Teaching Cardiac Auscultation Using Simulated Heart Sounds and Small-group Discussion

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Background and Objectives: *Several educators have reported poor identification of abnormal cardiac sounds by primary care residents. Practice and review with cardiology patient simulators and prerecorded heart sounds has been shown to increase the accuracy of diagnosis by medical students and residents.* Methods: *The participants were 15 members of an urban family practice residency. The residents were presented with simulated heart sounds and were asked to identify them in a pretest and posttest. Between the tests, participants were invited to three separate teaching sessions that involved a discussion of cardiac auscultatory findings and a review of audiotaped similar heart sounds. Residents who were unable to attend the teaching sessions formed a control group.* Results: *The pretest identification rate was 36% for the heart sounds. This improved to 62% for all residents after the intervention. Higher rates of improvement were demonstrated by the residents who attended one or more teaching sessions, compared with the residents who attended no teaching sessions.* Conclusions: *Small-group discussion and repetitive auscultation of simulated heart sounds can improve the cardiac auscultatory proficiency of family practice residents.*

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The physical examination of patients is integral to family practice. Cardiac auscultation is a particularly important part of the physical examination. In expert hands, assessment of cardiac pathology via auscultation correlates highly with the results of echocardiography or angiography at a fraction of the cost and with no risk to the patient.[1] Cardiac auscultation also allows for physical contact between patient and physician, which forms a bond that cannot be replicated with diagnostic machinery.[2,3] For these reasons, medical educators have placed significant emphasis on the value and clinical importance of cardiac auscultation. Nonetheless, one survey found that only 27.1% of internal medicine programs and 37.1 % of cardiology programs had structured teaching of auscultation.[4]

Several authors have reported poor auscultatory ability among residents. A study of 453 primary care residents and 88 medical students revealed an overall correct identification rate of 20% for prerecorded, abnormal heart sounds. There was little difference in overall scores among internal medicine residents, family practice residents, and medical students.[3] An earlier study of 187 internal medicine residents and 16 cardiology fellows had median identification rates of 21.9% for cardiology fellows and 19.3% for internal medicine residents.[4] Internal medicine residents who were tested on mannequins that mimic non-auscultatory examination findings, such as pulse and blood pressure, as well as simulated heart sounds, had identification rates as high as 54%.[5] Pediatric residents tested with the same type of mannequins had average identification rates of 33% for five common pediatric auscultatory findings.[6]

Improvements in diagnostic ability have been demonstrated by medical trainees who studied audiotapes of cardiac pathology and by students who received systematic instruction and practice with simulated heart sounds.[3,7] Fourth-year medical students who practiced auscultation with a simulator mannequin had higher scores on a written cardiology test and improved bedside examination, compared with peers who did not practice auscultation with the simulator.[8]

This paper details the development of a program to teach cardiac auscultation skills to family practice residents. The primary purpose of the program was to educate residents about auscultatory skills to improve their

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confidence and diagnostic ability. Data on resident performance were collected to quantify any improvement made by residents who participated in the program and to correlate improvement in diagnostic skills with exposure to various teaching modalities.

Methods

Setting

This study was conducted as part of a teaching intervention in an urban family practice residency program. The residency program was located in a 220-bed community hospital in a large, Midwestern city. At the time of the study, there were 18 residents in the program. The study was conducted during the months of February and March.

Subjects

All family practice residents in the program were invited to attend a series of small-group discussions about cardiac auscultation, preceded and followed by self-evaluation exercises. Three residents were unable to attend the teaching sessions due to rotations away from the residency site. Fifteen residents were evaluated during the exercise (five residents from each of the 3 postgraduate years (PGY) of family practice training).

Educational Intervention

The educational intervention was a series of three discussions that took place on consecutive weeks during time reserved for academic lectures. Each session lasted approximately 45 minutes. At the first session, we reviewed the "unknowns" from the pretest, with a focus on comparing and contrasting various similar heart sounds. In the second session, we discussed extra systolic and diastolic sounds. The third session covered murmurs.

During each session, the sounds were played for the residents. The discussion was directed to how one arrives at a correct diagnosis for each sound. Key components of each murmur or heart sound were identified during the teaching session, focusing on characteristic findings that physicians use to reach a diagnosis.[5] Residents were also instructed on how to identify different cardiac sounds by their pitch, timing, characteristic sound, location of maximal intensity, and response to diagnostic maneuvers. The pathophysiology responsible for each sound was discussed as well. Residents were informally tested during these sessions, and their responses to testing were discussed by the group. The content of the teaching session was based on the experience of the author, with additional input from family medicine faculty and a text about cardiac auscultation.[9]

The heart sounds that were tested and discussed are shown in Table 1, using examples drawn from *Rapid Interpretation of Heart Sounds and Murmurs, Fourth Edition* by Stein and Delman[9] and *Understanding Heart Sounds and Murmurs With an Introduction to Lung Sounds*, *Third Edition* by Tilkian and Conover.[10] The heart sounds from these sources were produced by a Cardionics CardioSim Digital Heart Sound Simulator® (Cardionics, Inc, Houston) and included on audiocassettes accompanying the texts. The cassette tapes were played on a standard commercial portable home stereo system. The participants were encouraged to listen with their stethoscopes to each sound over the speakers. Permission to use these sources was granted by the respective publishers and by Cardionics, Inc.

