Beyond Heart Sounds: An Interactive Teaching and Skills Testing Program for Cardiac Examination

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Abstract

Cardiac examination and auscultation are skills that are not adequately taught in training programs, and as a result are poorly performed by trainees in internal medicine and cardiology. In an attempt to address these deficiencies, we have videotaped bedside physical findings along with stethoscopic heart sound recordings in over 100 patients with “classical” forms of heart disease, and have developed a series of interactive multimedia programs designed to be used in training programs for medical students and residents. The programs have tutorial as well as skills-testing content. Formal evaluation of the program’s ability to teach cardiac examination skills is under way. Preliminary results from third-year medical students before and after training with software showed a significant improvement (P=0.0001). After training, these students tested at the level of first-year cardiology fellows.

1. Introduction

Clinical skills at the bedside are in decline. Failure to recognize significant cardiac lesions by physical examination leads to adverse patient outcomes as well as unnecessary costs for inappropriate and even potentially hazardous laboratory tests. These well-documented deficiencies [1-7] have been attributed to lack of exposure to structured teaching in medical schools, and to the lack of availability of inpatients representing an appropriate spectrum of cardiac conditions with the shift to brief patient encounters in an ambulatory care environment.

While the best teaching experience remains at the bedside under the supervision of a knowledgeable and patient instructor, such opportunities are rare. Only one in four internal medicine residency programs offer any structured teaching in cardiac auscultation [8], and only one in three cardiology training programs do so [3].

As the pool of skilled clinicians trained in the era before echocardiography continues to age, the skill of cardiac auscultation is in danger of disappearing, for want of instructors to teach it.

2. Materials

Since the patient encounter itself is a multimedia experience of sights, sounds, and palpable pulsations, computer programs that employ audiovisual technology would appear to be ideally suited to this educational challenge.

But processing this information intelligently at the bedside requires an understanding of the underlying physiological mechanisms that produce them. By combining animation, video, and audio to illustrate how heart sounds, pressure, and motion are all interdependent, multimedia programs have the potential of explaining and portraying normal and pathologic conditions as they are manifested during the cardiac physical examination. Table 1 lists available multimedia hardware and software, two of which, the Heart Sounds Tutor and the Heart Sounds and Murmurs CD-ROM, were developed by two of the authors [9,10].

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Price</th>
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<tbody>
<tr>
<td>Harvey</td>
<td>$100,000</td>
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<tr>
<td>UMedic</td>
<td>$40,000</td>
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<tr>
<td>CardioSim</td>
<td>$25,000</td>
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<tr>
<td>Heart Sounds Tutor</td>
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<table>
<thead>
<tr>
<th>Software</th>
<th>Price</th>
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<tr>
<td>Ears On!</td>
<td>$195</td>
</tr>
<tr>
<td>Mastering Auscultation</td>
<td>$165</td>
</tr>
<tr>
<td>Heart Sounds and Murmurs</td>
<td>$150</td>
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<tr>
<td>Cardiax</td>
<td>$149</td>
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When evaluating potential teaching media, however, two features are important to consider:
- is there a visual timing reference provided with the sounds, either a pulse or ECG, to place what is heard in the correct phase of the cardiac cycle?
- does the program present real data or a simulation? If a simulation, how transferable is the simulation to bedside encounters?
2.1 Developing eye-ear coordination

Cardiac auscultation without using a timing signal to determine diastole and systole is bad clinical practice. It is often impossible to know whether a murmur is diastolic or systolic by sound alone. Hazarding a guess, while a common test-taking strategy for medical trainees, is a poor method for developing clinical skills.

Since most clinical skills training is taught with audio recordings only, it is understandable why so many medical trainees in a clinical setting fail to use the carotid or jugular venous pulse as a timing reference. Moreover, we have found that even when a visual clue is presented to the trainee, too often he or she sits with eyes tightly shut deep in concentration, attempting to memorize the cadence or pattern of the sounds presented.

It is not enough, then, simply to provide this timing signal; a good teaching program should compel trainees to integrate sight and sound to establish when systole occurs, and to use this signal to place what they hear in the correct phase of the cardiac cycle.

2.2 Risks associated with simulations

Most multimedia programs resort to simulated sounds, largely for two reasons: actual heart sounds are technically difficult to acquire, and actual heart rates are too fast for many beginners. Simply slowing down the playback speed of a patient’s heart sounds for the beginner also lowers the frequency, distorting the sound. By simulating the sound, (or in the case of the mannequin Harvey, simulating the whole patient), the program developer has the ability to create crystal-clear findings in a patient with a slow, steady heart rate.

The disadvantage of artificial patients is that they force the developer to choose what to leave out of the simulation. The Harvey simulation, for example, shows respiration which if incomplete, may introduce inaccuracies to the program.

2.3 Methods

In designing a new teaching program, our goals were

- to create a teaching and testing multimedia program that will play on mid-range personal computers
- to supplement these patient presentations with animated tutorials on anatomy, pulsations, sounds, and hemodynamics
- to evaluate the program at teaching institutions

Since 1995, a video archive of over 100 patients has been assembled. For each patient, the senior author (JMC) recorded all listening locations that provided diagnostic data. For example, if different sounds or murmurs could be heard with a change in listening area or stethoscope head, all were recorded. Where it was useful and possible for the patient to perform them, recordings were made during maneuvers such as stand/squat, handgrip, or Valsalva. Video sequences were long enough to capture changes that can occur with respiration (e.g. a split second sound, or Graham Steell murmur), or with premature ventricular contractions (e.g. augmentation of a murmur with the postextrasystolic beat).

