# Detection of Atrial Septal Defect by Heart Sound Signal Analysis and its Relation with Tricuspid Failure

O. Akgun, and H.S. Varol

***Abstract*—Atrial Septal Defect (ASD) takes an important place in pediatric heart diseases. In ASD there is an opening in the wall between left and right atriums. This study addresses three heart sound signals obtained from two patients by the implementation of time amplitude analysis.**

**In the said examination, a murmur that developed due to fixed pairing at S2 and tricuspid failure was observed in diastole, and in addition, its significance in detecting the disease in the auscultation region was established.**

*Index Terms*— **Atrial Septal Defect, Heart sound signals, Time-amplitude analysis, Tricuspid.**

## I. Introduction

ATRIAL septal defect is the condition of having a hole in the heart, between the atriums, and it causes abnormal blood flow. Therefore, a certain amount of the heart passes to the right heart. This could cause damage in pulmonary veins and myocardium due to the increase in the amount of blood pumped into lungs in years. It is found in baby girls more compared to baby boys and it is generally common in children with Down syndrome.

Usually it does not develop any symptoms. There are cases that diagnosis was not possible in individuals until the ages between 30 and 40 who do not visit a physician or a hospital. In such patients, the disease is suspected when they pay a visit to a physician for another reason, and with hearing murmur and some additional sounds from the heart during a careful examination. [1].

## II. Auscultation Areas

Auscultation is of great importance in pre-diagnosis of heart diseases. Areas where auscultation is carried out are quite important in the diagnosis of some diseases.

These areas include:

a. Tricuspid Focus: This area is found between the fourth intercostals space on the left of sternum, that is, on the edge of left lateral sternum (chest bone). Tricuspid and right cardiac sounds are best heard from this area.

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b. Mitral Focus: It is the area at the line of eminentia-clavicle, fifth intercostals space. Mitral and left cardiac sounds are best heard from this area.

c. Aortic Focus: Aortic focus on the right of sternum is found in the second intercostal space. Sounds from aortic valve are best heard from this area.

d. Pulmonary Focus: Pulmonary focus on the left of sternum is located at the second intercostals space. Sounds from pulmonary valve are best heard from here (Fig.1) [2].

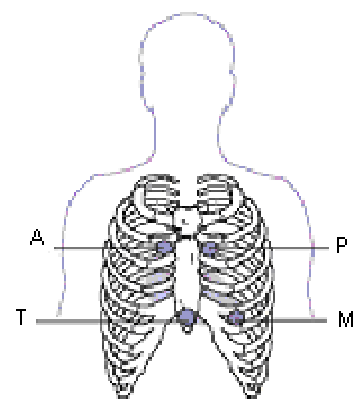


Fig. 1. Cardiac auscultation foci: A-Aortic, P-Pulmonary, T-Tricuspid, M-Mitral

## III. Time Amplitude Analysis of Heart Sound Signals with ASD

A heart sound signal recorded from a healthy heart and that complete a single cycle in about 0.8 seconds was sampled by fs = 11025 Hz sampling frequency, and one cycle was drawn with n = 8900 sample. Of this time period, systole takes up 0.3 seconds and diastole 0.5 seconds (Figure.2). S1 that is found at the beginning of systole and S2 seen at the beginning of diastole are two main components of normal heart sound signals.

S1 is comprised of mitral and tricuspid components and S2 includes aorta (A2) and pulmonary (P2) components and both are the main sound signals.

Normally, left atrium is contracted earlier than right atrium, and mitral valve closes earlier than tricuspid and aortic valve closes earlier than pulmonary valve. Due to the fact that aortic and pulmonary valves close at different times, the second heart sound is heard as double during auscultation. This pairing becomes more marked in ASD.