The heart sounds selected for discussion and testing were determined by the author. The decision about which sounds to include was based on sounds used in other published reports about auscultation and other cardiac sounds that seemed clinically relevant. In prior reports, Mangione and Nieman[3] and Mangione et al[4] used 12 different sounds, 8 of which were included in the curriculum reported here (mitral regurgitation [MR], aortic stenosis [AS], aortic insufficiency [AI], mitral stenosis [MS], patent ductus arteriosus [PDA], fourth heart sound [S4], third heart sound [S3], and mid-systolic click [MSC]). The other four sounds tested in the above-mentioned studies, but not in our curriculum, were the murmurs of combined AS and AI, the pericardial friction rub, a lone opening snap, and an early systolic click. Sounds not included in prior reports but used in our curriculum were the split second heart sound (split S2), fixed S2, hypertrophic obstructive cardiomyopathy accentuated by the Valsalva maneuver (HOCM), innocent systolic murmur (ISM), mitral valve prolapse with clicks accentuated by left lateral recumbent position (MVP) (essentially another version of MSC), and S3+S4. The same examples were used in the pretest, posttest, and discussion sessions.

Evaluation

Initial information regarding past use of recorded heart sounds was collected from each resident. All 15 residents were given a pretest. In the pretest, the participants were required to identify 14 cardiac auscultatory findings as represented by recordings of simulated heart sounds (Table 1).

The cardiac sounds for the pretest were played in a random order. The participants gave a written diagnosis for each unknown sound. Each sound was played for approximately 60–90 seconds; sounds were repeated as needed.

Test results were scored by the author and another family medicine faculty member. A correct answer received full credit, whereas half credit was given for answers that were partially correct or answers that contained the full correct answer but additional incorrect information.

Table 1

Simulated Heart Sounds Used in the Educational Intervention and Evaluation

Heart Sound	*Abbreviation*	*Source (See References)*
1. Physiologic splitting of the second heart sound	Split S2	Stein and Delman[9]
2. Fixed splitting of the second heart sound	Fixed S2	Stein and Delman[9]
3. Third heart sound	S3	Stein and Delman[9]
4. Fourth heart sound	S4	Stein and Delman[9]
5. Quadruple rhythm	S3+S4	Stein and Delman[9]
6. Mid-systolic click	MSC	Tilkian and Conover[10]
7. Aortic stenosis	AS	Stein and Delman[9]
8. Innocent systolic murmur	ISM	Stein and Delman[9]
9. Mitral stenosis	MS	Stein and Delman[9]
10. Patent ductus arteriosus	PDA	Stein and Delman[9]
11. Mitral regurgitation with S3	MR	Tilkian and Conover[10]
12. Aortic insufficiency	AI	Tilkian and Conover[10]
13. Hypertrophic obstructive cardiomyopathy accentuated by the Valsalva maneuver	HOCM	Stein and Delman[9]
14. Mitral valve prolapse with clicks accentuated by left lateral recumbent position	MVP	Stein and Delman[9]
15. Pulmonic ejection sound*	PES	Stein and Delman[9]
16. Aortic ejection sound*	AES	Stein and Delman[9]
17. Opening snap of mitral stenosis*	OS	Stein and Delman[9]

* Used only in the educational intervention, not tested in evaluation component

During the 2 weeks following the teaching intervention, a posttest was given to the residents. The posttest contained the same heart sounds as the pretest. The cardiac sounds were again presented in a random order. The answers to the posttest and pretest were scored simultaneously to improve consistency of grading. After the posttest, the residents were asked to complete an exit questionnaire, which asked whether they studied supplemental material or reviewed heart sounds outside the teaching sessions.

Experimental and Control Groups

Attendance by all residents at each session was encouraged from the beginning of the project. Clinical responsibilities and duties away from the residency site made complete attendance impossible. Those who were able to attend the teaching sessions formed the intervention group, while those who did not attend formed an informal control group.

Data Analysis

Mean scores for all residents and each subgroup were computed, along with standard deviations. Improvements in posttest scores were analyzed for statistical significance using *t* tests for paired data. Comparisons among groups of residents on the pretest and posttest were done with an ANOVA test. The *t* test for unpaired data was used to compare the results between two groups on the pretest and posttest.

