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Recording of the acoustic signal from the stethoscope electronically and investigation of abnormalities in the heart function

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ABSTRACT

This paper presents a diagnosis system based on heart auscultation. It has been demonstrated that the acoustic signal of normal and abnormal people taken electronically by a modified stethoscope can be recorded for analyzing of heart sounds. The system detecting heart sound has three main blocks: Data Acquisition & Pre-processing, Segmentation, and Detection of heart diseases. How the heart sounds vary between normal and abnormal people is discussed in this paper. The above system has been tested with heart sounds of 105 normal people and that of 10 heart patients. It has been proved to be quite efficient and robust while dealing with a large variety of pathological conditions.

1. INTRODUCTION

According to the World Health Organization (WHO) heart disease and stroke kill around 17 million people a year, which is almost one-third of all deaths globally. By 2020, heart disease and stroke will become the leading cause of both death and disability worldwide. So, it is very clear that proper diagnosis of heart disease is important for patients to survive. Physicians have to know the condition of the heart to decide whether it would be surgery or non-invasive treatment.

Heart Auscultation is defined as the process of interpreting acoustic wave produced by the mechanical action of heart. It is a non-invasive, low cost screening method which is used as a fundamental tool in the diagnosis of cardiac diseases. It provides valuable information concerning the function of and the hemo-dynamic of the heart and has high potential for detecting various heart disorders especially valvular problem.

Though electrocardiogram (ECG) is an important tool for diagnosis, it has some drawbacks such as:

- It can detect diseases that are more or less related to blood-circulation and blood vessels, but there are heart diseases (structural abnormalities in heart valves and defects characterized by heart murmurs) that are difficult to detect using ECGs.
- Cost of ECG equipment is high.
- Limited availability of ECG equipment.

- Special skill is required to administer and interpret the results of ECG.

The problem is similar with the recently developed echocardiography, as it is bulky and expensive. Thus, in remote areas in developing countries, auscultation (diagnosis through heart sounds) seems to be a feasible alternative and it would be better if we can use both echocardiograph or ECG and auscultation to achieve even better diagnosis.

It is worthwhile to mention that, historically, the bare ear and the stethoscope were of great help in diagnosing most heart diseases, but it has been somewhat eclipsed in the research literature due to the advent of electrocardiographic methods. However, forming a diagnosis based on sounds heard through either a conventional acoustic stethoscope or an electronic one is itself a very special skill, and it may take years to acquire. Despite its obvious utility, because this skill is also very difficult to teach and grasp in a structured way, the majority of medicine and cardiology programs offer no such instruction. It would be very useful if the benefits of auscultation could be obtained with a simpler method, and using low-cost, easy to use equipment.

Heart sound analysis by auscultation depends highly on the skills and experience of the listener. Despite the importance of auscultation the internal medicine and cardiology, training programs underestimate the value of cardiac auscultation and the new clinicians are not well trained in this field. It has been reported that extremely high percentages (as much as 87 %) of patients referred to cardiologists for evaluation have benign heart sounds. Therefore, a computer-assisted system can help the general physician in coming up to a more accurate and reliable diagnosis at early stages and can avoid unnecessary referrals of patients to expert cardiologists at a distant.

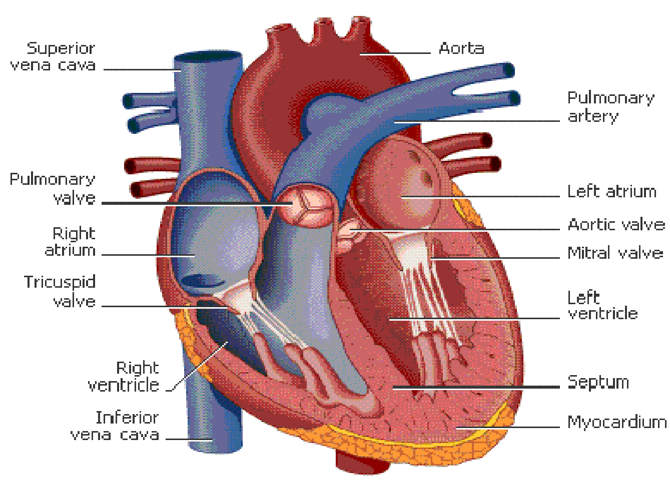

Figure 1 : The human heart

The heart is a pulsating pump that composes of four chambers and four heart valves (Figure 1). The upper chambers are the thin walled chambers called the right atrium (RA) and left atrium (LA) and the lower chambers are the right ventricle (RV) and left ventricle (LV). The LV has very thick muscular wall to withstand high pressures during contractions for pumping blood to the rest of the body. The heart valves are thin leaflets of tissues that open when each chamber contracts and close to prevent backflow of blood when the contraction is completed. The thin, filmy tricuspid and mitral valves (also called atrioventricular or AV valves) prevent backflow of blood from the ventricles to the atria, while the semilunar aortic and pulmonary valves prevent backflow from the aorta and pulmonary arteries into the ventricles.

