The Effect of Stethoscope-Applied Pressure in Auscultation

A New Instrument for Improving Discrimination

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The diaphragm stethoscope is usually credited to R. C. M. Bowles, an engineer of Suffolk County, Massachusetts, who was issued Letters Patent No. 526-502, October 2, 1894. Previous instruments had employed diaphragms but they were carefully recessed to avoid contact with the skin. Bowles concluded from his studies that sound conveyed by such instruments resulted from vibrations transmitted from the edge of the bell to the membrane "similar to beating a drum on the edge of the frame" and that a diaphragm in direct contact with the skin was more efficient. His improved chest piece introduced a new dimension in the art of auscultation making possible the appreciation of sound of higher frequency than usually detected with the bell. Clinical use ultimately proved the utility of both the bell and the diaphragm, explaining the widespread adoption of the composite instrument as introduced by Howard B. Sprague of Massachusetts General Hospital in 1926.

The bell, when held lightly against the chest wall, forms an air-tight compartment and at the same time holds the skin loosely as a membrane allowing optimum transmission of high-energy, low-frequency sound. This characteristic has led it to become the chest piece of choice of most in the detection of the low-pitched diastolic murmur of mitral stenosis. Even so, care must be taken to avoid the application of more than very light pressure or the skin will be made taut, interfering with the passage of the low-frequency sound. As pointed out by Butterworth, this effect may be readily demonstrated by the application of the bell with varying pressures over the mitral area. With light touch the low-pitched first sound may seem booming. With additional pressure the first sound may be attenuated and the higher frequency second sound better appreciated. Variable pressure in the use of the diaphragm provides a far wider spectrum of sound in the higher frequency range. The larger effective area, as would be expected, admits a greater volume of sound. The fidelity and intensity of the various frequency components of this sound are modified by passage through the diaphragm. A full explanation of these phenomena is far from simple. Certain contributing factors are self-evident, such as thickness and diameter, which lend themselves to simple mathematical analysis. However, the strain within the diaphragm proper contributes appreciably to the attenuation of various sounds. As in the case of a drum, the tighter the drum head, the greater is the strain and the higher the pitch. By increasing the strain or tension, the loud, low-pitched sounds are selectively suppressed, making audible those of higher frequency, but the phenomena are more complex than with the bell.

With a flat diaphragm it is necessary to compress the underlying tissue considerably in order to introduce strain by diaphragm deformation. The effectiveness of this maneuver in the appreciation of faint, high-pitched murmurs of aortic insufficiency has been emphasized by Harvey and Levine. The range of frequency of sound may also be altered for this type of chest piece by varying the aforementioned factors, i.e.—thickness, rigidity, and diameter. Indeed, stethoscopes have been introduced with as many as five removable chest pieces each slightly different in an attempt to widen the range. Because of inconvenience in use, they have not proved popular.

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A chest piece has been developed in which the diaphragm can be easily tuned to the frequency of the various sounds without appreciable compression of the underlying tissues. The selectivity of auscultation is enhanced by a new method for varying the rigidity or strain within the diaphragm. This allows a wide range of frequency appreciation by a single diaphragm chest piece.

**Chest Piece**

A thin (0.0075 inch) Mylar diaphragm is prestressed by being bowed forward slightly by a fulcrum action of the retaining ring at its periphery, as shown in figure 1.

A small raised area in the center of the diaphragm magnifies even further the increased tension resulting from pressure against the skin. Thus the Mylar diaphragm without pressure is thin enough to allow passage of many low-frequency sounds encountered clinically, while the addition of slight pressure attenuates the low-pitched sounds and improves the transmission of the high-pitched components through a wide frequency range. These characteristics have made this modified diaphragm useful in the detection of certain pulmonary sounds, cardiac murmurs resulting from valvular insufficiency, and in the timing of cusp closure. The performance of this diaphragm as compared to the conventional one was studied under simulated conditions.

**Equipment and Procedures**

The need for a specially constructed sound-proof room for adequate control of test conditions has been pointed out by Groom. The room was equipped with the following apparatus:

1. A Hewlett-Packard Model 200CD wide-range oscillator modified with a potentiometer to give a second signal, the voltage of which is proportionate to the change in frequency of the oscillator output.
3. An artificial precordium consisting of a 4-inch speaker embedded in a combination of semirigid plastic, rubberized hair, glycerin and plastic film to reproduce as nearly as possible the physical and acoustical characteristics of the human precordium.
4. An Altec M20 Microphone System consisting of a power supply and condensor microphone with relatively flat response from 20 cps to 5,000 cps, modified to accept stethoscope ear tips.
5. A Model 60D Moseley Logarithmic Converter.
8. A Parallel T Network.

