Mastering Cardiac Murmurs*

The Power of Repetition

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Background: The ability of medical students to recognize heart murmurs is poor (20%), and does not improve with subsequent years of training. A teaching method to improve this skill would be useful.

Study objectives: To determine whether intensive repetition of four basic cardiac murmurs improves auscultatory proficiency in medical students.

Design: Controlled intervention study.

Subjects: Fifty-one second-year medical students in an east coast medical school.

Interventions: Subjects were classified into three groups: (1) a monitored group, who listened to 500 repetitions of each murmur in a monitored setting, (2) an unmonitored group, who listened to 500 repetitions of each murmur in an unmonitored setting, and (3) a control group. All three groups were tested using a pretest and posttest methodology.

Measurements and results: The 20 subjects in the monitored group improved from 13.5 ± 9.8 to 85 ± 17.6% following the intervention (mean ± SD). Similarly, 21 students in the unmonitored group improved from 20.9 ± 10.9 to 86.1 ± 15.6%. Ten control students showed no significant improvement (24 ± 21.7 to 32 ± 22.3%). The differences between the two intervention groups and the control subjects was significant at p < 0.001 by analysis of variance.

Conclusion: Five hundred repetitions of four basic cardiac murmurs significantly improved auscultatory proficiency in recognizing basic cardiac murmurs by medical students. These results suggest that cardiac auscultation is, in part, a technical skill. (CHEST 2004; 126:470–475)

Key words: cardiac murmurs; heart auscultation; medical students; teaching

Abbreviations: ANOVA = analysis of variance; AR = aortic regurgitation; AS = aortic stenosis; CD = compact disk; MR = mitral regurgitation; MS = mitral stenosis

The standard approach in teaching cardiac auscultation consists of a 1- or 2-h classroom lecture. However, the results of this teaching method have been disappointing. Numerous authors1-2 have demonstrated that the ability of medical students to recognize common cardiac murmurs is poor (approximately 20%). We hypothesized that the recognition of cardiac murmurs is a technical skill that, like learning to tie surgical knots, requires repetition.3 To test this hypothesis, we studied the effect of 500 repetitions of four murmurs of left-sided valvular lesions on the proficiency of murmur recognition by medical students.

Materials and Methods

Subjects

The study protocol was reviewed by the Drexel University Institutional Review Board, which found it to be a teaching practicum requiring only the approval of the Chair of the Department. Accordingly, the study protocol was approved by the Chairman of the Department of Internal Medicine. Initially, 71 second-year medical students in an urban, east coast medical school were chosen as subjects. We studied second-year medical

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470 Clinical Investigations
students because of their common experience with cardiac auscultation, which comprised a 2-h lecture on cardiac auscultation early in their second year, and limited patient experience during their first and second years. The interventions occurred within 2 to 6 months after the lecture on auscultation. All subjects were volunteers.

**Study Design**

This was a controlled intervention trial using 59 intervention subjects and 12 control subjects. All subjects had the same exposure to cardiac auscultation prior to the study, namely a 2-h lecture with demonstration of abnormal heart sounds. The study took place over two semesters, and the subjects were enrolled sequentially. The first 21 subjects were assigned to the monitored group and attended six 1-h monitored sessions where they listened to 500 repetitions of each type of murmur. The next 12 subjects were assigned to the control group and received no instruction in cardiac auscultation during the study. The final 38 subjects were assigned to the unmonitored group, and they listened to the same number of repetitions of heart sounds in an unmonitored setting on their own time.

All subjects were tested prior to and following their respective intervention using the same set of recorded heart sounds. Finally, both intervention groups as well as the control subjects were instructed not to listen to recordings of heart sounds outside of the study. Because previous studies have demonstrated a median of 20% accuracy in murmur recognition, any subject in the three groups who scored ≥ 60% accuracy on the pretest was analyzed separately.

**Interventions**

The intervention for the monitored group consisted of a total of six 1-h monitored sessions held over the course of 1 month. For training purposes the murmurs of mitral regurgitation (MR), aortic stenosis (AS), aortic regurgitation (AR), and mitral stenosis (MS) were generated by a heart sound simulator (Cardionics; Webster, TX) and recorded on compact disks (CDs). Each type of murmur was digitally optimized to represent a classic example of the lesion under study; for example, the murmur of mitral regurgitation was plateau shaped and holosystolic. Each CD contained 50 repeats of one type of murmur interspersed with clinically relevant comments such as the location, timing, and shape of that murmur. These segments were repeated five times until a total of 250 repetitions of each murmur was played. This process was followed for each of the four pathologic murmurs. These CDs were played on a portable stereo system in a classroom. The entire procedure was then repeated until a total of 500 repetitions was played for each of the four murmurs. Sessions were held during the morning before classes to facilitate attendance, and subjects received a stipend for attending all sessions.