2. METHODOLOGY

As part of our major effort towards developing a system for detecting heart diseases, a signal processing module, which has been developed for detecting lightning sound wave has been modified and used for this purpose. The module uses heart sound signals as input from an electronic stethoscope, which can be made available to the primary healthcare units. A normal stethoscope was modified by making it short and covered with cotton wool to reduce noise level. The acoustic signal from the modified stethoscope was fed into a sensitive microphone connected to the data acquisition system. These signals are then processed through embedded sophisticated signal processing algorithms before a final diagnosis can be made.

2.1 Structure of classification system

Classification is the process of assigning a label to an unknown pattern so that it is categorized into one of several known categories. In this work, heart sound samples were classified into heart-disease categories. In this section, the theoretical foundations for the pattern recognition and classification system used in this study are discussed. The following figure 2 represents the block diagrams of a typical classification system.

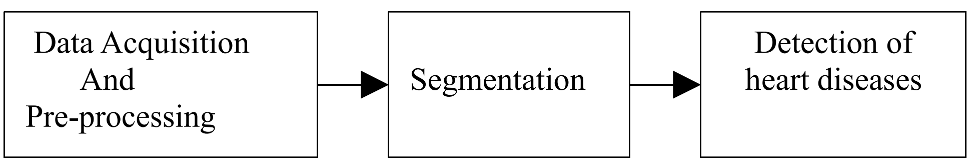

Figure 2: Block diagram of classification system

2.1.1 Data Acquisition and Pre-processing

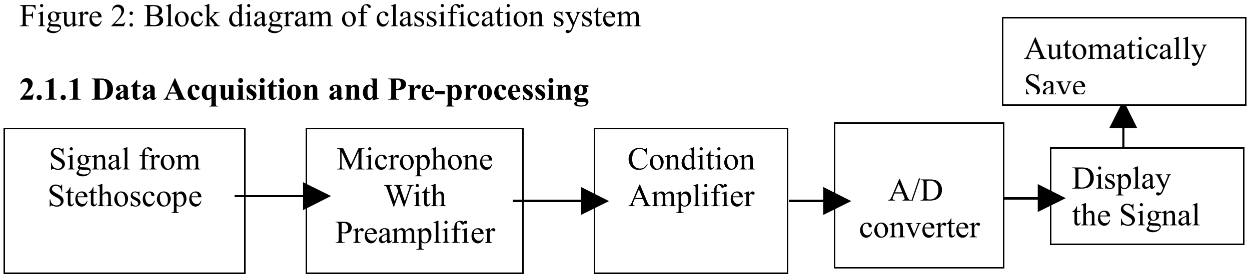

Figure 3: Block diagram of data acquisition system

The heart sounds of normal people were collected on a voluntary basis. The recordings were made using a Chinese made stethoscope (HS-30B) sparing 20-30 seconds per each person. Heart sounds of 105 normal persons were recorded under different age groups.

Heart sounds were recorded in a quite calm room (reduced environment noise). First, a good auscultation place on the chest of each person was selected by using another stethoscope. Signals from stethoscope were transferred to microphone. Signals were amplified by its preamplifier because the signals were collected with long cable wire (to avoid machine noise). Signals were filtered by a condition amplifier (with inside filters) and then amplified (lower cut off frequency of 0.1Hz and upper cut off frequency of 1 kHz. These are filters fixed in the conditioning amplifier. These cut off frequencies were selected according to the requirements).Then signals were fed into A/D converter to convert them into digital signals and displayed the signals graphically using labview program. (Figure 3) The recordings were saved automatically at every 5 sec.

