

Throw the Stethoscope Away: A Historical Essay

Am I going deaf, or are hearts not as noisy as they used to be? I've had my hearing tested, just some high-frequency loss (probably from that Edgar Winter concert). So I think it's that hearts are more finely tuned than in the past. I can't remember the last good S4, the one you could palpate. Or the rumble S3 complex or opening snap you called in the medical students to hear. Many of the wonderful sounds we heard have vanished because the diseases that spawned them have been tamed. Rheumatic heart disease, the most prolific composer of eponymous symphonies (Graham Steell, Austin Flint) has long put down the baton. Similar fates have befallen S4, the product of untreated hypertension, and S3, the result of untreated heart failure. The thrill of post-myocardial infarction ventricular septal defect was gone once it encountered streptokinase, and tuberculous pericarditis no longer knocked after streptomycin.

As a result, the importance and skill of listening to the heart has disappeared in our thinking and in our notes. A default entry for cardiac examination in our hospitals electronic medical record is "CV: RRR,S1S2" Honestly, that's it. I mean S1S2 is pretty much a given isn't it? The only patients I know without S1 and S2 are dead. Part of the reason we have become complacent in performing a physical examination is that no one will pay for it. Simply checking the box S1S2 satisfies the auditor and simply checking a few other boxes for other organ systems indicating that the patient indeed has a normal-shaped head and 2 legs satisfies that you have performed a "comprehensive" physical exam.

This reminds me of a shortcut we were taught on our surgery rotation: "the universal point of auscultation." By placing your stethoscope at a single point around the xiphoid process, you could hear the heart, the lungs, and the stomach all at once and therefore speedily perform our era's version of the "comprehensive" physical exam. On to better things that required scalpels.

There's an App for That

So I fear that the heart's sound is threatened by extinction like some lost tribal dialect. To make the art and science of auscultation more appealing to the current generation of students I think it would help to rekindle the discipline of phonocardiography. By using phonocardiography as the springboard, we can first "see" what the heart sounds like and then go back to the bedside to "hear" the same sounds.

I value my stethoscope highly, but if the phonocardiogram had been invented before the stethoscope, I believe the stethoscope, when it came along, would have been regarded as no more than a curiosity—a cardiac party toy—no longer carried in our jacket pockets. Even so, as we will see, if the

phonocardiogram hadn't come along when it eventually did, the use of the stethoscope might have disappeared into obscurity.

The phonocardiogram translates what we hear with our ears and feel with our hands onto a piece of paper, where it can be seen with our eyes and be far more easily measured and quantified. Heart sounds and murmurs barely cross the threshold of audibility of the human ear; we hear only a fraction of the sounds produced. Loud sounds frequently mask adjacent shorter or softer sounds. Furthermore, at best we can discriminate time differences in sound of 20 or 30 milliseconds and clinically significant components of heart sounds such as the splitting of heart sounds or timing of ejection clicks can be much narrower. The phonocardiogram overcomes these handicaps. Its allure is that it is digital, technical, visual, objective—far more science than art. And so, engineers are working on a way to be able to place your mobile phone on a patient's chest and record a high-fidelity display of the patient's heart sounds. If they are successful, it will revolutionize the physical exam and perhaps make auscultation obsolete. But for now, establishing the visual image of heart sounds in the clinician's brain will allow him or her to go back to the bedside with the stethoscope and listen for and appreciate what they have already seen.

Phonocardiography and its sister science apexcardiography had a cometlike 40-year trajectory of popularity beginning roughly in 1935 then largely burning out by



Figure 1. The phonocardiogram apparatus. Reproduced from Leatham A. Auscultation of the Heart and Phonocardiography. London: Churchill Livingstone, 1975:11.

See page 1828 for disclosure information.

1975, extinguished by the new science of echocardiography. To give some perspective on the purpose of reviving phonocardiography and adapting it to the contemporary age, I would like to revisit some of its fascinating history and, along the way, retell some amusing vignettes about cardiac auscultation. As we will see, the results of the phonocardiogram frequently allowed clinicians to go back to the bedside and hear for the first time what they had previously overlooked or misinterpreted.