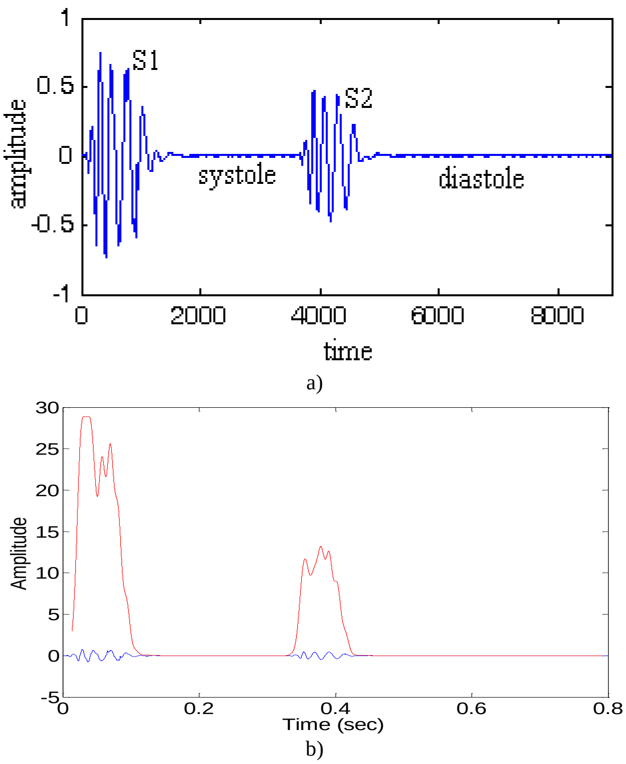


Fig. 2. Time amplitude and energy graph of a normal heart sound signal

The salient elements in the auscultation of ASD are as follows:

Findings that are observed during the auscultation are systolic ejection murmur in pulmonary focus, fixed pairing (typical finding) in the second heart sound, tricuspid related diastolic murmur (due to relative tricuspid failure) in cases with left-to-right-shunt at advanced levels, and findings related to tricuspid in cases with atrial fibrillation. In cases that develop pulmonary hypertension, a decrease occurs in the murmur heard in pulmonary focus. P2 becomes rigid. Pulmonary failure and early diastolic Graham-Steel murmur due to pulmonary failure may occur [3,4].

However, if the possibility of overlooking also in auscultation is taken into consideration, it is aimed to help with the diagnosis of the disease by detecting its general characteristics through analyses mentioned in this study.

## IV. APPLICATION

The analyses were conducted on signals obtained from two ASD patients. The signals were sampled by a sampling frequency of 44000 Hz.

The recording shown on Figure 3 was obtained from the upper left sternal edge of a 5 year old child with atrial septal defect having a hole of 12 mm diameter in right atrium. Fixed pairing at S2 (time between A2 and P2 components being approximately 70 milliseconds) and systolic injection murmur are clearly observed [5,6,7].

Figure 4 shows the recording of a diastolic murmur obtained from the lower left sternal edge of the same patient and observed in relation with tricuspid stenosis.

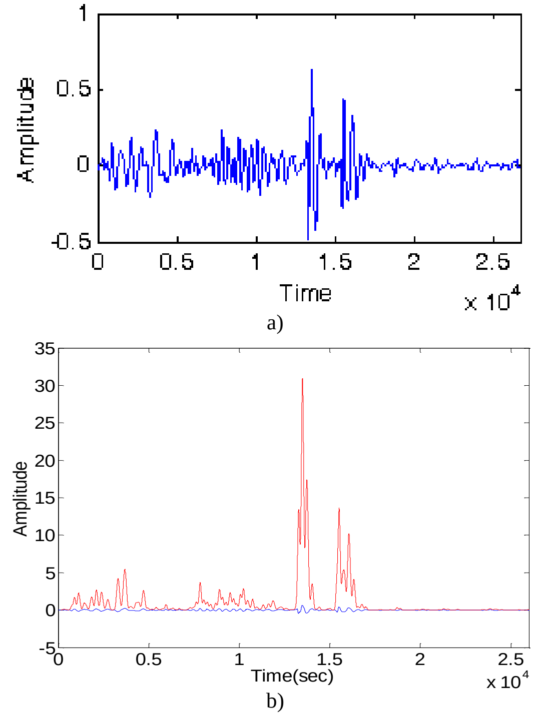


Fig. 3. Time amplitude and energy graph obtained from the upper left edge of the sternum of a heart signal with ASD

A normal atrioventricular valve demonstrates a normal blood flow without causing turbulence. In an atrial septal defect in which left-to-right shunt is in advanced stage, turbulence would occur in tricuspid valve in diastole due to excessive blood.