2.1.2 Heart sound segmentation

Then text file is loaded to Matlab program and analyzed these signals. A typical waveform of recorded heart sounds by the module and loaded into Matlab is shown in Figure 4. First and second heart sounds were identified and then systolic and diastolic periods of each individual cycle were measured.

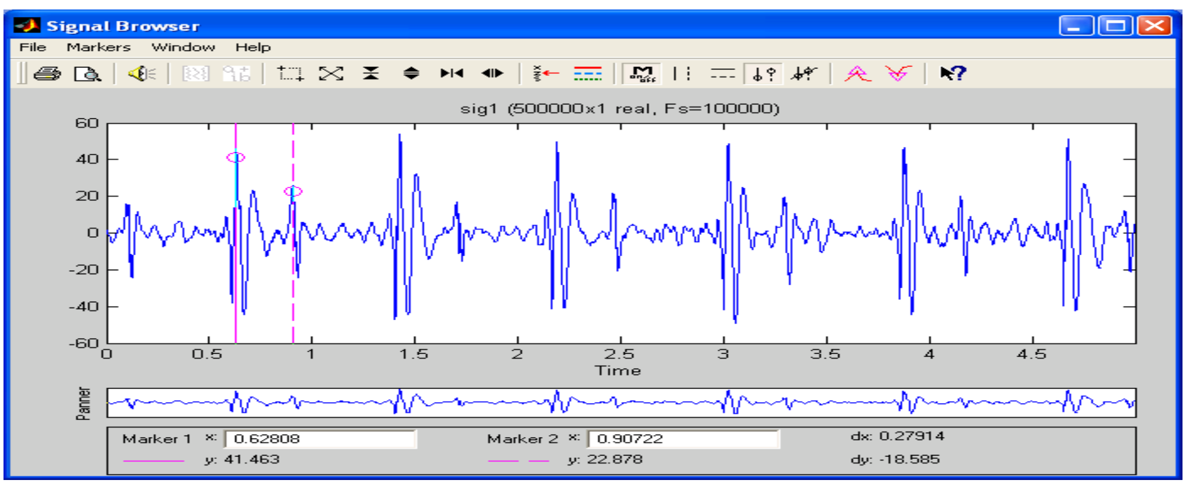

Figure 4: The graphical user interface of the imported signal

2.1.3 Detection of heart diseases

Heart sound of abnormal people was compared with that of normal people. i.e. any difference in first / second heart sound (such as frequency or amplitude or pattern) or systolic / diastolic periods indicates various symptoms. These symptoms were diagnosed and then matched with theoretical symptoms of any heart diseases. This helps to predict that there is a possibility for presence of the heart diseases. However, other tests like chest x-ray, ECG, and echocardiogram (echo) are needed to help confirmation of the diseases.

3. RESULTS AND DISCUSSION

3.1 Heart sound of normal persons

In normal persons, first heart sound (S1) has two components, tricuspid component and mitral component. Due to the difference in pressure, mitral valve closes first and then the tricuspid valve follows this (oxygenated blood has high pressure than non-oxygenated blood) and therefore two peaks for first sound could be observed. Second heart sound (S2) has two components aortic component and pulmonary component. Mostly both are closed at the same time and therefore one peak for second sound could be observed. In these persons, murmurs of the systolic and diastolic periods are absent or negligibly small (Fig 5)

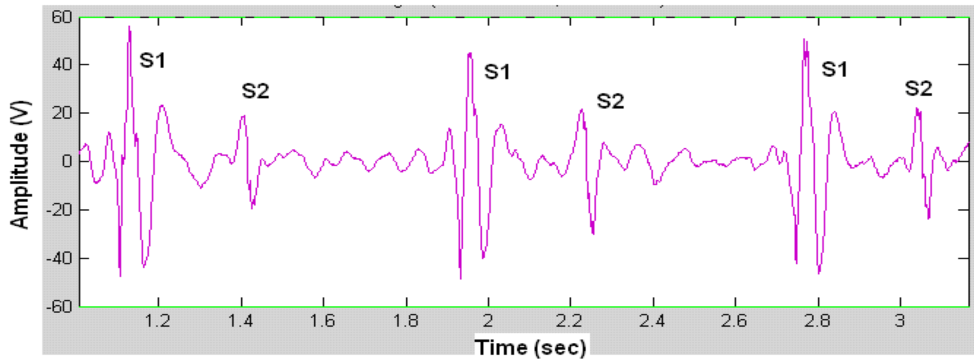

Figure 5: Heart sound of a normal person

3.2 Atrial Septal Defect (ASD) Patient

Figure 6 shows two peaks in second sound (S2) clearly. Those are aortic component and pulmonary component. Normally aortic and pulmonary valves close at the same time. But due to the lack of blood into the right ventricle [3], the pulmonary valve closes late. That is aortic valve closes first and nearly after 0.0365sec pulmonary valve closes. Hence aortic valve closes at 39.17Hz and pulmonary valve closes at 26.34Hz.