The phonocardiogram apparatus was huge, like an early computer mainframe (Figure 1). Replete with vacuum and oscilloscope tubes, it could fill a typical hall closet. It was throughout its earlier existence a research tool. Fastidious technique was demanded in recording: the barium titanate crystal microphones applied to the chest delicate and fragile, the patient needing to be cooperative with breath holding, the recording on photographic plates that required darkroom development. Yet many mysteries of heart sounds were solved—answers that we now presume to be obvious—only through the application of the phonocardiogram. The sequence of the heart sounds, the implication of splitting of the sounds, and the interpretation of many murmurs were all unknowns before the phonocardiogram.

For example, that the second heart sound could be fixed in its splitting was recognized only by studying phonocardiographic recordings in Aubrey Leatham's laboratory at the London Hospital. The superb clinicians of the day recognized atrial septal defect but despite listening to scores of hearts with this affliction, the pathognomic fixed splitting was not described until the eureka moment when Leatham's lab technician, watching the galvanometer string wiggle, announced that the sounds were not moving with respiration, that "the split was fixed"¹ (Figure 2).

Cardiac thinking in that era was strongly influenced by the opinions of its great minds—James Mackenzie and

Thomas Lewis, among a few others. As astonishing as this is to us today, they were completely dismissive of the significance of systolic murmurs. This was a belief fostered by their experience in World War I. During the Great War, so many soldiers suffered from "neurocirculatory asthenia," or "soldier's heart," that the British Military Heart Hospital was established to research and treat the near epidemic of cases.² Thirty-six thousand soldiers were discharged during the war as unfit for cardiac reasons, and many fold more were hospitalized, on average for 5 months at a time. This threatened to cripple the fighting force. A feature of the soldier's heart was the presence of a systolic murmur heard at rest or after exertion, and this was used as an objective finding that could lead to discharge on medical grounds and the awarding of a lifelong pension. Lewis, lecturing after the war, discussed the significance of systolic murmurs at length, especially those produced by exertion. "They will find in these young men precisely the signs which have been used widely during the period of the war as evidences of 'organic' disease of the heart, which have led to so many improper rejections of recruits, to some many improper discharges from the service, and now form the basis of many unnecessary or unnecessarily high pensions."³

The great minds rebelled against the practice of labeling systolic murmurs as a source of invalidism. They responded that not only were these systolic murmurs in soldiers innocuous, but, taking it a step further, they argued that virtually all systolic murmurs were inconsequential. Mackenzie, acknowledged as the founding father of British cardiology, was frequently heard to say, when faced with a systolic murmur, that it would be better "to throw the stethoscope away."⁴ Lewis lectured, "It is my confident belief that, had systolic murmurs and modifications of the heart sounds never been discovered, the practice of the profession would have stood on a much higher plane today than it actually does."³ In fact, both Mackenzie and Lewis believed that devices such as the stethoscope, along with the electrocardiograph, were better kept out of the hands of the general practitioner. They felt the findings were often misinterpreted and detracted from the proper physical exam that was conducted by palpation. If they had their way, they would have banished the stethoscope from general use.

Thinking was so colored by rheumatic heart disease that valvular diseases producing systolic murmurs, pure aortic stenosis and mitral regurgitation, were not believed to exist independently from their rheumatic counterparts, aortic regurgitation and mitral stenosis. Lewis indicated, "To diagnose aortic stenosis in the absence of signs of incompetence is outside the province of general practice; it is for everyone a hazardous undertaking. To recognize that mitral incompetence is present, while mitral stenosis is not, is a task fraught with not inconsiderable difficulties; furthermore, when it is done, it gives little or no aid when we come to prophecy."³ Lewis's colleague, William Evans, said the diagnosis of mitral incompetence was more a description of the physician who diagnosed it (Figure 3). Thus, it was in