The apparatus was assembled as shown in figure 2.

The signal from the oscillator was applied to the speaker in the artificial precordium from which it was detected by the stethoscope chest piece. The output from the binaurals of the stethoscope was converted from a logarithmic to a linear function and plotted in decibels on the Y axis of the recorder. It will be remembered that the decibel, which is the accepted unit of measure for the intensity of sound, is a logarithmic expression. A 3-db increase is equivalent to twice the sound power; a 10-db increase equivalent to 10 times the sound power; a 20-db increase equivalent to 100 times, etc. The power level of the input to the artificial precordium was kept constant for each test by means of the vacuum tube voltmeter. As the frequency of the input signal was varied, it was plotted on the X axis of the recorder in response to the voltage change from the potentiometer on the oscillator. It was necessary to incorporate a parallel T network in the

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*The technical assistance of Richard Weinzierl, Project Engineer, Taylor Instrument Co., in the development of this facility is acknowledged.

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circuit to suppress a major resonant peak of the system. By placing the artificial precordium on the balance, it was possible to duplicate exactly, the pressure with which the stethoscope was applied to the precordium for each individual test. This complex made possible accurate control and reproduction of all variables. Although there is considerable overlapping of the basic heart sounds with reference to their pitch, Segal stated that they are all within a range from 20 cps to slightly above 1,000 cps. Therefore, for test purposes, a spectrum from 20 cps to 1,600 cps was considered to be more than adequate. Figure 3 shows the effect of pressure change in use of the special chest piece and Mylar diaphragm described above. Figure 4 is a similar curve for the more conventional chest piece with a flat diaphragm of the same material and diameter.

The solid lines represent the intensity of the

![Figure 2](image)

**Figure 2**  
Schematic diagram of test equipment.

![Figure 3](image)

**Figure 3**  
Effect of variable loading on sound-frequency spectrum with stethoscope having new chest piece.
Effect of variable loading on sound-frequency spectrum with stethoscope having conventional flat diaphragm chest piece.

sound signal at the ear tips when the chest piece was applied with a 200-Gm. load. The broken lines represent the intensity when an applied load of 2,000 Gm. was used. An increase in pressure not only permitted the high-frequency tones to come through louder, but actually attenuated the low-frequency tones, thus making the high-pitched sounds audible (fig. 3). When the conventional flat diaphragm stethoscope was used, an increase in precordium pressure at-

Response of conventional flat diaphragm chest piece and new tensioned chest piece with 200-Gm. pressure against the chest wall.

Figure 5

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tenuated the low-frequency tones only slightly and did not change the response to the high-frequency tones (fig. 4). This effect necessitated excessive chest pressure to attenuate further the low-pitched sounds with use of a flat diaphragm. Figure 5 compares the conventional flat diaphragm stethoscope with the new modified diaphragm stethoscope: at a chest pressure of 200 Gm., the tensioned diaphragm amplified the low-frequency sounds to a greater degree and was superior in attenuating the high-frequency sounds to which the ear is more sensitive. When the pressure was increased, the new diaphragm brought out the high-pitched murmurs somewhat better, simultaneously reducing the intensity of the low-frequency sounds (fig. 6).

It is apparent that at certain specific frequencies the intensity of sound transmission is nearly identical for the two diaphragms, for example, in the region of 150 cps where the murmurs of aortic insufficiency are heard. Even in such cases the new diaphragm gives improved performance by virtue of superior attenuation of the lowest frequency sounds with heavier loading permitting better appreciation of sounds in the region of 150 cps.

Summary

The effect of pressure against the chest wall in the use of the stethoscope for both the bell and the diaphragm chest piece is discussed.

A modified diaphragm chest piece in a single head designed to increase the auscultatory discrimination is discussed.

Comparison of the modified and conventional diaphragm chest pieces on an artificial precordium and with the employment of accepted engineering principles in the study of sound revealed the superiority of the modified diaphragm.

References

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