auscultation.

Repetition has been shown to be crucial to initially learning and maintaining physical diagnostic skills [9]. Just as repetition is required to master a procedural skill (eg, tying a surgical knot, inserting a central venous catheter), proficiency in recognizing abnormal heart sounds requires practice [10,11]. Perceptual learning via intensive repetition is accompanied by neural events that evolve over different time frames, as documented by electroencephalographic recordings [12]. In a study by Atienza et al [12], intensive training in complex auditory patterns produced both fast and slow changes in neural function. Fast neural changes occur during the training session, probably via rapid receptive field modulation of cortical neurons [13,14]. Between training sessions, slower neural changes occur in the absence of any new stimulus. These changes, which occur in the somatosensory, auditory, and visual cortex [15,16], have been correlated with consolidation of the information in long-term memory [17].

Although repetition is effective for perceptual learning, in the current training environment, practicing cardiac auscultation on the wards or in clinic is impractical due to time constraints and irregular exposure to patients who provide good teaching opportunities [7,18]. We propose that an alternative to practice on actual patients is practice with an electronic stethoscope that serves as a patient simulator. Currently available electronic stethoscopes can record, amplify, and digitize heart sounds, allowing clinically relevant sounds to be stored and replayed. As such, electronic stethoscopes afford trainees the opportunity to practice listening to heart sounds, which may lead to greater proficiency in recognizing heart murmurs during clinical examination of patients.

Previous research by one of the authors (MJB) has shown that medical students who listened to 500 repetitions of 4 basic heart murmurs had significantly improved proficiency in recognizing these murmurs [10]. In the current study, we tested the hypothesis that medical residents could improve their ability to correctly identify 6 commonly heard murmurs after listening repeatedly to electronically simulated versions of these murmurs via an electronic stethoscope.

## Methods

### Participants

The study was conducted within the internal medicine residency program at Temple University Hospital in Philadelphia, PA. The study protocol was approved by the institutional review board of Temple University and did not require written consent because the intervention was part of the core curriculum for residents.

All 111 medical residents were invited to participate in the intervention, which was introduced as a learning tool in the core curriculum. Participation was voluntary. Forty residents were enrolled prospectively between 1 July 2005 and 1 August 2006. Of the 40 residents who participated, 18 were in their first year of postgraduate training (PGY-1), 11 were in their second year (PGY-2), 10 were in their third year (PGY-3), and 1 was an internal medicine chief resident.

### Study Design

The study was a controlled intervention involving 30 intervention and 10 control participants. All participants were given a test of cardiac auscultatory proficiency before and after the intervention. Participants signed up for a specific day for the initial test, so that testing could be limited to 8 to 10 physicians at a time. After background information was provided and goals were explained, each resident took the proficiency test. Once completed, the test was turned in and could not be accessed. Following the pretest, the residents were randomized to 1 of 3 groups: monitored intervention, unmonitored intervention, or control.

Sixteen residents were randomized to the monitored intervention. Following the pretest, each physician in this group was given an electronic stethoscope with memory tracks containing 6 different electronically simulated cardiac murmurs: aortic stenosis, aortic regurgitation, mitral regurgitation, mitral stenosis, mitral valve prolapse, and innocent systolic murmur. The physicians were instructed to listen to each murmur 500 times during a monitored session that lasted 2 hours. Monitored intervention participants were then allowed to use the stethoscopes during clinical duties, but no further instruction on using the stethoscopes was provided. The group returned 1 week later for a posttest.

Fourteen residents were allocated to the unmonitored intervention. Following the pretest, each physician in this group was given an electronic stethoscope with the same memory tracks (6 simulated murmurs) as those provided to the monitored intervention group.

**Table 1.** Change in Proficiency by Study Group

| Group | Participants, *n* | Pretest Proficiency, % (SD) | Posttest Proficiency, % (SD) | *P* Value |
|---|---|---|---|---|
| Monitored | 16 | 26.3 (20.6) | 68.8 (25) | < 0.001 |
| Control | 10 | 37 (17) | 46 (23.7) | 0.22 |
| Unmonitored | 14 | 32.1 (13.7) | 70.7 (23.4) | < 0.001 |

The unmonitored group was instructed to listen to each memory track for at least 10 minutes to achieve a total of 500 repetitions of each murmur. Unmonitored intervention participants were given 1 week to fulfill the formal instructions, but there was no independent corroboration of compliance with the intervention. The group returned 1 week later for a posttest.

Ten residents were randomized to the control group following the pretest. These physicians were given no instructions relevant to cardiac auscultation and did not have access to the electronic stethoscopes. The group returned 1 week later to participate in the posttest.

At the conclusion of the study, the control group was given the opportunity to undergo the intervention for training purposes. Control group physicians were given the stethoscopes for use on their own, unmonitored, following their posttest. The group was given the same instructions as were given to physicians in the unmonitored intervention; 1 week later the 10 residents returned for a post-posttest. In a subgroup analysis of physicians by training level, the control group's post-posttest data were pooled with the unmonitored intervention group's posttest scores. Essentially, all of these physicians underwent an unmonitored intervention. Preintervention and postintervention scores were compared.