Table 2

Results of the Pretest and Posttest

Mean Score (+/- SD) Out of a Possible 14 Correct and Percentage

Group	*Pretest*	*Posttest*	*Improvement*	P *Value*
All residents	5.0 (2.24)=36%	8.7 (3.46)=62%	+3.7 (26%)	<.005
PGY-1	4.0 (1.87)=29%	6.0 (2.74)=43%	+2.0 (14%)	NS
PGY-2	4.7 (1.15)=34%	9.1 (3.25)=65%	+4.4 (31%)	<.05
PGY-3	6.3 (3.03)=45%	11.1 (1.56)=79%	+4.8 (34%)	<.005
Teaching sessions				
0	5.3 (1.26)=38%	5.9 (2.84)=42%	+.6 (4%)	NS
1	6.0 (1.87)=43%	9.4 (2.46)=67%	+3.4 (24%)	<.005
2	4.3 (3.77)=31%	9.4 (3.57)=67%	+5.1 (36%)	<.05
3	4.3 (1.44)=31%	10.8 (3.01)=77%	+6.5 (46%)	<.05
Did not study texts (10 residents)	5.3 (2.4l)=38%	9.2 (3.56)=66%	+3.9 (28%)	<.005
Studied texts (five residents)	4.5 (2.00)=32%	7.9 (2.68)=56%	+3.4 (24%)	<.05
Did not study course material (nine residents)	5.2 (2.40)=37%	8.9 (4.04)=64%	+3.7 (27%)	<.005
Studied course material (six residents)	4.7 (2.14)=34%	8.5 (1.84)=61%	+3.8 (27%)	<.05

SD—standard deviation
PGY—postgraduate year
NS—not significant

Table 3

Ranking of Heart Sounds by Percentage of Correct Responses

PRETEST			POSTTEST		
1.	AS	90%	1.	S3+S4	90%
2.	Split S2	69%	2.	Fixed S2	90%
3.	S3	60%	3.	AS	87%
4.	S3+S4	50%	4.	Split S2	87%
5.	Fixed S2	50%	5.	PDA	87%
6.	S4	37%	6.	MVP	67%
7.	MVP	37%	7.	S4	60%
8.	MR	30%	8.	S3	53%
9.	AI	27%	9.	HOCM	47%
10.	MS	20%	10.	ISM	47%
11.	MSC	20%	11.	MS	43%
12.	PDA	13%	12.	MSC	43%
13.	HOCM	7%	13.	MR	37%
14.	ISM	0%	14.	AI	37%

See Table 1 for definitions of abbreviations.

Results

Pretest Results

No residents reported that they reviewed audiotapes or other recordings of heart sounds during the project. Only one resident had previously used either of the sources for simulated heart sounds used in this project but had not done so within the past year. One resident had completed a cardiology elective prior to the intervention.

Results from the pretest are shown in Tables 2 and 3. The overall mean rate of identification was 5 of 14 sounds (36%) on the pretest. Mean scores on the pretest were higher among residents at higher levels of training, but the differences were not statistically significant. There was also no statistically significant difference in pretest scores between residents who studied course material or texts and those who did not. There was not a statistical difference in pretest scores among the residents who subsequently attended different numbers of teaching sessions, with the lowest-scoring residents subsequently attending more sessions. Aortic stenosis was the most accurately identified sound, and the innocent systolic murmur was the least accurately identified sound on the pretest.

Posttest Results for the Experimental Group

Results of the posttest are shown in Tables 2 and 3, and results of the posttest questionnaire are shown in Table 4. The mean posttest score for all residents was 8.7 correct identifications out of 14 (62%). The posttest scores for residents attending three teaching sessions (10.8 out of 14 or 77%) were higher than the posttest scores for residents attending one or two sessions (9.4 correct in each group or 67%). Posttest scores for residents who studied cardiology texts or the course material, however, were not significantly higher than scores for residents who did not. On the posttest, the S3+S4 gallop, fixed S2, AS, split S2, and the PDA were each identified at least 87% of the time. Recognition of AI and MR was poor on the posttest (37%).

Statistical Significance for Pretest and Posttest Scores Among Participants

Participants who attended at least one teaching session displayed a statistically significant increase in scores from pretest to posttest. The largest improvement, and highest posttest score, was made by the residents who attended three sessions. Their scores increased from 4.3 to 10.8, an improvement of 46% (P<.05). The residents who attended one or two sessions had the same mean score on the posttest, 9.4 (67%). Since the residents who attended two sessions scored lower on the pretest, their improvement of 36% was superior to the 24% improvement by the residents who attended one session. There were no statistically significant differences between posttest scores for the residents who attended one, two, or three sessions.