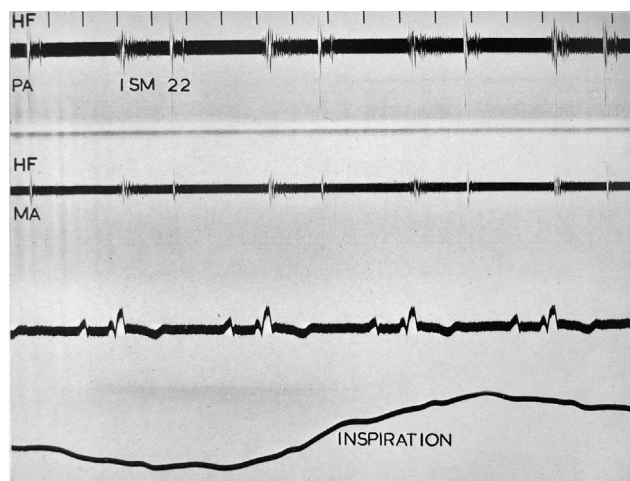


Figure 2. Phonocardiogram display of fixed splitting of second heart sound (labeled 2,2) through respiratory cycle. Reproduced from Leatham A, Gray I. Auscultatory and phonographic signs of atrial septal defect. *Br Heart J* 1956;18:193–208.

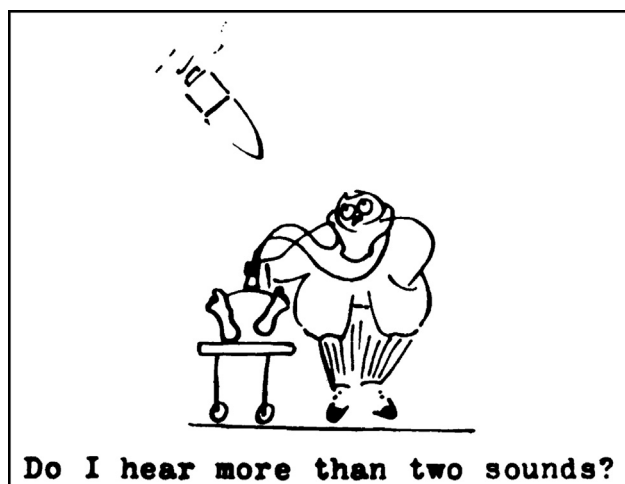


Figure 3.

This cartoon of William Evans at work appeared in the London Hospital Gazette in 1941 during the heavy bombings of London. There is an inside story to the cartoon. Evans advocated a "self-catechism" of 6 questions the examiner should ask when listening to the heart, 1 of which was whether there were more than 2 heart sounds. The London Hospital was indeed heavily bombed; on 1 occasion, all of its windows were blown out.

In teaching auscultation, professors mimicked heart murmurs to their classes. The most skilled imitations were remembered years later. In his autobiography Journey to Harley Street, Evans recalls his professor, Lewis Smith, who imitated the harsh systolic and diastolic murmur of aortic valve disease and likened it to the sound of a locomotive engine idling at Cambridge Heath train station. Evans did not understand the specific allusion to that train station and had never been there. One night during the war, Evans was returning to London via an unfamiliar train route and was awakened from dozing by a sound exactly like that mimicked by Dr Smith. They were stopped at a platform, but signs identifying train stations had been removed in case the country was invaded by the enemy. He asked a passing porter where they were stopped, and the porter replied, "Cambridge Heath." In return, Evans started to laugh so uncontrollably he believed the porter thought he was crazy.

By permission of the Royal London Hospital Archives & Museum, this figure is reproduced from Leatham A. Auscultation and phonocardiography: a personal view of the past 40 years. *Br Heart J* 1987;57:397–403.

this setting, despite the forceful opinions of the great minds that Leatham, again armed with his phonocardiogram, established the character and qualities of systolic murmurs that are still recognized today. By studying the pattern of phonocardiographic recordings, he defined the "ejection" murmur, which was diamond shaped due to ejection of blood into the great vessels and ended before or with the closing sound of the respective valve (Figure 4) and the "pansystolic" murmur (Figure 4), rectangular shaped, beginning with the first and ending with the second heart sound of the valve affected, which he recognized was due to valvular regurgitation and which he declared could exist in

isolation. Today, when we go into a patient's room, we try to listen for the same murmur qualities and timing that he established but that were not recognized or believed to exist before the advent of phonocardiograms, even by the great auscultators of the day. And so phonocardiography rescued the stethoscope from irrelevance by defining visually and scientifically what was being heard, a role it could fulfill today as well.