### Proficiency Tests

Each proficiency test (pre, post, post-post) consisted of 10 human heart murmurs played in random order. These sounds were different from the sounds programmed into the stethoscopes. The stethoscopes were programmed with simulated heart sounds to ensure clarity and precision in auditory learning. Recordings of human heart sounds were used during testing to more closely mimic the patient examination. During each test, each murmur was repeated twice and participants were asked to identify the murmur and record its name on a blank answer sheet.

### Scoring and Statistical Analysis

All proficiency tests were scored individually by hand, with each physician given a score from 0 to 10 for each test. Scoring was primarily done by one of the authors (AS); a second author (MJB) was involved as needed to resolve scoring issues. Group proficiency (ie, percentage of correct answers across the group) was expressed as a mean ± SD. A paired *t* test was used to evaluate the significance of the change in each group's proficiency pre- to postintervention. Scores for different groups were compared using the unpaired *t* test and analysis of variance (ANOVA).

## Results

### Proficiency by Study Group

All 40 residents randomized to the monitored, unmonitored, and control groups completed both a pretest and a posttest. Pretest and posttest scores for the 3 groups are shown in **Table 1** and compared in **Figure 1**. Mean pretest proficiency across all groups was poor (31.8% ± 17.1%).

The monitored intervention group showed a statistically significant increase in proficiency in recognizing the 6 murmurs tested; proficiency for this group increased from 26.3% ± 20.6% preintervention to 68.8% ± 25% postintervention ($P < 0.001$). Proficiency among the unmonitored intervention group also improved significantly, increasing from 32.1% ± 13.7% to 70.7% ± 23.4% ($P < 0.001$). The control group scores pre- to postintervention were not significantly different (37% ± 17% versus 46% ± 23.7%; $P = 0.22$).

Pretest and posttest scores were also compared across the intervention groups. There was no statistical difference between pretest scores for the 3 groups by ANOVA. There was a statistically significant difference between posttest scores for the monitored intervention group and the control group ($P = 0.03$) but no statistical difference between posttest scores for the monitored versus unmonitored intervention group ($P = 0.826$).

### Proficiency by PGY Level

For this proficiency analysis, the study participants were divided into 3 subgroups based on their current

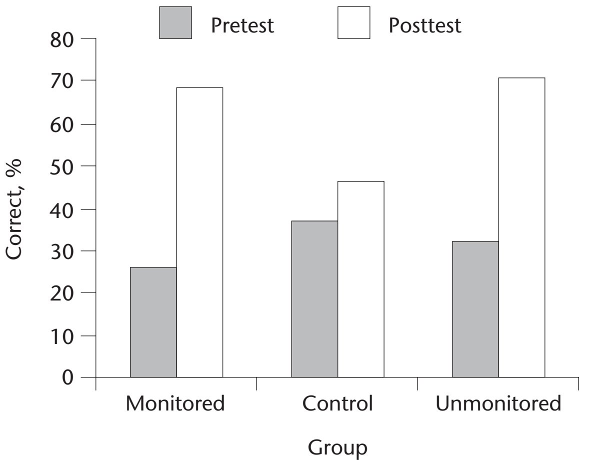


**Figure 1.** Change in proficiency of cardiac auscultation by study group.

year of training. There were 18 PGY-1 residents, 11 PGY-2 residents, and 10 PGY-3 residents (the chief resident was not included in this analysis). Post-posttest scores of the control group were incorporated into this analysis. Pretest and posttest scores for the 3 PGY groups are shown in **Table 2** and compared in **Figure 2**.

The pretest scores between the 3 subgroups were not statistically different as determined by ANOVA. There was a major improvement in the mean proficiency scores at each level of training after the intervention. Interestingly, when posttest scores between PGY-1, PGY-2, and PGY-3 residents were compared using ANOVA, the postintervention results were equal among all residents regardless of the level of training.

## Discussion

In this controlled intervention study, medical residents who had the opportunity to use an electronic stethoscope to listen repeatedly to 6 electronically simulated cardiac murmurs demonstrated significant improvement in their ability to recognize recordings of human heart sounds. The improvement in proficiency occurred independent of the level of training and regardless of whether the resident's use of the stethoscope was supervised. This study suggests a novel approach that clinical trainees can use to improve their proficiency in identifying cardiac murmurs commonly heard in inpatient and outpatient settings.

We found that cardiac auscultation skills appear to be independent of clinical experience. The subgroup analysis showed that the level of training did not influence proficiency, which was low in all trainees, and that major improvements can be attained at all levels of training. Other studies have found that cardiac examination skills do not change or improve as a function of years of training [6,7]. Given current barriers to developing proficiency in cardiac auscultation during clinical training and evidence that proficiency is unlikely to improve once in practice, electronic stethoscopes hold promise as a lifelong learning tool by which physicians can improve their ability to accurately identify common cardiac murmurs. Improving skills in cardiac auscultation could have a significant impact on the quality of patient care. For example, a prompt diagnosis of acute aortic regurgitation in a dyspneic patient could lead to more specific diagnostic testing and prompt surgical consultation. Correct identification of innocent systolic murmurs could be cost-effective by allowing for less utilization of cardiac echocardiography. Improving patient care is the mission not only of the ACGME [2] but of each trainee who wants to become a skillful clinician.