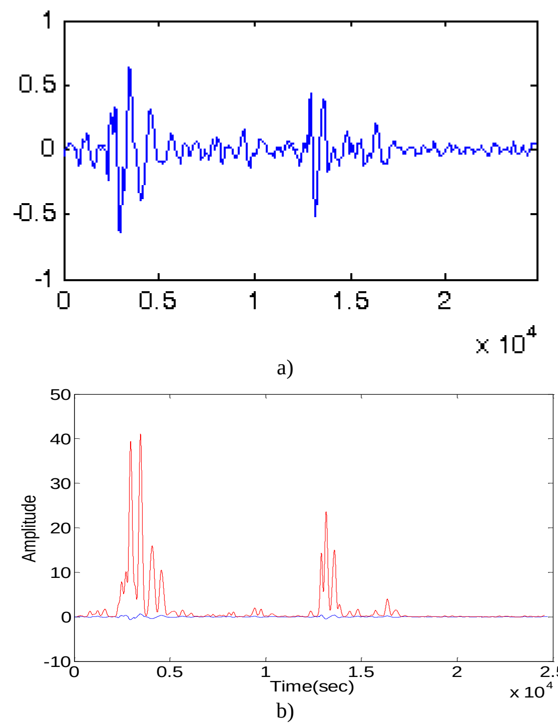


Fig. 4. Time amplitude and energy graph obtained from lower left sternal edge of the same sound signal from the heart with ASD.

Figure 5 shows the recording obtained from lower left sternum of another patient at the age of 5 with atrial septal defect of

20mm in diameter. Also observed in this recording is diastolic murmur due to relative tricuspid stenosis [8].

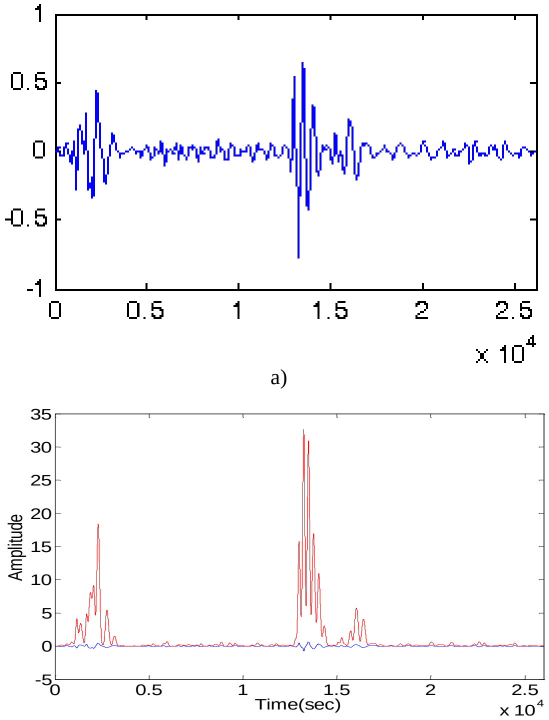


Fig. 5. Time amplitude and energy graph obtained from lower left sternal edge of the sound signal from another heart with ASD.

AR model in the practical application of the discrete-time systems are very effective. In the synthesis model y(*n*) it is an output. If the heart input white noise is considered as a linear dynamic system, y(*n*) output signal and v(*n*) is white noise (Fig.6).