Case-matched laboratory data were assembled and digitized using Adobe Photoshop, and patient videos were digitized using a MiroVideo DC30 video capture card, with secondary compression of the signal using the Intel Indeo 5.1 codec* for playback on a personal computer.

4. Results

The program contains diagnostic quality full-motion video scenes that permit simultaneous inspection and auscultation of patients and the ability to move the stethoscope to different listening areas as well as to change from close-up to wide-angle views. The requirement for full-motion video with audio-visual synchronization is critical to the success of this program as a teaching and testing tool. It is designed to run on entry-level computer systems available for under $900.

Each case includes:

- pertinent patient history
- chest X-ray and 12-lead electrocardiogram
- full-motion videos with simultaneous heart sounds
- extra videos of close-up shots of the neck or precordium to illustrate pulsations
- videos of patient extremities where appropriate†
- 10-15 multiple-choice questions on the physical examination of the patient and differential diagnosis
- full-motion echocardiogram
- hemodynamic/catheterization data where available
- detailed discussion of the diagnosis, explanation of the physical findings, the patient’s treatment, and follow up

* codec: compression-decompression routine
† e.g. videos of the brachial pulse to demonstrate Corrigan’s sign, videos of patient fingers to show cyanosis, clubbing, embolic phenomena
4.1 Interactive case presentations

Figure 1. The patient presentation interface is divided into three main areas, labeled in this figure a, b, and c. A: The video screen plays the appropriate scene when the user clicks on the diagram to the left. B: The chest diagram indicates that the stethoscope is over the second left intercostal space; clicking over a different circle on the chest will play a video scene from that listening area. C: The text area contains questions to be answered by the user, the review of physical findings, and the discussion.

4.2 Tutorials

Tutorials using animations, sounds, and text supplement the case studies. The topics of anatomy and the location of listening areas, use of the stethoscope, hemodynamics in health and disease, as well as arterial and venous pulsations are presented in an interactive format with explanatory text.

Figure 2. The hemodynamics tutorial shows the interrelation among ECG, pressures, sounds, and the motions of chambers and valves. The cutaway of left heart is animated, and synchronized with the sounds.

4.3 Sound Builder

It is often difficult to recognize an opening snap that occurs close to the second heart sound, or to hear the low frequency mid-diastolic rumble of mitral stenosis. To train the ears to distinguish closely timed sonic events, the sound builder (Figure 3) plays actual heart sounds in an infinite loop. A mid-systolic murmur can be toggled on and off to aid detection, or it can be compared with a midsystolic murmur without interrupting playback. The user can add and remove sounds and murmurs at will. Sounds that are similar in quality, but differ in temporal position can be compared: for example, an opening snap versus an ejection click. In the same manner, sounds that occur in the same temporal position, but differ in the quality of that sound, can be compared: for example, a third heart sound versus an opening snap.

Figure 3. The sound builder allows the user to construct complex combinations of sounds and murmurs from individual components. In this example, an opening snap, mid-diastolic murmur, and presystolic murmur have been added to first and second heart sounds to emulate mitral stenosis as it would be heard at the cardiac apex.

4.4 Program evaluation

To assess the program’s efficacy in auscultation instruction, formal evaluation is underway at the University of California, Los Angeles, School of Medicine. Third-year medical students beginning their inpatient medicine clerkship are tested during orientation; those who volunteer for instruction with software receive 90 minutes supervised instruction once a week for eight weeks. At the end of their rotation, students are tested once again.

The test consists of 50 multiple-choice or true-false questions on a computer, combined with animations, recorded sounds, and digital movies of patient examinations. Questions test the trainee’s general knowledge of
anatomy, physiology and pathophysiology as it pertains to cardiac examination, as well as testing their ability to make observations and draw meaningful conclusions from patient presentations.

Preliminary data on the first group of seven students show an improvement of mean test scores from 59 to 73. Despite this modest sample size, a paired t-test on the mean test scores was statistically significant for a two-tailed distribution ($P = 0.02$).

Figure 4. Trainees from third-year medical students (MS3) to third-year cardiology fellows (PGY6) were tested on cardiac auscultation skills in the first week of the academic year. MS3 students who underwent instruction with the software during their eight-week rotation were tested again at the end of their rotation (MS3 after software training). Comparing the mean test scores using $t$-tests that assume unequal variances and a two-tailed distribution, there was a statistically significant difference in each group when compared with the others, except for PGY5 and PGY6. Comparing MS3 students before and after training with software using a paired $t$-test and a two-tailed distribution showed a significant improvement ($P=0.02$). After training, these MS3 students tested at the level of first-year fellows.

5. Conclusion

Technical barriers to bringing video and sounds from actual patient encounters to the personal computer have been overcome; interactive patient presentations that deliver realistic and diagnostic signs make it possible to teach and to test medical trainees critical physical examination skills in an objective, reproducible manner.

Preliminary results suggest that it is possible to learn cardiac examination skills from a multimedia program incorporated into their clinical clerkship rotations. Test scores showed a marked improvement after training with the heart sounds software.

As promising as these initial results are, more complete testing is warranted. An important control will be to test students at the end of their clinical rotations who have not had software training; another will be to test the program at other institutions to confirm whether these findings can be reproduced elsewhere. Phase II of our research project will establish programs at several other medical schools, both to confirm these findings and to refine the teaching and testing material into a robust clinical skills curriculum.

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References


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