Our continent's equivalent of the great mind, Samuel Levine from the Peter Bent Brigham Hospital in Boston, also served at the British Military Heart Hospital as an American officer. He, along with Freeman, published an enjoyable article in 1933 analyzing his findings of systolic murmurs from 1,000 subjects. This is the article in which he proposed the 6-point scale for grading heart murmurs that is still used today. Of note, he indicates that the definition of a 1/6 murmur is one so soft that only he can hear it. If you, the general reader, can hear a murmur it must be 2/6 and goes up from there. Levine predicated his article on examining whether the skepticism of the time of the significance of systolic murmurs is justified. As his healthy controls, he picked a diverse patchwork of subjects from a tuberculosis sanitarium, the neighboring children's hospital, the surgery ward, and the nurses, residents, and medical students at his hospital as "noncardiac" cases. He found that systolic murmurs were common, present in almost 20% of individuals but <10% of whom he found to have definite organic heart disease. Nevertheless, he indicated the presence of a murmur pointed to possible anemia, fever, or thyroid disease and was therefore valuable to seek out and note. (Of historical note, Lewis found a systolic murmur in 50% of his "soldiers heart" patients of whom he believed <10% had organic heart disease—very similar numbers.)

It was an accepted practice of the day to exercise the patient to bring out murmurs, and if the murmur was found, to label it as pathologic. He disputed this by making 10 of his fellow attendings, age 24 to 41, run 100 yards. Then listening to their hearts shortly afterward, he found 9 of the 10 to have grade 1 or 2 murmurs. So he indicates that a systolic murmur brought about by exertion is innocuous.

In the same article, Levine amusingly indicated that "it has become the habit of some house officers and students to say that a systolic murmur is heard . . . fearing that some one else will hear a murmur which they have not noted." So he decided to investigate that as well, finding that in 77% of cases, he was in agreement with the house staff, in 7% he heard a murmur when none was previously noted, and in 16% he failed to find a murmur when it was previously described as present. He offered no opinion on these findings, but this seems like a pretty respectable batting average against the great auscultator.

"Valvulists" Versus "Cardiohemists"

It seems incredible that as recently as the late 1970s, there was still uncertainty as to the fundamental source of

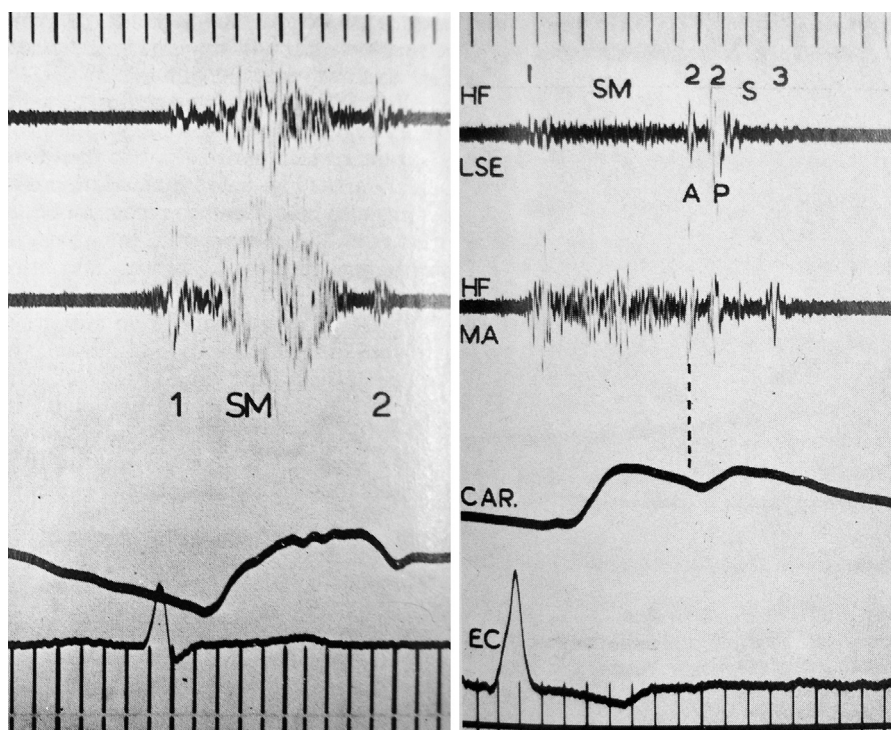


Figure 4. Phonocardiogram display of diamond shaped ejection murmur (*left panel*) and rectangular shaped holosystolic murmur (*right panel*). Note relationship to second heart sound. Reproduced from Leatham A. *Auscultation of the Heart and Phonocardiography*. London: Churchill Livingstone, 1975;83:128.