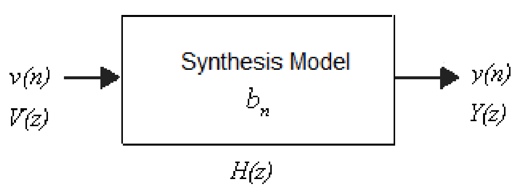


Fig. 6. AR model of the heart sound signal (Synthesis Model).

y(*n*) output expression is given Eq.(1).

$$y(n) = \sum_{k=0}^{M} b_k . v(n-k) \ , b_0 = 1 \tag{1}$$

The current value of the process y(*n*), the previous value can be given Eq.(2).

$$y(n-1), y(n-2), ......, y(n-M) \tag{2}$$

Therefore equation (1) expression of the AR model can be evaluated as the synthesis process.

$$y(n) = b_1 . y(n-1) + b_2 . y(n-2) + ....... + b_M . y(n-M) + v(n) \tag{3}$$

$b_1, b_2, \ldots, b_M$ constants are AR parameters. ($b_M = -a_M$), Equation (3) is generalized, Equation (4) is obtained.

$$B(z) = 1 + b_1 z^{-1} + ....... + b_M z^{-1} \tag{4}$$

$$B(z).y(z) = v(z) \tag{5}$$

$$H(z) = \frac{Y(z)}{V(z)} = \frac{1}{\sum_{n=0}^{M} b_n . z^{-n}} \ , \tag{6}$$

The transfer function of the synthesis model, equation (6) is also provided.

Transfer function of the synthesis model also assumes an IIR filter task will be infinite duration. Thus, H(*z*) has only in polarity. Therefore, stability is determined by the locations of the poles. The roots of the characteristic equation H(*z*) are the pole. $p_1, p_2, \ldots, p_M$, are the pole of the H(*z*).

$$1 + b_1 z^{-1} + b_2 z^{-1} + ....... + b_M z^{-1} = 0 \tag{7}$$

$$H(z) = \frac{1}{(1 - p_1 . z^{-1})(1 - p_2 . z^{-1})........(1 - p_M . z^{-1})} \tag{8}$$

Sign on AR method, all-pole input and output of the discrete filter is modelled as white noise (Fig.6). Equation (3) linear filters based on equation (Fig.7) as in the statement is determined as a *z*-domain transfer function comprising poles. Unit output of the filter evaluated on apartments with zero mean and variance, s2, driven by white noise.

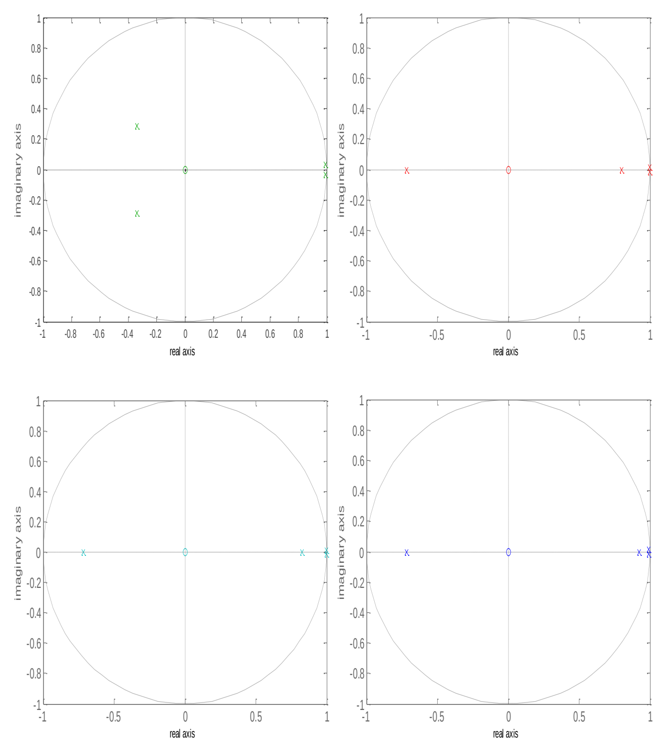


Fig. 7. Zero-polar maps of normal and 3 ASD patients

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Zero-polar maps of normal and ASD patients were compared (Fig.7).

## V. CONCLUSIONS

1.Typical symptom of atrial septal defect in time-amplitude analysis is the fixed pairing at S2.
2.Murmur found in diastole in patients with atrial septal defect occurs due to relative tricuspid failure caused by ASD.
3.Murmur in diastole that occurs due to relative tricuspid stenosis caused by ASD can be detected from lower left sterna edge.

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