Acoustic Stethoscopes

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Check Points

- ✓ Breath and heart sounds have diagnostic information that cannot be obtained except by listening.
- ✓ The diaphragm (a plastic disc) or bell (a hollow cup) are used to hear different sounds.
- ✓ Stethoscopes are used for three primary purposes: heart sounds, lung sounds, and blood pressure measurements.

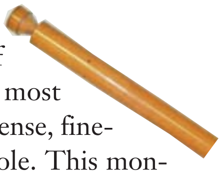
It was Hippocrates, in the fifth century BC, who first discovered that there is information to be gathered from listening to sounds in a patient's chest. Breath and heart sounds have diagnostic information that cannot be obtained except by listening.

It took more than 2,200 years before French physician René Théophile Hyacinthe Laënnec published his treatise on auscultation, adapting the practice of listening to the sounds in a patient's chest by using a transmitting medium. Laënnec is generally considered to be the father of chest medicine and the inventor of the stethoscope.

Examining a female patient with heart disease, he could not effectively apply percussion as a way to determine respiratory state due to the obesity of the patient. Because of the young age and sex of the patient, he also did not want to apply his ear to the chest. Taking a sheaf of paper, he tightly rolled it into a cylinder and applied it to the patient's chest, with the other end to his ear. The small aperture in the center of the cylinder aided hearing, although Laënnec later found that a cylinder without any aperture is best for the exploration of the heart.

He freely acknowledged that his work was influenced by the writings of Hippocrates, who found that immediate auscultation could be of benefit to determine the influence of fluid in the thoracic cavity. Laënnec used the term stethoscope from the Greek (stethos for "chest" and skopein for "to examine"), pointing to its Hippocratic origins. Today, mediate auscultation is defined as the use of a stethoscope to examine the internal sounds of a body.

The First Stethoscopes



Laënnec experimented with many materials and shapes. The version of the stethoscope with which he was most satisfied was made of a cylindrical, dense, fine-grained wood with a longitudinal hole. This monaural stethoscope was made in two parts, fitted together by wood screw threads and brass tube fittings. The instrument was made with a funnel-shaped distal end, used in assessing respiration. When applied to the heart and the voice, it was converted into a simple tube, with thick sides, by inserting a plug into the patient end.

This first version is described in Laënnec's text on auscultation, where he describes the stethoscope as 12 inches long and 1.5 inches in diameter. Laënnec made the first stethoscopes himself; an example is in the collection of the Wood Library Museum of Anesthesiology, northwest of Chicago.

As with the adoption of most medical technologies, there was significant skepticism in the medical community on the value of Laënnec's invention. Noted physicians claimed that the naked ear could detect sounds as well as when aided by the stethoscope. In addition, direct

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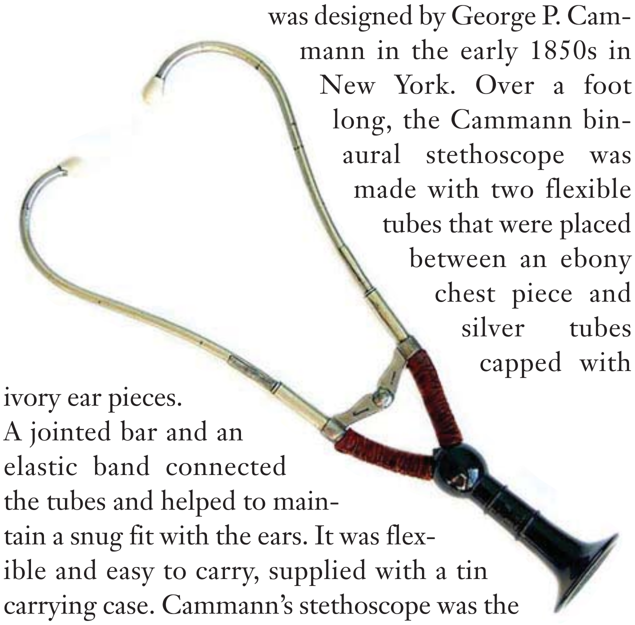
application of the ear could distinguish shades of sound that had escaped detection when assisted by this new instrument. The fact that physicians were slow to accept the use of the stethoscope was acknowledged by Dr James Hope; the resistance was due, in part, to their fear to learn a new technique.

Despite initial resistance, there were proponents of Laënnec's instrument. Hope, who had studied under Laënnec's successor, pursued experimental work on heart sounds related to aortic valve disease, providing detailed insight into the use of this tool in determining what was being heard.

The monaural stethoscope was slowly adopted in the second half of the 19th century. Shortly after Laënnec described his stethoscope, innovating physicians started experimenting with the original design. Many configurations appeared, including several versions with flexible tubes between the ear piece and the bell-shaped chest piece.