most heart sounds, especially the first heart sound. Some phonocardiographers were of the camp that the sounds were produced by closure of valves, whereas the competing camp disputed that view and asserted that heart sounds including snaps and clicks were not caused by “clapping” of the valve leaflets but instead were the product of vibration of the “cardiohemic” system as a whole: the blood and ventricular and aortic walls produced by acceleration and deceleration of the blood mass. They believed that valves, especially the right heart valves, were silent.⁵ This chapter in phonocardiography featured pointed feuding between the factions as well as some distinctive experiments to prove their particular point of view.

In 1933, William Dock, one of the first proponents of the valvular theory, noted, “the similarity between the first heart sound and that made when a handkerchief, held with one edge in either hand, is suddenly drawn taut.” He subsequently built a Rube Goldberg–like vibrating machine, immersible in water, to reproduce this scientifically and to show “it is almost impossible to create that noise with a piece of thick carpet or with strips of meat as thick as the wall of the left ventricle”^{6,7} (Figure 5).

In 1963, Faber embedded multiple crystal microphones made from phonographic needles in beating dog hearts in an attempt to triangulate the source of the first sound. Although the concept was ingenious, limitations from the primitive fidelity of the microphones, originally intended to

play 45 records, rendered his findings inconclusive⁸ (Figure 6).

Leatham analyzed the intensity of heart sounds at various phonographic recording positions in the precordium and their response to events such as bundle branch block and the newly invented pacemaker. By the mid-1950s, he had correctly deduced the sequence of the first sound, mitral followed by tricuspid and the second heart sound, aortic followed by pulmonic. However, definitive proof of the valvular source of the first heart sound had to await the arrival of the cardiac ultrasound—but the first-generation ultrasound beams could just barely penetrate the front of the heart. Leatham’s group took clever advantage of one of nature’s experiments, Ebstein’s anomaly, to overcome that shortcoming—assuming the ultrasound would be just good enough to visualize the large anteriorly displaced tricuspid leaflet. The “cardiohemic” group had performed experiments by resecting the tricuspid valve or diverting flow past the right ventricle that reinforced their belief that the tricuspid valve was silent even in patients with Ebstein’s. With simultaneous phonocardiographic and echocardiographic recording, Leatham showed that the loud second component of the first heart sound in this condition occurred precisely with valve closure.⁹

Over the course of the next several years, combined echophonocardiographic studies confirmed that the first and second heart sounds, ejection clicks and opening snaps, were coincident with valves reaching fully open or closed