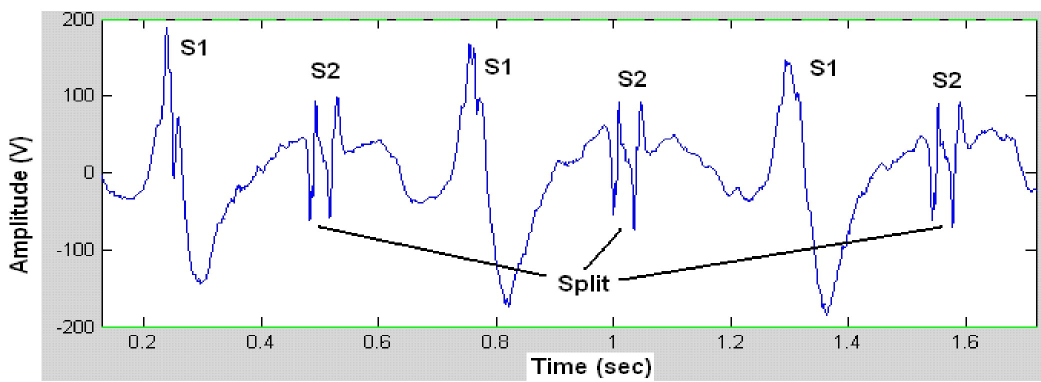

Figure 6: Heart sound of an Atrial Septal Defect (ASD) patient

In ASD patients both first and second heart sounds have high amplitude than that of normal person (Figure 5). Due to continuous blood flow from right atrium to right ventricle, most of the time tricuspid valve does not close. So, first heart sound has only mitral component. Ejection systolic murmur is also observed in the systolic period. As far as ASD is concerned when there is splitting of second sound, we can conclude that most probably such a patient has ASD. The hospital records also say that, this patient has ASD. This further confirms the findings of the work.

3.3 Small Ventricular Septal Defect (VSD) Patient

Figure 7 shows that first and second heart sounds are normal, but continuous murmurs with in systolic period were observed. That means early, mid as well as late diastolic phase contains murmurs. This type of continuous murmur is called pan systolic murmur. Most likely this would be ventricular septal defect (i.e. small VSD- small hole in the septum between the two ventricles-[3]). The hospital records also indicate that this patient has VSD. This further confirms the findings of this work

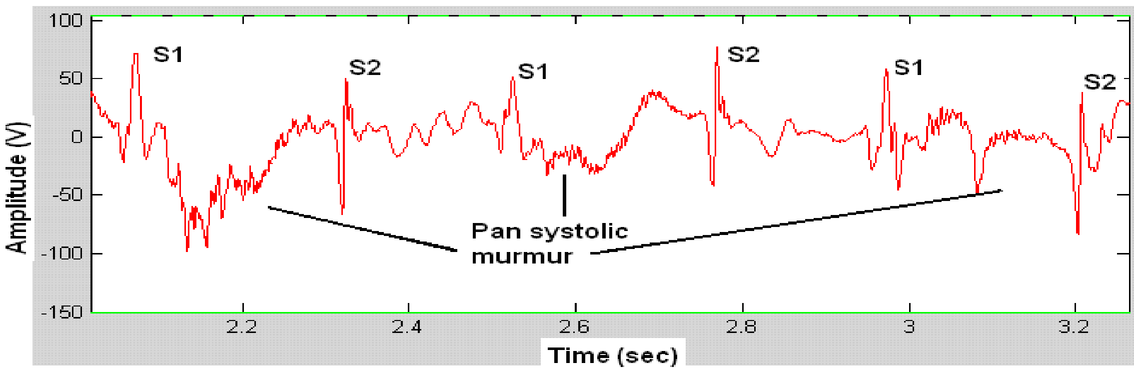

Figure 7: Heart sound of a small Ventricular Septal Defect (VSD) patient

3.4 Large Ventricular Septal Defect (VSD) Patient

Continuous murmurs at systolic period (pan systolic murmur) as well as diastolic period (mitral flow murmur) was noticed in this VSD patient (Figure 8). And also second sound has accentuated at high amplitude (compare to Figure 6). Most of these symptoms relate with large VSD. The hospital records also say that this patient has VSD. This further confirms the findings of this work.