In parallel with developments of the monaural stethoscope, several attempts were made to design a binaural stethoscope. The first workable binaural stethoscope was designed by George P. Cammann in the early 1850s in New York. Over a foot long, the Cammann binaural stethoscope was made with two flexible tubes that were placed between an ebony chest piece and silver tubes capped with ivory ear pieces. A jointed bar and an elastic band connected the tubes and helped to maintain a snug fit with the ears. It was flexible and easy to carry, supplied with a tin carrying case. Cammann's stethoscope was the pattern for further developments in acoustic stethoscopes and the basis for the most popular designs today.



By the end of the 19th century, binaural stethoscopes had almost completely replaced monaural stethoscopes based on Laënnec's original design. Work by various physicians and engineers, often working together, experimented with stethoscope design into the 20th century.

Improving the Design

Sprague established a series of parameters important for capturing cardiac and respiratory sounds and worked with an engineering colleague to make this information generally available. The "ideal" stethoscope is described by Littmann in the *Journal of the American Medical Association*. Littmann stated that the device should include an "open chestpiece for the appreciation of low-pitched sounds, a closed chestpiece with a stiff plastic diaphragm to filter out low-pitched sounds, firm tubing with a single lumen bore, the shortest practical overall length, a spring with precise tension to hold the ear tubes apart, and light and convenient to carry and use."

The diaphragm (still typically a plastic disc) or bell (a hollow cup) are used to hear different expected sounds. If the diaphragm is placed on the patient, body sounds vibrate the diaphragm, creating acoustic pressure waves that travel up the tubing to the listener's ears. If the bell is placed on the patient, the vibrations of the skin directly produce acoustic pressure waves traveling to the listener's ears. The bell transmits low frequency sounds, while the diaphragm transmits higher frequency sounds, as described by Littmann above. This type of stethoscope is often now referred to as a combination or two-sided chestpiece stethoscope and is in common use. However, there are still discussions on the preference of the bell or the diaphragm.

Sound vibrations can be described by the two components of frequency and amplitude, which are heard as pitch and loudness, respectively. In complex sounds, the presence of simultaneous higher frequencies give the sounds their distinctive character. When a complex sound is heard, we tend to hear the lowest note (called the fundamental note in music). The predominance of a lower note is increased as the amplitude of the sound rises, which masks the higher frequency components by lower frequencies. Anyone sitting at a traffic light next to a driver with the radio volume turned up will note that increasing the volume of music accentuates the bass.

Welsby and colleagues describe this phenomenon in their testing of bell and diaphragm chest pieces. They describe their results, which are summarized in Figure 1. This figure shows the difference in the output between the stethoscope bell (SB) and the stethoscope diaphragm (SD) over a range of frequencies. From this figure, we see that the stethoscope bell provides greater amplification of sound in the middle range. However, there is no difference in frequency response.

