Study on Diagnosis of Pleural Effusion from Lung Sounds

Technical Report · June 2017

DOI: 10.13140/RG.2.2.33809.99681

7 authors, including:

Mahtab Noor Shaan
Hiperdyne Corporation

Asir Intisar Khan
Stanford University

Study on Diagnosis of Pleural Effusion from Lung Sounds

Md. Serajum Monir, A.N.M. Nafiz Abeer, Mahtab Noor Shaan,
Md. Sanzid Bin Hossain, Monowar Mahmud, Asir Intisar Khan, Md. Aynal Haque
Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology

***Abstract*—The lungs, being the primary organs of respiration, are affected by many diseases that cause things like effusion of fluid, both gaseous and liquid, which are harmful in every aspect. This study focuses on how such diseases that involve effusion of pleural fluid can be detected from their effects on sound transmission. By using the data taken from a single patient as well as multiple healthy persons with the help of a digital stethoscope, a number of simulations are performed to evaluate the performance of the proposed method. This method can be used as a cheap but reliable alternative of the present diagnosis methods, as evident from the analysis of the simulations.**

***Index Terms*—Lung sounds, Egophony, Pleural Effusion.**

I. Introduction

PLEURAL EFFUSION is the excess fluid that accumulates in the pleural cavity, the fluid-filled space that surrounds the lungs. This excess fluid can impair breathing by limiting the expansion of the lungs. This can be of various types depending on the fluid that is accumulated (blood, urine, pus, air etc.). This paper concerns the study of effect of pleural effusion on sound transmission from the lungs to chest wall. The proposed method tries to establish a useful correlation between voice sounds and the excess fluid in the pleural space.

Pleural effusion can be linked to the malignancy of the lungs, lung infection i.e. pneumonia, ineffective pumping of blood due to weakening of the heart muscle. Diagnosis of this abnormality includes visual inspection of chest wall expansion while breathing, listening to the sound transmitted from the lungs through the chest wall, X-ray, ultrasound scan [1], computerized tomography (CT) scan etc. The excess fluid in the pleural space modifies the acoustic properties of the lung and results in different sound transmission to the chest wall. In [2] the effects of pleural effusion on sound transmissibility through the canine thorax is studied by measuring the relative level of transmitted sound wave before and after controlled injection of saline into the bilateral pleural space. It is reported that pleural effusion decreased the sound transmissibility in the frequency range between 100 and 300 Hz. In another study [3], the effect of pneumothorax (PTX), an abnormal accumulation of air in the lung space, on the pulmonary acoustic transmission is studied through measurement of sound before and after lung collapse. Stronger acoustic transmission blocking by excessive air reduces the frequency contents of the controlled sound in 400 to 600 Hz.

The paper is organized as follows. Section II presents the proposed method. Section III describes the details of simulations and results. Concluding remarks are presented in section IV.

II. Methodology

Transmitted voice sounds over healthy lung and pleural spaces are normally heard as unintelligible mumble. But this transmission is enhanced when the tissue is consolidated. One of the abnormal voice sounds is known as egophony which is detectable over the upper border region of pleural effusion. In this paper correlation of this abnormality with the pleural effusion is studied from the power spectral density(PSD) of the acquired data.

A. Data Acquisition

To record the lung sound, a digital stethoscope is made from a binaural stethoscope (Fig. 1). The recorded sounds are saved as wav, 32-bit float format with a sampling frequency of 44100 Hz.

Figure 1: A Modified Binaural Stethoscope (used as a Digital Stethoscope with the mobile phone as a recorder)

B. Noise Reduction

The recorded lung sounds are mainly corrupted with the motion noise generated due to movement of chest piece of the stethoscope during recording and heart sounds picked up from the chest wall. The first one has a very high frequency component which is fortunately outside the region of interest. But the normal heart sounds have peaks in energy in the 50-70 Hz range and are also higher in pitch. To remove this component along with the background noise the recorded signals are enhanced by subtractive noise suppression analysis [4]. A noise profile is estimated by assuming the noise environment remains stationary to the extent that during recording the expected spectrum of the noise remains same as that of the estimation. Fig. 2 shows the enhancement of a noisy recorded signal.