For the unmonitored group, the intervention consisted of listening to the same four murmurs (MR, AS, AR, and MS) repeated 250 times each with clinically relevant comments on a single 1-h CD. The subjects were required to listen to the entire CD at least two full times on their own in the space of 1 month to be eligible for inclusion. We relied on the subjects' self-report of the number of times they listened to the CD. There was no stipend for the unmonitored group since their time commitment was significantly smaller than that of the monitored group. We anticipated a higher dropout rate in this group and increased recruitment accordingly.

For the control group, subjects were required to complete both the pretest and posttest in a 1-month time frame for inclusion in the analysis. No stipend was available for the control subjects.

**Proficiency Tests**

Two tests of auscultatory proficiency were administered to all subjects during this study. The first was a pretest before any intervention. The second was a posttest after completion of their respective interventions. Each test consisted of 10 heart sounds played in random order. Subjects were asked to identify the timing of the sound (systolic or diastolic) and the name of the murmur on blank answer sheets.

Subjects were tested against the four pathologic murmurs as well as an innocent (nonpathologic) systolic murmur and normal heart sounds. Each murmur was used twice, and the normal sounds were used once each, for a total of 10 sounds on each test. The heart sounds used on the tests were the same sounds as on the CDs. The order of the test sounds was randomly altered for each test using a random-numbers table. A cardiologist (M.J.B.) reviewed and scored each test. Correct responses were tabulated separately for the timing of the sound and the identification of the murmur. To assess the transferability of these results to human heart sounds, a subset of the last 10 subjects assigned to the monitored group was also tested against recordings of human heart sounds (supplied courtesy of Dr. Sal Mangione).

**Statistics**

Data were entered into an Excel spreadsheet (Microsoft; Redmond, WA), checked, and read into SPSS Version 11 (SPSS; Chicago, IL) for statistical analysis. Basic descriptive statistics, including a measure of skew to assess normality, were obtained for all measures and for pretest and posttest differences. Since most of the variables demonstrated substantial skew—defined here as the absolute value of skewness statistic as >0.6 in at least one subgroup—all analyses were done using nonparametric tests.

Accordingly, we chose a Kruskal-Wallis analysis of variance (ANOVA), a nonparametric test to compare the three groups at pretest. To compare changes between the three groups, differences between the pretest and posttest scores were calculated for all measures. These differences were then compared between groups using a Kruskal-Wallis rank ANOVA. Significant Kruskal-Wallis ANOVAs were then followed with Bonferroni adjusted Mann-Whitney U tests to compare two groups. For these latter tests, the actual p values are reported. The Bonferroni adjustment requires that each p value be ≤ 0.05/3 = 0.0167 for significance.

To explore an ad hoc observation that the recognition of systolic murmurs and diastolic murmurs appeared to differ at the pretest level, a Wilcoxon test was performed comparing the mean score of AS and MR to the mean score of AR and MS across all 51 subjects. A Wilcoxon test was also performed to detect a change in the control subjects' ability to recognize MS on the posttest.

**Results**

All 21 subjects assigned to the monitored group completed the protocol; however, one subject scored ≥60% on the pretest on murmur identification and was excluded from the analysis, leaving 20 subjects in this group. Of the 38 students assigned to the unmonitored group, 5 subjects did not complete the posttest, 8 subjects did not listen to the CD two full times, and 4 subjects scored ≥60% on the pretest for murmur identification. These 17 subjects were excluded from the analysis, leaving 21 subjects in this
group. The 21 subjects in this group listened to the CD an average of 2.3 times. In the control group, 2 of 12 subjects did not complete the posttest, leaving 10 subjects available for analysis. At completion a total of 51 subjects were included in the analysis.

Murmur Recognition

There was a significant difference between the three groups in the change in the recognition of murmurs between the pretest and posttest scores \((p < .001)\) by Kruskal-Wallis ANOVA. The 20 subjects in the monitored group scored an average of 13.5 ± 9.8% correct on the pretest and 85 ± 17.6% correct on the posttest in the identification of murmurs (mean ± SD). This change was significant compared to control subjects by a Mann-Whitney \(U\) test \((p < 0.001)\). The 21 subjects in the unmonitored group scored an average of 20.9 ± 10.9% correct on the pretest and 86.1 ± 15.6% on the posttest. This change was also significant at \(p < 0.001\) compared to control subjects by a Mann-Whitney \(U\) test. The control subjects scored an average of 24 ± 21.7% correct on the pretest and 32 ± 22.5% on the posttest \((p = 0.59)\). The pretest scores did not differ significantly between the three groups \((p = .139)\). There was no significant difference in the improvement between the monitored group and the unmonitored group by the Mann-Whitney \(U\) test for murmur recognition \((p = 0.191)\) [Fig 1].