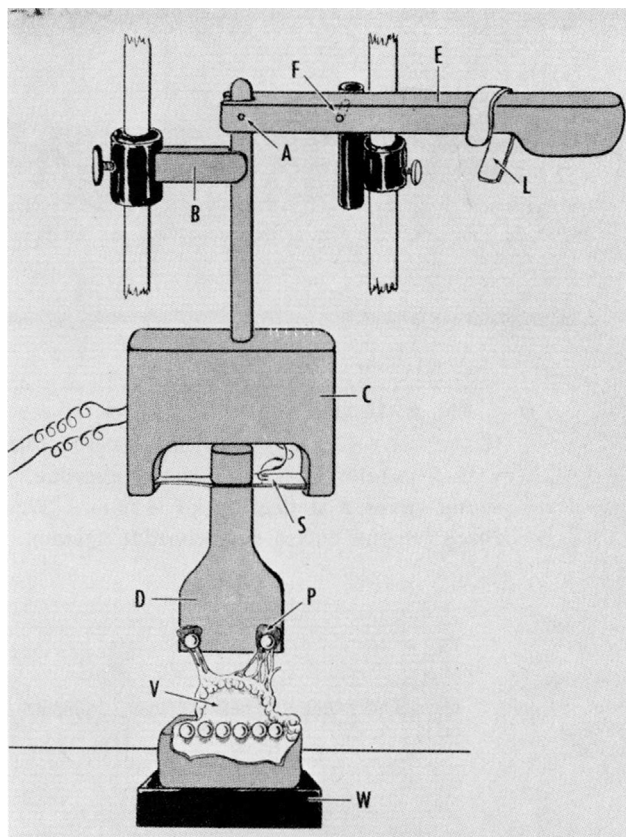


Figure 5. William Dock's vibrating machine. Reproduced from Dock W. The forces needed to evoke sounds from cardiac tissues, and the attenuation of heart sounds. *Circulation* 1959;19:376–385.

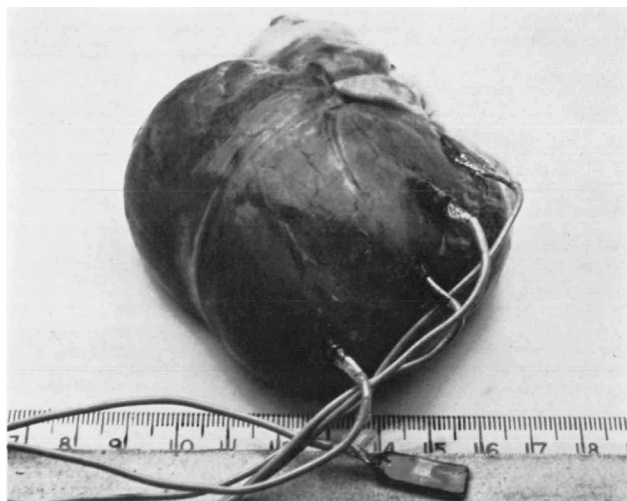


Figure 6. Faber's embedded multiple crystal microphones made from phonographic needles. Reproduced from Faber JJ. Origin and conduction of the mitral sound in the heart. *Circ Res* 1964;14:426–435.

positions. Nonetheless, the final explanation for these sounds advanced in today's leading textbooks indicates that the sounds are due to vibrations of the "cardiohemic" system and that the valves are closing or opening simply to reflect

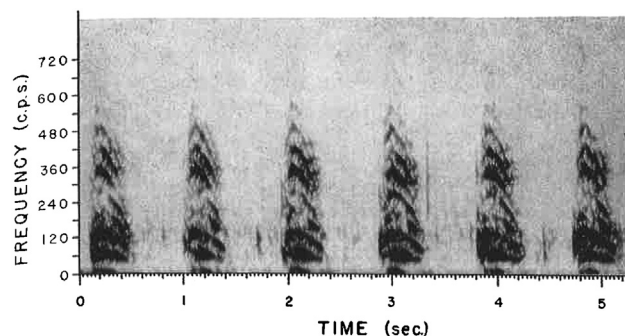


Figure 7. Spectral phonocardiogram display of musical aortic diastolic murmur with harmonic bands. By permission of the Alan Mason Chesney Medical Archives of The Johns Hopkins Medical Institutions, this figure reproduced from Mckusick VA, Webb GN, Brayshaw JR and Talbot SA. Spectral Phonocardiography: Clinical Studies. *Bull J Hopkins Hosp* 1954;95:90–110.

the acceleration or deceleration of the blood mass occurring at those times. I don't buy it. I've seen a lot of 2-dimensional echocardiograms with contrast and tissue Doppler, and if something is vibrating, I think I would have seen it—certainly something with the duration and frequency of a transient heart sound. Perhaps we need to resurrect one of Dock's vibrating machines and attach a "cardiohemic" system to it, along with some phonograph needles. That will surely figure it out.

How Did the Murmur Get Its Coo?