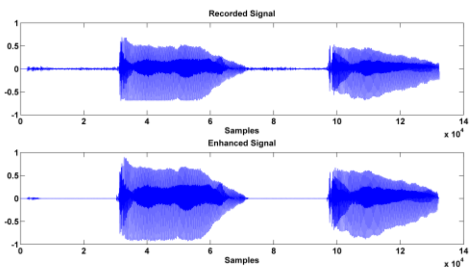

Figure 2: Recorded Signal by the Digital Stethoscope and the Enhanced Signal as an Output of Spectral Subtraction

C. Silence Detection

To detect the windows for lung sound the log-energy, in (1), for each frame is calculated and then compared to a threshold value. (Fig. 3)

For ith frame, $P_i = \log_e(\sum_{n=0}^{L-1} |x(n+iD)|^2)$ (1)

Where, D is number of overlapped samples and L is the window length.

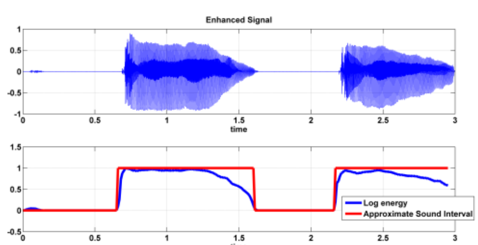

Figure 3: Sound activity is detected by comparing to a threshold value.

D. Spectrum Estimation

The enhanced version of the recorded signals, $x(n)$ are divided into overlapped sequences $x_i(n)$ and Hamming window is applied to the sequences. Estimated power spectrum for these sequences is then averaged. Finally the estimate produced with Welch's method [5] are expressed in terms of $x(n)$ as follows

$$\hat{P}(e^{j\omega}) = \frac{1}{KLU} \sum_{i=0}^{K-1} \left| \sum_{n=0}^{L-1} w(n)x(n+iD)e^{-jn\omega} \right|^2 \quad (2)$$

Where, D is the offset of successive sequences, L is the sequence length , K is number of sequences $x_i(n)$ that cover the entire data points of $x(n)$ and U is a normalization factor for power in the window function given by (3).

$$U = \frac{1}{M} \sum_{n=0}^{L-1} w^2(n) \quad (3)$$

The window sequence in time domain for Hamming follows (4).

$$w(n) = 0.54 - 0.46\cos(\frac{4\pi n}{L-1}) \ ; 0 \le n \le L-1 \quad (4)$$

III. Experiments and Results

We have collected lung sounds from four male subjects and one of them is affected by pleural effusion, confirmed by the chest X-ray image (Fig. 4).

Figure 4: Chest X-ray Image of Subject 1. The whitish area at the right lung base is the excessive fluid between the pleural spaces.

All test subjects are asked to say the letter 'E' as in 'bee' several times and the sound transmission from the lung to the chest area is recorded by the digital stethoscope. The recorded data are then processed through noise cancellation block and then the power spectrum density (PSD) for every test subjects are estimated by Welch's method. The PSD for all four test subjects are showed in Fig. 5.