The four subjects in the unmonitored group and the one subject in the monitored group who scored ≥ 60% on the pretest also demonstrated significant improvement from 72 ± 8.3 to 98 ± 4.5% \((p < 0.005)\). The results of the subset of 10 subjects in the monitored group when tested against human heart sounds revealed a sixfold improvement from 9 ± 8.7 to 60 ± 27.5%. These results, although somewhat lower than the subjects’ score on the standard test sounds \((12 ± 11.3\) to \(78 ± 20.9\%))\), were not significantly different \((p = 0.102)\). The five subjects in the unmonitored group and the two subjects in the control group who did not complete the posttest scored 21.4 ± 24.7% at pretest, which was not significantly different from the other subjects.

Timing Recognition

The three groups did not differ significantly at the pretest \((p = 0.664)\). The average accuracy across all three groups was 69% on the pretest in recognizing whether a murmur was systolic or diastolic. However, there was a significant difference between the groups in the change on this measure as well \((p = 0.025)\). The 20 subjects in the monitored group scored 64 ± 29% correct on the pretest and 95.5 ± 6.8% on the posttest. This change was significant at \(p = 0.011\) compared to the control subjects. In the unmonitored group, the average score for timing recognition was 68.5 ± 22.8% on the pretest and 94.7 ± 9.8% on the posttest. This change was
not quite significant at $p < 0.018$ compared to control subjects since the Bonferroni correction required the $p$ value to $< 0.0167$. The controls scored $75 \pm 16.4\%$ correct on the pretest and $80 \pm 11.5\%$ on the posttest ($p = 0.157$). There was no statistically significant difference in the improvement between the monitored group and the unmonitored group by the Mann-Whitney $U$ test for timing recognition ($p = 0.722$) [Fig 2].

**Individual Murmurs**

At pretest, the 51 subjects in the combined study sample were able to recognize the systolic murmurs of AS and MR ($26 \pm 24.4\%$) significantly better than the diastolic murmurs of AR and MS ($7.4 \pm 13.5\%$) [$p < 0.001$ by Wilcoxon signed rank test]. However, following the interventions, monitored and unmonitored subjects were able to recognize all four murmurs significantly better than control subjects. When the changes in the recognition of individual murmurs are analyzed by Kruskal-Wallis rank ANOVA, there was a significant difference between the three groups. Using a Mann-Whitney $U$ test, the changes in both the monitored and unmonitored groups were significantly greater than those in the control subjects ($p \leq 0.004$ for all murmurs) [Fig 3, top and middle]. Control subjects, however, had no statistically significant improvement in their ability to recognize the individual murmurs, but they did increase somewhat their ability to recognize MS from 5 to 30% ($p = 0.059$) [Fig 3, bottom].

**Discussion**

Our study demonstrates that 500 repetitions of four basic cardiac murmurs produced dramatic improvement in the ability of medical students to recognize cardiac murmurs. This intervention was effective whether the students listened to the repetitions in a monitored setting in a classroom or in an unmonitored setting on their own time. No significant improvement was seen in the 10 control subjects.

There has been concern among medical educators for many years that cardiac auscultation is an important clinical skill that is being lost.$^{5,6}$ Several authors$^{1,2,4}$ have reported deficiencies in cardiac auscultation among physicians and medical students. Results from a landmark study by Mangione et al$^1$ showed that the median rate of identification of 12 cardiac events was only 20% for medical students, 19% for medical residents, and 22% for cardiology fellows. This low level of proficiency changed little with years of training and was never better than that of third-year medical students. Nor was this poor performance in cardiac auscultation limited to physicians in training. Two studies of primary care physicians by Paauw et al$^7$ and Roy et al$^8$ found that attending physicians correctly identified $< 40\%$ of auscultatory findings. These findings suggest that effective teaching of cardiac auscultation during medical school is essential if this skill is to be acquired. However, the most effective teaching method has not been defined.
The standard approach in teaching cardiac auscultation consists of a 1- or 2-h classroom lecture. Alternative teaching interventions have included additional lecture-based courses,9 computer-assisted instruction,10 and a combination of discussion and audiotape.11 Two observations are apparent from these interventions. First, lecture-based teaching does not appear to improve recognition of cardiac sounds. As demonstrated by Mangione et al9 in a 9-month study of classroom lectures, there was no significant improvement in auscultation skills. Second, interventions that include repetition of heart sounds on audiotapes or other multimedia tools do improve auscultatory proficiency.8,11 For example, a study by Horiszy6 involving family practice residents showed a significant improvement in the identification of heart sounds after participation in small-group discussion and repetition of simulated heart sounds. Similarly, a study by Roy et al8 involving attending physicians found a significant improvement in cardiac auscultation skills after using a computer program with repetition of heart sounds. However, the number of repetitions of heart sounds was not quantified in these studies.