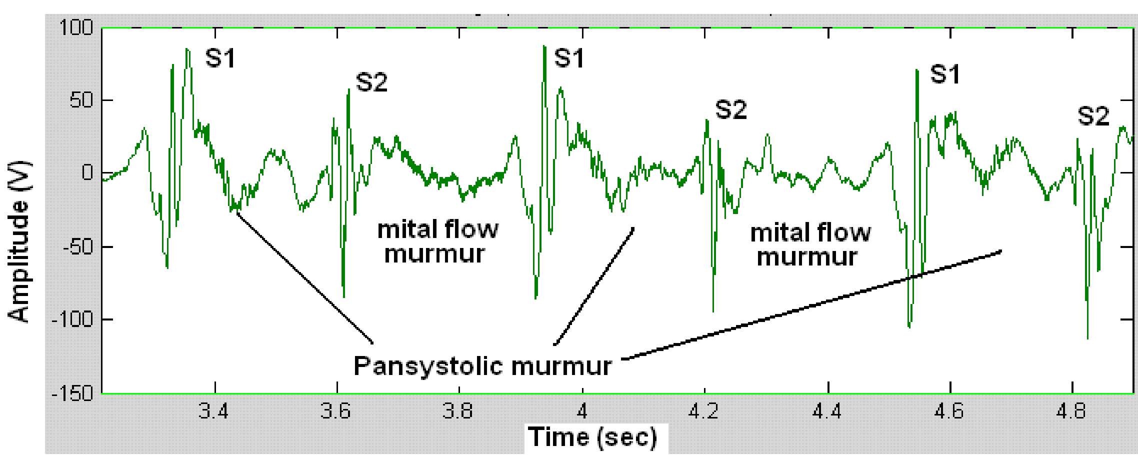

Figure 8: Heart sound of a large Ventricular Septal Defect (VSD) patient

3.5 VSD with pulmonary hypertension Patient

Figure 9 shows that high frequency of second heart sound (nearly 105.8Hz) and unimpressive ejection murmur appeared in systolic period. Due to high pressure in the lung arteries, [3] pulmonary valve closes quickly. This may make second heart sound louder. Most symptoms may be related with large VSD with pulmonary hypertension. The hospital records also say that this patient has VSD with pulmonary hypertension. This further confirms our findings.

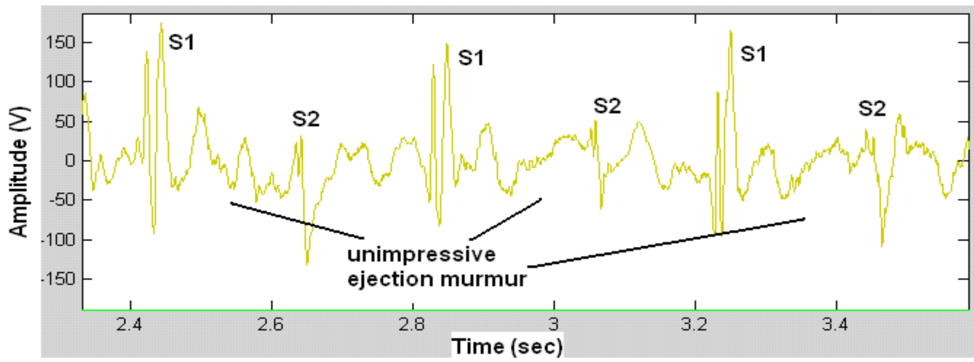

Figure 9: Heart sound of a VSD with pulmonary hypertension patient

3.6 VSD with tricuspid atresia Patient

Figure 10 shows first heart sound has only one component. It may be due to any of tricuspid / mitral valve absent or imperforate (does not have an opening to allow blood flow across between atrium and ventricle). There is high frequency & high amplitude in second sound (98.14Hz) and murmur was noticed during the systolic period. The hospital records also say that this patient has several of diseases such as tricuspid atresia, VSD, and pulmonary stenosis. According to this it may be concluded that tricuspid valve is absent in the first heart sound [3]. Pulmonary stenosis may also be present due to tricuspid atresia.

