Visualization of Heart Motion by Analysis of Chest Vibration

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Abstract. As there are various difficulties associated with auscultation techniques, we have devised a technique for visualizing heart motion to assist in the understanding of heartbeat for both doctors and patients. The technique based on the measurement of chest vibration using 64 sensors as a multiple-auscultator to show global and simultaneous heart motions. A new mount plate with 64-sensor was developed to install the chest quickly. As a result, the total time of the measurement was five minutes approximately, which allows to clinical use easily. To overcome difficulties in auscultation technique, the technique can be applied to the detection of heart disease in visual and to the digital database management of the auscultation examination.

1 Introduction

With the invention of the stethoscope by Laennec in 1816, “auscultation” became possible, introducing an exciting and practical new method of bedside examination [1]. Auscultation is performed for the purpose of examining circulatory system and respiratory system as well as gastrointestinal system, known as bowel sounds. It requires substantial clinical experience, a good listening skills. When many students first attempt to use a stethoscope in clinical settings to detect/diagnose diseases of the heart and the lungs, they often have difficulties hearing the characteristic sounds. As a result, we are concerned about potential for missed diagnoses. In fact, the shared bands (frequency and sound pressure) between audible sounds and heart sounds are very narrow as shown in Fig. 1; thus, special techniques are required for auscultation. Therefore, it is essential to establish new analysis techniques for heart and breath sounds for better understanding by both doctors and patients.

Fig 1. Schematic diagram showing frequency bands of audible and heart sounds.
Some reports on 3-D graphic techniques [2] and data-recording apparatus [3, 4] have been seen, but visualization methods of heart motion have not been established. Echocardiography is generally used to diagnose cardiovascular diseases, but requires special equipment and another associated techniques [5-9].

In order to globally and simultaneously show heart motion to assist diagnosis heart diseases in visual and digital, a new measurement technique for visualizing the chest vibration was established and demonstrated. The device consists of a 64-channel including ECG signal sensor unit and an imaging analysis unit. The visualized results are clear, showing a typical waveform motion of the strong pressure shock due to closing of the tricuspid valve and mitral valve of the cardiac apex, and the closing of the aortic and pulmonic valves in sequence. It concluded that the system is applicable to diagnose heart disease and a monitor of heart motion during an operation.

2 Experiment procedures for visualizing heart motion based on multichannel sensing of the chest vibration

Figure 2 shows a set-up of multichannel measurement system for visualizing the heart motion developed. The present system consists of a 64-channel amplifier unit and an A/D converter unit, connected to a personal computer with MATLAB software installed. The acceleration sensor unit consisted of 8×8 sensors fixed at intervals of 20 mm (63 acceleration sensors with one ECG sensor, or 64 acceleration sensors all). The chest-surface vibration using the acceleration sensor (6 mm in diameter, S12-M1SSB) and electrocardiographic wave using ECG electrodes was measured, and heart motion was then visualized for a couple of heartbeats. In the preliminary experiment, each 64 sensors were adhered singly on the chest skin surface using double-stick tape. However the time of experiment was needed 30 minutes approximately, we then developed a soft mounting plate for fixing 8×8 sensors, which could fix rapidly to the chest surface. The total time of the installation and measurement was five minutes approximately [10].

Figure 3 shows the outline of experimental performance. When recording heart sounds, the subject was asked to stop breathing for several seconds. Heart sounds were digitalized at a sampling frequency of 3 kHz and at a quantization of 12 bits.

![Fig 2. A set-up of multichannel measurement system for visualizing the heart motion.](image-url)
3 Results and discussions

The heart sounds are noises generated by tissues vibrations with the heart motion and resultant flow of blood through the heart. In healthy adults, there are two normal heart sounds that occur in sequence with each heart beat. These are the first heart sound (S1) and second heart sound (S2), produced by the closing of valves. Ordinarily, S1 is caused by the sudden blockage of reverse blood flow due to closure of the atrioventricular valves (mitral and tricuspid) at the beginning of ventricular contraction. S2 is then caused by the sudden blockage of reverse blood flow due to closure of the aortic and pulmonary valves at the end of ventricular systole, i.e., the beginning of ventricular diastole. In addition to these normal sounds other sounds may be present including cardiac murmurs, adventitious sounds, and gallop rhythm sounds, S3 and S4. Figure 5 shows a typical auscultATORY sounds at the cardiac apex and ECG signal. As shown in the figure, there are the healthy sounds, S1 and S2 mainly, including abnormal sounds during quick term, one second approximately. Thus, not only auditory information but also visual information is strongly needed to auscultatory technique.

Figure 6 shows the all acceleration-time curves for S1 and S2 obtained using the 64 sensors on the chest surface, a 23-year-old male. From the graph, clear and strong waveforms are seen around the heart valves (mitral, tricuspid, pulmonary and aortic valves) at the position of a right-angle triangle. It also suggests contour shape of the heart. Thus, abnormalities in the
pattern of valve motion form can be seen in these waveforms.

Fig 5. An illustrative example showing auscultatory sounds at the cardiac apex and ECG signal

Figure 7 a), b) shows sixty-three signals of the chest surface vibration and ECG signal and the visualized heart motion at the seven typical motion events during one heartbeat cycle respectively. The results visualized by frame-by-frame advance showed a typical heart motion of the strong pressure shock due to closing tricuspid valve and mitral valve (S1), and the closing aortic valve and pulmonic valve (S2) in sequence. Where S1-1 is the beginning contraction; maximum ventricular pressure (S1-2, S1-3); opening of mitral and tricuspid valves (S1-4); atrioventricular contraction (S2-1); and blood flow into the ventricle (S2-2, S2-3). In the figure, these events of the heartbeat and the position of the valves are clearly seen.

Fig 6. Acceleration-time curve recorded by the 64 sensors on the chest surface, a 23-year-old.
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By using the ECG signal scale, movement time-lag of heart’s each tissue (atrioventricular, cardiac chamber, and valves) are clear, which allows examination of heart function as well as monitoring heart movement in operation. In combination with auscultation, these visual imaging techniques would be very effective in helping to understand heart disease in clinical assessment.

Fig 7. Chest vibration and behavior of heart motion: a) Sixty-three signals and ECG signal for one heartbeat, b) Visualized heart motion with time at typical seven-motion events (Green shows convex and blue shows concave shape of the chest surface).

4 Concluding remarks

Auscultation requires substantial clinical experience, a good listening skills. They often have difficulties hearing the characteristic sounds. As a result, we are concerned about potential for missed diagnoses. It is essential to establish visualization of sounds, heart
movement, and to the digital database management of the auscultation examination. As a summary of the report, it can be shown as follows.

1) To globally and simultaneously show heart motion to assist diagnosis heart diseases in visual and digital, a new measurement technique for visualizing the chest vibration was established and demonstrated. The device consists of a 64-channel including ECG signal sensor unit and an imaging analysis unit. Using a new mounting plate for multi-sensor that can be fixed rapidly to the chest surface has been developed.

2) The visualized results are clear, showing a typical waveform motion of the strong pressure shock due to closing of the tricuspid valve and mitral valve of the cardiac apex, and the closing of the aortic and pulmonic valves in sequence, thus the events of the heartbeat and the position of the valves. Together with auscultation, the present visual imaging techniques will assist in understanding heart disease.

Acknowledgements
The authors wish to thanks Mr. Shigeru Hayashi, Miss. Xi Zhang and Miss. Sayo Momiyama who were joined the project as a graduate and/or an undergraduate student in 2005-2008 belonged at Gifu University.

References