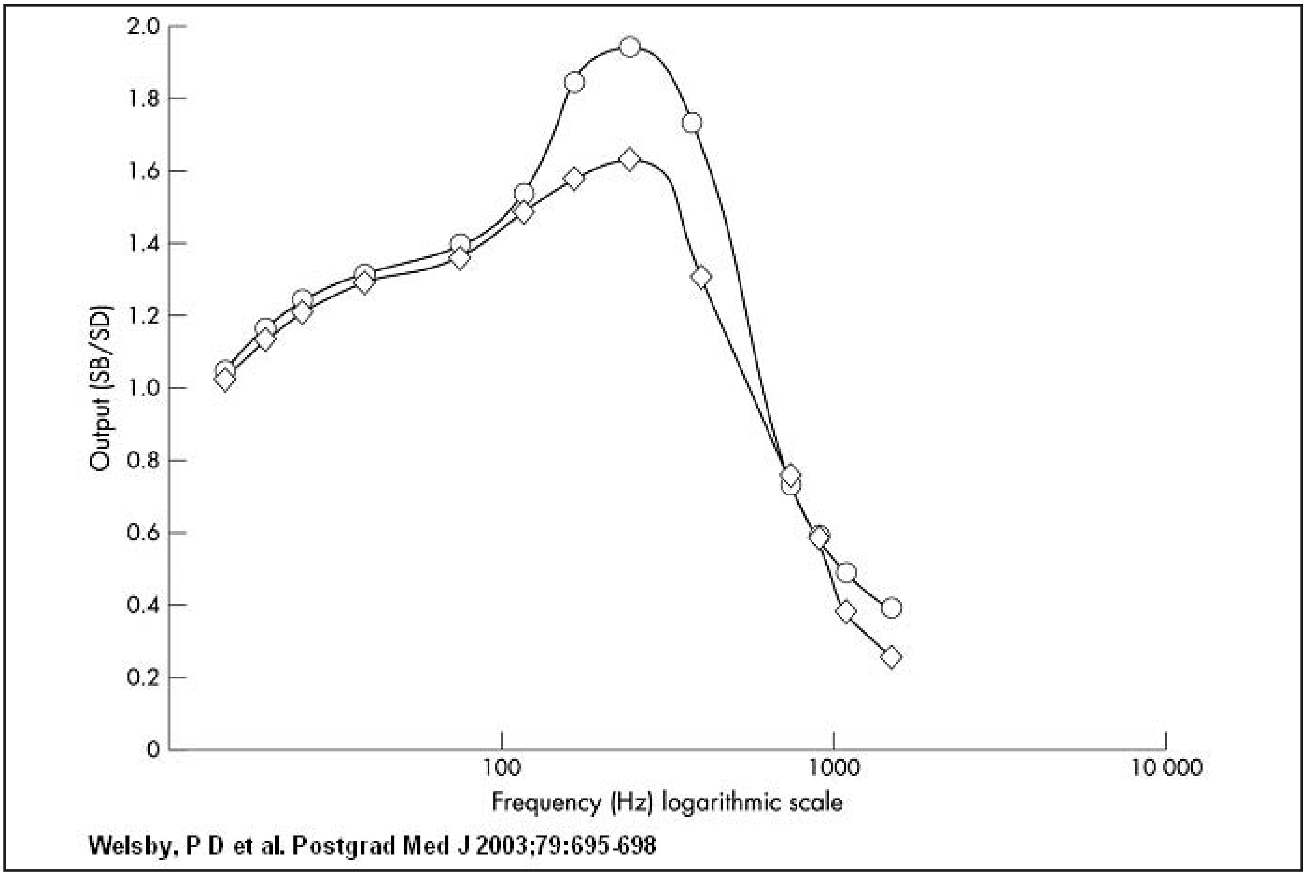


***Figure 1.** Results from the testing of bell and diaphragm chest pieces, which show the difference in the output between the stethoscope bell (SB) and the stethoscope diaphragm (SD) over a range of frequencies.*

Uses of Stethoscopes

Stethoscopes are used for three primary purposes: heart sounds, lung sounds, and blood pressure measurements. Heart sounds are associated with the closing of valves. In adults, they are called S1 and S2 where S1 has peak power characteristics between 10 and 140 Hz and S2 has peak power characteristics between 10 and 400 Hz. In order to eliminate interference for hearing and interpreting heart sounds, patients can cooperate (when possible) by breath holding, particularly helpful at end-expiration.

The first heart sound signals the onset of ventricular systole and has the components of M1 (mitral valve closure) and T1 (tricuspid valve closure). In the normal heart, the M1 and T1 components can not be distinguished by the human ear. The second heart sound signals the onset of ventricular diastole and has the components of aortic valve closure (A2) and pulmonic valve closure (P2). During respiratory expiration A2 and P2 are very difficult to distinguish. However, during inspiration, P2 is slightly delayed. Analysis of these components and resulting diagnosis have been accomplished by wavelet signal processing.

Pasterkamp and his colleagues have summarized the requirements for reproducing lung sounds and presented the range of <100 Hz to over 1,000 Hz. Lung sounds are measurably above background noise at frequencies as high as 1,000 Hz. Measurements have been made for wheezing at frequencies approaching 1,500 Hz. Various configurations of stethoscopes will provide varying frequency response in respiratory diagnosis.

When used with a sphygmomanometer, a stethoscope can measure blood pressure. In 1896, Scipione Riva-Rocci determined systolic pressure by placing a band on the upper arm and releasing it until he could feel a pulse. In 1901 Nikolai Sergeyevich Korotkoff used a stethoscope with a wider Riva-Rocci cuff. He related sounds that had been previously identified to the systolic and

The modern stethoscope, one of the most common medical instruments in use today.

diastolic blood pressures in the brachial artery during slow cuff deflation when he placed a stethoscope over the brachial artery below the cuff. This process of using a stethoscope along with a sphygmomanometer is known as the auscultatory method (also the Riva-Rocci or Korotkoff method) and the sounds are known as Korotkoff Sounds. Korotkoff Sounds are of low frequency and may be better heard with the bell of the stethoscope.

Electronic Stethoscopes

Although outside the scope of this paper, it should be noted that acoustic stethoscopes have been challenged by electronic versions. Clinical studies performed to evaluate the advantages and limitations of acoustic and electronic stethoscopes have shown that it is possible to design an electronic stethoscope by considering the advantages of both the acoustic and electronic stethoscopes. Through microprocessor technology, electronic stethoscopes can supplement traditional acoustic stethoscopes without an increase in size or weight. Key advantages of electronic over acoustic stethoscopes may include:

- possibility of volume control for amplification
- elimination of sound loss and resonance effects experienced with acoustic stethoscopes by selectively amplifying signals at different frequency ranges
- mode control to allow switching between bell and diaphragm without interrupting auscultation
- electronic noise filtering

Using a stethoscope is an age-old art in medicine and is a very useful, non-invasive diagnostic tool to help localize problems. Stethoscopes are important to allow the doctor to determine what further tests are needed to diagnose disease. Although stethoscopes are not the most sophisticated medical instrument in use today, they are the most common. They are an essential diagnostic tool for determining proper cardiac and respiratory function, typically as a screening tool to determine the need for further patient evaluation. ■

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