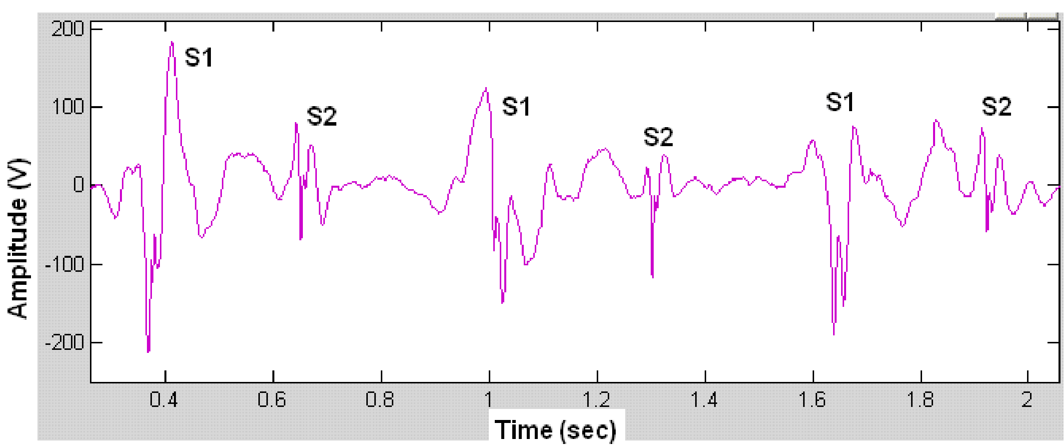

Figure 10: Heart sound of a VSD with tricuspid atresia patient

3.7 Patent Ductus Arteriosus (PDA) Patient

Figure 11 shows high frequency of murmur in systolic as well as diastolic phases. This type of continuous murmur (machinery murmur) may be extending through second heart sound. Due to these continuous murmur, first and second heart sound maybe absent [3]. It can be concluded that this patient has PDA. This is a further conformation of the present findings.

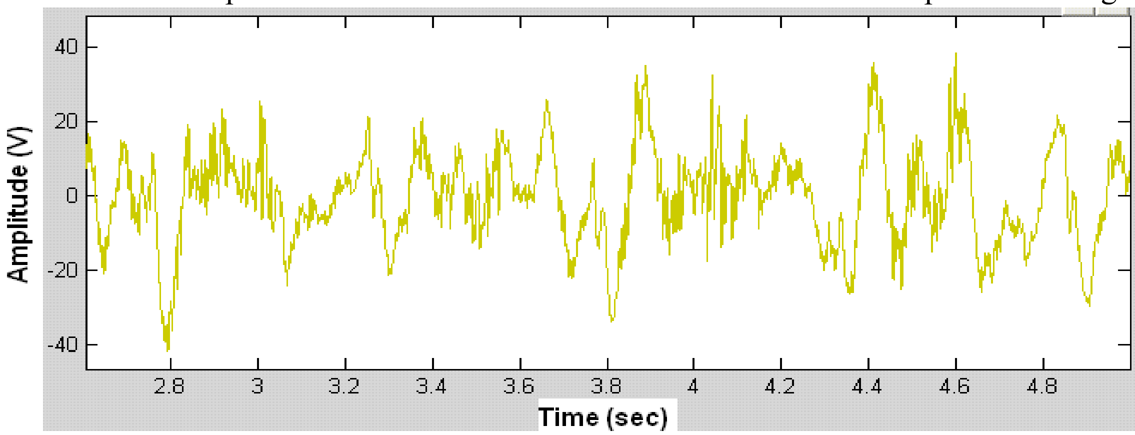

Figure 11: Heart sound of a Patent Ductus Arteriosus (PDA) patient

4. CONCLUSION

It has been demonstrated that the acoustic signal for the heart of normal and abnormal persons when measured electronically by using a modified stethoscope and computer based data acquisition system detection could be recorded successfully. Heart sound of abnormal persons was investigated and compared with the heart sound of normal person.

- Heart diseases of ASD, VSD, and PDA were successfully and quickly detected from the patients with system used.
- This can assist the general physicians in coming up to a more accurate and reliable detecting heart problems at early stages and can reduce unnecessary referrals of patients to expert cardiologists at a distant.

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