The fact that listening to heart sounds repetitively improves auscultatory proficiency is not surprising if one considers auscultation to be an auditory pattern recognition skill that is best learned through repetition rather than through didactic teaching. While a lecture format may be an effective means of learning pathophysiology, we believe auditory recognition requires intensive repetition to achieve proficiency. To our knowledge, no published data exist that explore the effect of quantitative repetition on cardiac auscultatory proficiency among medical students.

Our study demonstrates that 500 repetitions of four basic cardiac murmurs are sufficient to achieve proficiency in recognizing these basic cardiac murmurs. Whether fewer repetitions would be as effective was not evaluated in our study. However, it should be noted that, for the unmonitored group, this intervention required only 2 h to achieve proficiency in these four murmurs.

There were certain limitations to our study that may affect its application to the general medical student population. First, there was a possible selection bias in that all subjects were volunteers. These students may have had a special interest in cardiology or a desire to achieve mastery of cardiac auscultation. Second, because the study took place over two semesters, subjects were not randomized but allotted to the interventions sequentially, which is also a potential source of selection bias. However, we do not think that either of these possible selection biases significantly affected the results since we have obtained similar results in a group of nonvolunteer medical students who were randomly assigned to the intervention.12

Third, guessing at the correct responses may have occurred and influenced the results. Although we chose a blank answer sheet instead of a multiple-choice format in an attempt to minimize this effect, some medical students are exceptionally skilled at taking tests.

Figure 3. Top: Results by murmur in the monitored group. Middle: Results by murmur in the unmonitored group. Bottom: Results by murmur in the control subjects.
Fourth, the transferability of recognizing simulated heart sounds to the recognition of heart sounds in actual patients is not established. However, it seems to us that if students cannot recognize simulated heart murmurs, which tend to be clearer and louder than murmurs in patients, then there is little chance of their recognizing these murmurs in patients. We briefly assessed the transferability of these results by testing a subset of 10 subjects from the monitored group against human heart sounds. The results showed a sixfold improvement in recognizing human heart sounds, although the scores were slightly lower than those obtained with the standard test sounds. We believe the question of transferability of this skill is an important one and we plan to explore this question formally in future studies.

Finally, some may question the utility of learning cardiac auscultation at all in an age of readily available two-dimensional and Doppler echocardiographic studies. We believe, as others, that cardiac auscultation is a useful, cost-effective tool in the graphic studies. We believe, as others, 1,5,6 that cardiac auscultation is a useful, cost-effective tool in the initial evaluation of cardiac symptoms. Lembo et al13 and Etchells et al14 have presented persuasive evidence that cardiac auscultation, when properly performed, can be quite accurate in the diagnosis of a number of cardiac abnormalities.

Cardiac auscultation appears to be a compound skill requiring both a cognitive skill, namely a knowledge base of disease and a technical skill, which we termed auditory recognition, that is, the ability to recognize normal and abnormal heart sounds. We believe our findings represent a new paradigm in teaching cardiac auscultation. This new paradigm emphasizes the technical nature of auditory recognition and the need for repetition in achieving mastery of cardiac murmurs. A number of important questions remain to be answered. Will this method be as effective in teaching extra heart sounds and more complex murmurs? What is the retention of these skills over time? Most importantly, does proficiency in recognizing simulated heart sounds translate to more accurate bedside auscultation? The answer to these questions must await further research.

CONCLUSIONS

Our study demonstrates that 500 repetitions of four basic cardiac murmurs dramatically improved proficiency in recognizing cardiac murmurs by medical students. This effect was equally robust whether the students listened to the repetitions in a monitored setting in a classroom or in an unmonitored setting on their own time. No such improvement occurred in the control subjects. These results suggest that cardiac auscultation is, in part, a technical skill.

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