New Stethoscope With Extensible Diaphragm
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Background: This study compared the diagnostic efficacy of the common suspended diaphragm stethoscope (SDS) with a new extensible diaphragm stethoscope (EDS) for low-frequency heart sounds.

Methods and Results: The EDS was developed by using an ethylene propylene diene monomer diaphragm. The results showed that the EDS enhanced both the volume and quality of low-frequency heart sounds, and improved the ability of examiners to auscultate such heart sounds.

Conclusions: Based on the results of the sound analysis, the EDS is more efficient than the SDS. (Circ J 2016; 80: 2047–2049)

Key Words: Auscultation; Extensible diaphragm stethoscope; Suspended diaphragm stethoscope

In 1816, Rene T. Laennec, was the first person in the world to use a wooden cylinder as an auscultation instrument.1 After this, the forms and materials of stethoscopes have been modified, but since information technology such as electronic stethoscopes and echocardiography has been introduced into the medical field, stethoscopes have been gradually losing their significance as an important diagnostic tool. Today, there is some controversy concerning the diagnostic significance of cardiac auscultation in various clinical settings.2-7

We wondered if the reason for declining auscultation skills was related to difficulty in hearing heart sounds or murmurs by examiners, or a structural problem of the stethoscope itself? The most commonly used stethoscopes have double-headed chest pieces and single-headed chest pieces have been popular in the past 3 decades. The suspended diaphragm stethoscope (SDS) is considered able to catch all heart sounds, from low frequency (S3 and S4) to high frequency,8 but it does not differentiate these sounds well. Therefore, we developed a new extensible diaphragm stethoscope (EDS), which has a different structure and a good ability to catch lower frequency heart sounds clearly, even for beginners.

Methods and Results
We made the new chest piece from aluminum (50 mm OD, 10 mm in thickness), with a triangular ring. 1 mm inside the extended edge, on the chest piece. The EPDM diaphragm (46 mm OD, 0.5 mm thickness) was placed on this extended ring and an opening (24 mm ID) in the center of the rubber diaphragm causes it to adhere to a plastic vibration plate (28 mm OD, 0.25 mm thickness) around the edge of the hole (Figure A, Left). The EPDM diaphragm is firmly fixed and the force is extended by tightening a lid with a spiral groove, which lifts the center by 1 mm, thus increasing the vibration of the plastic plate, and so the sound volume also increases. The comparative structure of the SDS and EDS is shown in Figure A, Right.

As a preliminary test, 2 of the authors investigated the acoustic characteristics of various stethoscopes, both diaphragm and bell type, using an acoustic response test system, and found that the Master Classic II (Littmann) was the best and most suitable for the comparative study (Figure S1).

The acoustic differences of the EDS and SDS were recorded during auscultation testing of 3 patients by 5 physicians. The 3 patients (69-year-old male with angina pectoris; 42-year-old male with hypertrophic cardiomyopathy; 83-year-old male with hypertensive heart disease) gave informed consent. The 5 physicians (4 cardiologists, 1 internist) were not informed about the purpose of the test of listening to S4 sounds using 2 types of stethoscope (EDS and SDS). They were instructed to listen to S4 at a marked point of the apex, in 3 stages (no hand pressure, mild pressure, and moderate pressure), after they were handed an EDS or SDS randomly by an assistant. After listening to S4, all the examiners agreed that the EDS was louder and much clearer (Levine’s criteria) when using mild pressure (Figure B), compared with the SDS. Furthermore, to confirm this auscultation test, one of the authors used both the SDS and EDS to test S3 and S4 sounds stored in a cardiology patient simulator,9 as another comparative study. The examiner turned the sound volume switch down as low as possible, ~30 points (lowest: ~50). First the SDS, Master Classic II (Littmann), was tested and then the EDS under the same
Figure. (B) Results of an auscultation test using 2 types of stethoscope [suspended diaphragm stethoscope (SDS); extensible diaphragm stethoscope (EDS)] on 3 patients performed by 5 physicians using 3 stages of pressure. There are clear differences in Levine scores between the SDS and EDS. AP, angina pectoris; HCM, hypertrophic cardiomyopathy; HCVD, hypertensive cardiovascular disease. (A) Structure of the EDS. The EPDM membrane (46mm OD, 0.5mm thickness) is placed on the extended ring and the central hole (24 mm ID) enables the diaphragm to adhere to a plastic vibration plate (28 mm OD, 0.25mm thickness) around its edge. The EPDM membrane is firmly fixed and forces are added by screwing a lid with a helical groove, which lifts the center of the diaphragm by 1 mm, and thus increases both the vibration of the plastic plate and the sound volume. The structural difference (Right) between the EDS and SDS is the direction of the diaphragm.
conditions, and it was confirmed that the EDS was able to pick up S3 and S4 at –30 points, but the SDS could not.

The Table shows the acoustic analysis of the EDS and SDS using DSSF3 (YmecStore, Japan), which is an acoustic sound analyzer comprising 3 software components: (1) real-time analyzer (RA) using fast Fourier transform analysis and an oscilloscope, (2) sound analyzer and (3) environmental noise analyzer. Heart sounds fed into a computer through a high-sensitive microphone (RA) are shown on the desk top oscilloscope, (2) sound analyzer and (3) environmental noise analyzer (RA) using fast Fourier transform analysis and an analyzer comprising 3 software components: (1) real-time analysis, it became clear that the EDS is superior to the SDS for low-frequency sounds (<60 Hz), particularly when examining elderly people, who expect to have a physician’s touch. Therefore, the EDS will be very useful in future medical practice, and evaluating heart sounds, respiratory sounds and abdominal sounds will be easier for beginners. We believe the EDS shows promise, not only in the medical field, but in other fields of science also, such as veterinary medicine and acoustic engineering.

Disclosures
The authors declare no conflicts of interest.

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Grants
None.

References

Supplementary Files
Supplementary File 1
Figure S1. Comparative study of various stethoscopes.
Please find supplementary file(s):

### Table. Acoustic Analysis of SDS and New EDS

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Average value (±SD) of acoustic analysis of 5 tests [date and time of test: 14: 53 hours (February 10, 2016)]. dB, decibel; EDS, extensible diaphragm stethoscope; SD, standard deviation; SDS, suspended diaphragm stethoscope.