Certain heart murmurs are described with colorful terms such as "honking," "groaning," or "whistling." When a murmur is portrayed colorfully, it usually signifies that it is musical, a feature first examined scientifically by Victor Mckusick. Before he became the renowned medical geneticist, Mckusick was first a cardiologist specializing in phonocardiography. He adapted a Bell Telephone Laboratories invention used to fingerprint voice patterns to the recording of heart sounds. This new technology, spectral phonocardiography, graphically displayed sound frequencies along with timing and intensity. One of its most valuable insights was the recognition that "murmurs are in general of two types: musical murmurs and noisy murmurs. Furthermore the distinction between the two is a function of the presence or absence of harmonic pattern."¹⁰

Symphony season subscribers will appreciate that Mckusick could even identify the specific instruments playing certain murmurs—the trumpet, the harp, the reed, and the violin—and proposed a differential diagnosis of the cause of the murmur based on its orchestral section.¹¹

The most classic musical murmur is the "cry of the seagull" or the "cooing of the dove" produced by a prolapsed or fenestrated aortic leaflet which Mckusick categorized as from the reed group and pathognomonic of syphilitic aortitis. His phonographic technique depicted the layered harmonics that produced its musicality and also the

doming pattern of its ascending and descending frequency, which creates the classical cooing sound (Figure 7).

Mckusick cautions that a particular sound quality, whether “the croaking of a bullfrog,” “the whistling of the wind,” or “the spinning of a top,” will not precisely identify the source of the murmur but may narrow down the possibilities. I believe his most valuable clinical lesson is that if you hear a musical sound—a honk or squeak or croak—it means that a structure is vibrating, and the list of things that can vibrate within the heart is relatively short. He lists some structures capable of vibrating and causing musical murmurs that we scarcely remember today as culprits, including ruptured mitral chordae, ventricular false tendons, Chiari networks, and the flaps of aortic dissections. If lucky, one day I will hear such a sound and be able to recognize it.

It seems every older generation of physicians decries the abandoning of skills that they personally deemed essential. So Mackenzie and Lewis thought the stethoscope stole from attention to a proper physical exam best performed using one’s hands. Later, in 1949, Samuel Levine wrote, “The greater the time spent in taking three electrocardiographic leads and later nine and now twelve leads, the less time is left to elicit an adequate history of the case or the auscultate the heart properly.”¹² Perhaps a future Dr Levine will look out and see a class of students, heads bent down over lit mobile phone screens, staring at phonocardiograms, and then marching to the patient’s bedside to listen with their stethoscopes. If lucky, one day I will see such a sight and be able to recognize it.

Disclosures

The author has no conflicts of interest to disclose.

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1. Leatham A. Auscultation and phonocardiography: a personal view of the past 40 years. *Br Heart J* 1987;57:397–403.
2. Wooley CF. From irritable heart to mitral valve prolapse—World War I, the British experience and Thomas Lewis. *Am J Cardiol* 1986;58:844–849.
3. Freeman AR, Levine SA. The clinical significance of systolic murmur: study of 1,000 consecutive “noncardiac” cases. *Ann Int Med* 1933;6:1371–1385.
4. Lewis T. On cardinal principles in cardiological practice. *Br Med J* 1919;2(3072):621–625.
5. Luisada AA. *The Sounds of the Normal Heart*. St. Louis: Warren H. Green, 1972; 13–14.
6. Dock W. Mode of production of the first heart sound. *Arch Int Med* 1933;51:737–746.
7. Dock W. The forces needed to evoke sounds from cardiac tissues, and the attenuation of heart sounds. *Circulation* 1959;19:376–385.
8. Faber JJ. Origin and conduction of the mitral sound in the heart. *Circ Res* 1964;14:426–435.
9. Crews TL, Pridie RB, Benham R, Leatham A. Auscultatory and phonocardiographic findings in Ebstein’s anomaly. Correlation of the first heart sound with ultrasonic records of tricuspid valve movement. *Brit Heart J* 1972;34:681–687.
10. McKusick VA. Musical murmurs. *Bull J Hopkins Hosp* 1955;97:136–176.
11. McKusick VA. Musical murmurs: spectral phonographic studies. In: Segal BL, ed. *The Theory and Practice of Auscultation*. Philadelphia: F.A. Davis, 1964:93–101.
12. Levine SA. Diagnostic value of cardiac auscultation. *JAMA* 1949;141:589–593.