Posttest Results for the Control Group and by Residency Class

Residents in the control group (0 teaching sessions) showed a modest, statistically insignificant improvement from the pretest to the posttest. They improved from 5.3 sounds correctly identified on the pretest to 5.9 on the posttest, a 4% improvement.

Each class improved on the posttest, with an increase of 14% in the PGY-1 class, 31% in the PGY-2 class, and 34% in the PGY-3 class. The PGY-3 class scored significantly higher than the PGY-1 class on the posttest.

Table 4 gives the mean PGY of each of the teaching session groups. There was no statistically significant difference in mean PGY year among the various teaching session groups.

Posttest Results for Experimental and Control Groups

The posttest score for those who attended three sessions was significantly higher than the posttest score for those who attended 0 sessions (P<.05). When compared to the 0-session group, the one- and two-session groups had posttest scores that approached, but did not reach, statistical significance at the P<.05 level (P<.10).

Discussion

The performance of family practice residents on the pretest portion of this project compares favorably to what has been reported by other investigations using a similar set of heart sounds. Overall, the scores obtained by resident trainees in those studies were 19%–20% correct.[3,4] Participants in this study identified 36% of the sounds presented to them on the pretest. They also identified 36% of the eight sounds used in the other, larger studies.[3,4]

In this study, cumulative posttest scores were significantly higher for PGY-3 residents, compared with PGY-1 residents. The higher pretest scores of PGY-3 residents approached statistical significance as well. Other studies of internal medicine and family practice trainees have not shown improved cumulative scores for senior residents, although the ability to identify some auscultatory findings did improve with advanced training.[3-5] A study of pediatric residents displayed a trend toward improved cumulative performance by senior residents, but it was not statistically significant.[6] Superior performance by senior residents probably did not cause the improvement in posttest scores by the experimental groups, because the experimental and control groups had similar mean PGYs (Table 4).

It may be that upper-level residents in our program were getting additional training or practice in auscultation that was not monitored in this test. Physical examination skills receive great emphasis in the residency program where this study was conducted, and additional years of auscultatory training in such a setting could be expected to enhance examination proficiency.

Studying textbooks and course material seemed to have little effect on residents' scores on the test. Other educators have also noted that teaching auscultation with texts or lectures does not improve diagnostic accuracy; only use of audiotapes improves auscultatory performance on an unknowns test.[3] It has been justifiably argued that there is probably too much didactic teaching of auscultation instead of actual auditory teaching, especially since cardiac auscultation skills seem to be learned in a manner different than other skills in medicine.[3,7]

Limitations

It is difficult to draw broad generalizations from the study because it involved only 15 participants, all from the same residency program. Any findings that were not statistically significant may have been due to the low power of the study.

A second limitation is that the sounds used in this study were from a simulator and not patients. As such, the sounds did not all sound completely genuine. Residents may be able to perform better in actual clinical situations than on simulations, though tachycardia and distant heart sounds can make identification more difficult in clinical situations than in the classroom. The simulated sounds in this study were played at a constant speed and volume.

A third limitation is that the same sounds were used in both the pretest and posttest sessions. Had we used different sounds, it would have allowed an internal control and made the data more reliable. Further, the duration of the improvement, beyond the 5 weeks of the program, cannot be determined from these findings. Finally, randomization of the experimental and control groups would have improved the validity of the data, since the control group was not a matched or randomly selected sample.

Directions for the Future

Several options are possible for future work in this area. Repeating the study with more participants, and perhaps more teaching sessions, would help validate the findings. Comparing scores for simulated heart sounds with the ability to identify heart sounds in patients would be illustrative as well. Examining the

Table 4

Resident Groups Separated by Number of Teaching Sessions Attended and Whether Residents Studied Texts or Course Material

	Teaching Sessions Attended	*# of Residents*	*PGY of Residents*	*Mean PGY (SD)*
	0	4	1,1,2,3	1.8 (.96)
	1	4	1,2,2,3	2.0 (.82)
	2	4	1,3,3,3	2.5 (1.00)
	3	3	1,2,2	1.7 (.58)
Residents who did not study texts		10	1,1,1,2,2, 2,3,3,3,3	2.1 (.88)
Residents who studied texts		5	1,1,2,2,3	1.8 (.84)
Residents who did not study course material		9	1,1,1,1,2 2,3,3,3	1.9 (.75)
Residents who studied course material		6	1,2,2, 2,3,3	2.2 (.75)

PGY—postgraduate year
SD—standard deviation

duration of the improvement from the teaching intervention would also be useful. The effect of booster doses of auscultation training on residents' ability to identify heart sounds would allow educators to effectively time teaching interventions during residency training.

Conclusions

Participation in small-group sessions involving discussion and repetitive auscultation of audiotaped heart sounds can improve residents' ability to identify audiotaped heart sounds. There was a dose-response effect, whereby residents attending more sessions had more improvement in performance.

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