Barrett and colleagues [10,11] have demonstrated that intensive repetition is effective in helping medical students achieve proficiency in cardiac auscultation. Although an effective method for mastering cardiac auscultation, the classroom style of learning by repetition is time consuming and impractical for trainees who have excessive time demands and whose hours must be kept within the 80-hour work week limit. In addition, a limited number of patients with classic findings are available and healthy enough to endure the long hours required for trainees to learn these key heart sounds. If each trainee requires an average of 10 minutes to learn a specific murmur, patient availability would severely limit learning.

Our experience suggests that self-directed learning with an electronic stethoscope that serves as a patient simulator may help overcome some of the barriers to repetitive training. Because these devices can record and store auscultated sounds or can store preprogrammed sounds that mimic the classic murmurs, trainees can listen repeatedly to clinically relevant heart sounds whenever and wherever it is convenient and for as long as needed to develop proficiency in recognizing these murmurs. Although our study did not evaluate the use of electronic stethoscopes for teaching purposes, we believe—as others do [19]—that the electronic stethoscope could be a useful teaching tool for ensuring that accurate information is obtained on physical examinations. For example, electronic stethoscopes can serve as a database of normal and abnormal heart sounds that are available

**Table 2.** Change in Proficiency by Postgraduate Year (PGY)

| Group | Participants, *n* | Pretest Proficiency, % (SD) | Posttest Proficiency, % (SD) | *P* Value |
|---|---|---|---|---|
| PGY-1 | 18 | 28.3 (18.2) | 64.4 (29.4) | ≤ 0.001 |
| PGY-2 | 11 | 28.3 (16.6) | 75.5 (14.4) | ≤ 0.001 |
| PGY-3 | 10 | 36 (16.5) | 75 (15.8) | ≤ 0.001 |

to the trainee for immediate comparison with sounds auscultated at the bedside or for review later with a mentor [20].

At present, there are limited studies examining the use of electronic stethoscopes for teaching or improving skills of cardiac auscultation. Lam et al [21] recorded human heart sounds onto electronic stethoscopes during the SARS (severe acute respiratory syndrome) outbreak in order to train medical students in cardiac auscultation when direct patient contact was severely limited. Accuracy of auscultatory diagnoses by students in relation to amount of learning exposure was measured, and an improvement was found in mean scores among the students. In a subsequent study by the same authors, physicians were asked to identify 10 cardiac sounds played on an electronic stethoscope [22]. A decline in auscultation skills was shown as a function of years out from graduation. The authors suggested that the electronic stethoscope is a valid teaching tool at the trainee or attending physician level in improving cardiac auscultation skills. Høyte et al [23] found no difference in cardiac auscultation proficiency in third-year medical students who used an electronic stethoscope versus a conventional acoustic stethoscope during cardiac auscultation training, but these students did not receive repetitive training.

While we believe that our study suggests a novel use of electronic stethoscopes for improving cardiac auscultation skills, there are limitations to our conclusions that deserve mention. First, all participants were volunteers, so there is the possibility of selection bias. Whether the same results would be obtained in all resident cohorts is unknown. Second, we had no independent corroboration that the unmonitored group actually listened to the full 500 repetitions of each murmur, although the residents stated that they had done so at the posttest. Whether these residents used the stethoscopes in a different way to learn or practice recognizing the murmurs is also unknown. Third, our study did not examine whether the improvement in posttest scores persisted or if proficiency changed over time. It also is unknown whether continued exposure

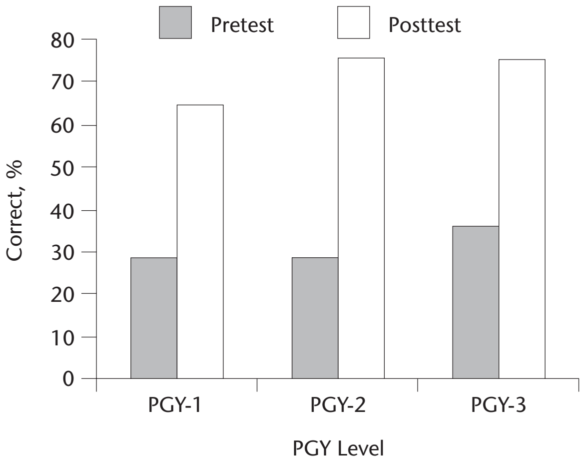


**Figure 2.** Change in proficiency of cardiac auscultation by postgraduate year (PGY) of training.

could lead to further improvements. These are important questions for a future study. Finally, whether recognizing human heart sounds on a test predicts performance with actual patients is unknown at this time. Future studies confirming these results in actual patients would be helpful.

## Conclusion

In conclusion, this study shows that improvement in cardiac auscultation skills can be achieved through repetitive training using an electronic stethoscope. Whether a physician is still in training, is an attending, or has been in practice for years, improvement in proficiency can be achieved on an independent basis.

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