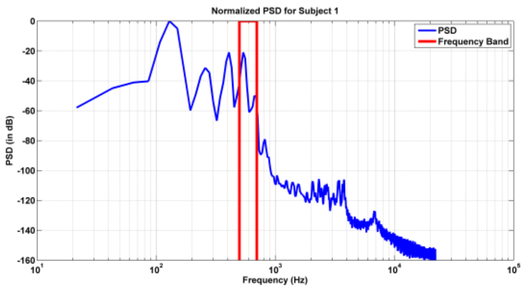

Figure 5a: Estimated PSD for Subject 1

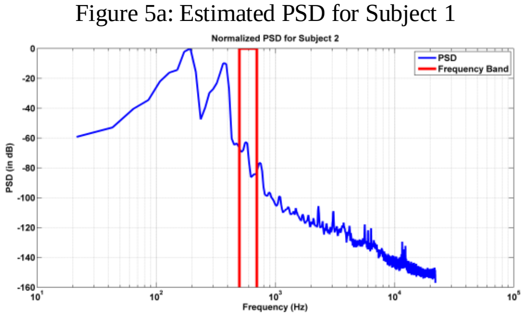

Figure 5b: Estimated PSD for Subject 2

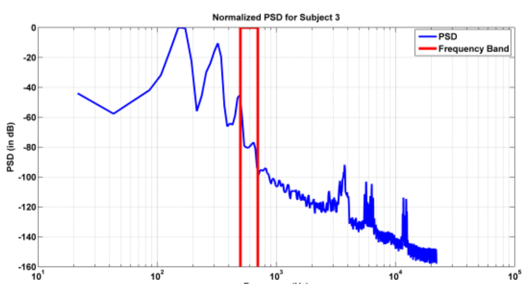

Figure 5c: Estimated PSD for Subject 3

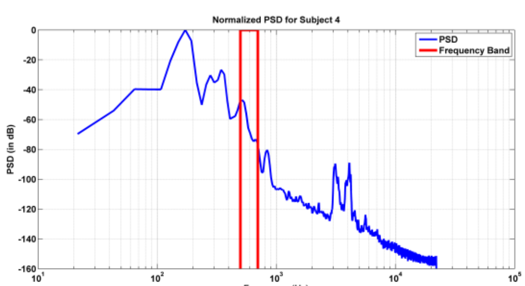

Figure 5d: Estimated PSD for Subject 4

We have also analyzed the data of lung sounds (egophony) from online source [6]. The estimated PSD for those data also shows (Fig. 6) the increase of energy in the frequency band 500-700 Hz as our recorded data.

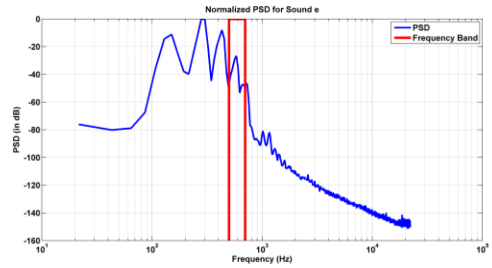

Figure 6a: Estimated PSD for Sound 'e' over Healthy Lung

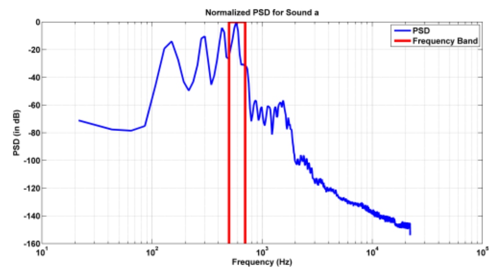

Figure 6b: Estimated PSD for Sound 'e' over Consolidated Lung heard as 'a-aay'

When the lung is affected by pleural effusion, the region between the chest wall and the consolidated area becomes narrower. This results in impedance matching between the lung and the chest wall and it enhances the sound transmission in such areas. In our analysis the sound transmission in range of 500-700 Hz is increased for data of the subject 1. In all other cases this frequency band has little significant energy. Fig. 7 shows the energy in two significant frequency bands, e.g. 200-400 Hz and 500-700 Hz.

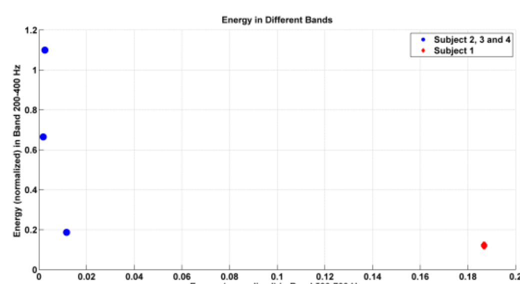

Figure 7: The spectrum was divided into two bands. Band 1 = 200-400 Hz; Band 2 = 500-700 Hz. The point on the far right corner corresponds to the case with excessive fluid between the pleural spaces.

IV. Conclusion

Based on the study from limited number of test subjects, the absence of egophony over the area of suspected region reduces the necessity of a chest radiograph to confirm the diagnosis of absence of pleural effusion. This hypothesis needs to be tested on more patients to be justified.

References

[1] Soni NJ, Franco R, Velez MI, Schnobirch D, Dancel R, Restrepo MI, Mayo PH.Ultrasound in the diagnosis and management of pleural effusions.JHosp Med. 10(12):811-6. Dec. 2015.

[2] Yonemaru M, Abe T, Kobayashi H, Kawashiro T, Yokoyama T. Changes in sound transmissibility through the canine thorax due to the experimental pleural effusion[Japanese]. Nihon KyobuShikkanGakkaiZasshi.29(7):829-35. July 1991.

[3] Mansy HA, Balk RA, Warren WH, Royston TJ, Dai Z, Peng Y, Sandler RH. Pneumothorax effects on pulmonary acoustic transmission. Journal of Applied Physiology. 119(3): 250-257. Aug. 2015.

[4] Steven F. Boll. Suppression of acoustic noise in speech using spectral subtraction. IEEE Transaction on Acoustics, Speech, and Signal Processing. 27(2):113-120. April 1979.

[5] P. D. Welch. The use of fast Fourier transform for the estimation of power spectra: A method based on time averaging over short modified periodograms. IEEE Trans. Audio and Electroacoust. AU-15:70-73, June 1967.

[6] Online resource: https://www.practicalclinicalskills.com/breath-sounds-reference-guide