Development of Computer- Aided Diagnosis System to Evaluate the Lung Efficiency Using Electrical Impedance Tomography

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ABSTRACT

Nowadays, one of the most common diseases of industrial and developed societies is pulmonary disorders. Creating a smart computer system to identify the patient's lung function and check the disruption of each region can significantly contribute physicians in better and more accurate treatment of the disease. In this paper, an algorithm is proposed to determine the efficiency of each part of the lung due to the amount of oxygen received using the electrical impedance tomography system. The data used in this paper include 82 of the registered data from both the inhale and exhaling modes of 52 patients with lung disorders that have a sampling frequency of 20 Hz. As mentioned in this paper, the signals from each part were extracted and analyzed while the lung segmentation was done as quadrants. Then the peaks of each section were identified, and their ratio with the total signal was calculated which is a total of four parts. The relative variation of each inhale and exhalation cycle compared to the standard volume of each lung component in healthy person was considered as an indicator to define the level of lung's function in receiving oxygen levels. Although the ratios mentioned above are closer to the standard criterion of each section, it is that the person receives the desired oxygen content. Otherwise they have lung impairments, such as asthma and asthma. As a result, by comparing the lung volume signals in healthy individuals and patients and determining the relative index, we can be helpful to different people and patients during and after surgery to diagnose their lung's efficiency as well as their health.

Keywords: Pulmonary Disease, Lung Volume Changes, Inhalation-Exhalation, Signal Processing, Electrical Impedance Tomography

1. INTRODUCTION

Annually, a large number of people get pulmonary diseases which are affected by air pollution, tobacco or genetic tribulation, etc. Lungs are the member of the body which expanded and contracted thousands of times a day and separate carbon dioxide from oxygen. Their disorders can make a serious problem with all of the respiratory system [1].

Pulmonary diseases include Asthma, chronic obstructive pulmonary diseases (COPD), Pneumonia, Tuberculosis, Lung cancer. Asthma is a disturbance which is detected by a cough, and it is rising from the Inflammation of the respiratory tract. Some kinds of that are caused by an allergy to something such as dust, the breath of the animals, plants or other things. These show themselves with a reaction of the body immune system [2,3]. Chronic obstructive pulmonary diseases, consist of Bronchitis and Emphysema. Chronic Bronchitis creates Phlegm a cough, but in Emphysema make some disorders of the lungs. Many patients usually have both of them [4]. Chronic Bronchitis is generated from a mucus overproduction of the lung cells, and it causes the lung function to reduce., Increasing the risk of airway obstruction, raising the risk of respiratory infection or death [5]. Pneumonia is One of the infectious diseases in adults and enters bacteria into the body from the respiratory tracts [6]. Tuberculosis is also one of those diseases that is another bacterial infectious disease and is spread by blood circulation or lymph node [7].

Lung cancer is a disease which has many forms and the most common has existed in the middle of the lung lobes [8].

Electrical impedance tomography (EIT) uses the low-frequency electrical current to probe a body; the method is sensitive to changes in electrical conductivity. The continuous assessment of respiratory status is one of the cornerstones of modern intensive care unit (ICU) monitoring systems. It may also quantify gains (recruitment) and losses (over distention or DE recruitment), granting a more realistic evaluation of different ventilator modes or recruitment maneuvers, and helping in the identification of responders and non-responders to such maneuvers.

There is now a large and growing clinical interest in the technology, and commercial devices have been recently introduced to the market. First, the feasibility of localizing small non-conductive objects within a saline phantom model was evaluated. Second, this result was utilized for the detection of the aorta by the EIT in ten anesthetized pigs in with a comparison to thoracic computed tomography (CT). In result, reflux of saline solution into the heart happened with a consecutive increase of conductivity within the heart chambers. Possible causes could be an anatomical insufficiency of the aortic valve or, more likely here, a functional insufficiency of the aortic valve as a result of our bolus injection which was conducted rapidly and with high pressure. Furthermore, the bolus was administered over the left carotid artery in the aortic arch. Alongside it, utilization for monitoring of resin curing, absorbed water or homogeneity monitoring during stirring of carbon nanotubes is also considered and they described the development of the multiplexer, which is one of the essential parts of the impedance tomography system.

In 1980, Barber, and Brown from EIT used in the fields of lung evacuation this method was tested on the acute respiratory distress syndrome [10] in this way that the EIT and frequent measurement of surface voltage by electrodes do [11]. In 1985, a lot of clinical applications were offered by the EIT which is an appropriate way for the long imaging and respiration function when connecting ventilator [12]. The EIT is used in medical imaging, material engineering, civil engineering, biotechnology, nanotechnology, chemical engineering, etc. Comparing images resolution with the other images demonstrated economically, imaging by the EIT has less danger, more care and more advantageous [13].

In addition to this, research assessed in the fields of the various patterns of the EIT measurement to maximize the heart rate signal of the heart to the lung by Tobias Menden and this workmate in 2017. What they found out heart rate signal is different from the respiration signal in the size of one magnitude. In effect, one method of the filter was used for both signals [14]. In the past and present, the computed tomography was used as a complement procedure besides the EIT system, but because of applying the x-ray, carrying out it has been harmful to the patient. Moreover, frequent supervision is not done for the patient who has an acute disorder, especially when they are connected to the ventilator apparatus [15]. In 2018, Wodack and his co-worker did the researches on the figuring out of the vessel structure of the chest by the Electrical Impedance Tomography. In this form, they have used two ways of the imaging, including CT and EIT on ten pigs and the area was known for the possibility of being Aorta vessel [16]. In 2017, Jakub Rosler and his colleagues made the multiple plans for the EIT system to be able to simplify visual recognition in this procedure [17].

2. MATERIAL AND METHODS

2.1 Data Base

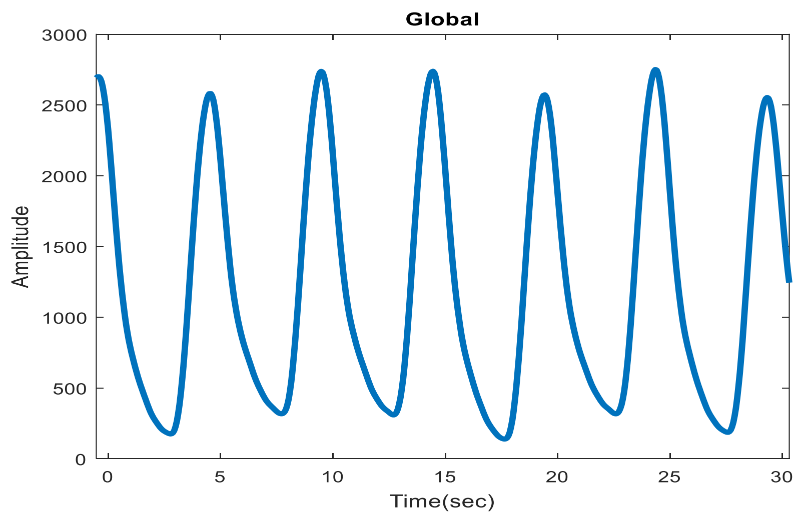
The data used in this paper includes 82 registered cases recorded from 52 patients with lung disorders collected by Dr. Hashemian in Masih Daneshvari hospital of Tehran. The sampling frequency is 20 Hz.

Most of these data are recorded from patients who have gone out of the surgery room and are using artificial respiration. To record the data, a belt with 16 electrodes which is attached to the device is used. This belt is adjusted according to the size of an adult's body and closes below the patient's breast, right around the lung.

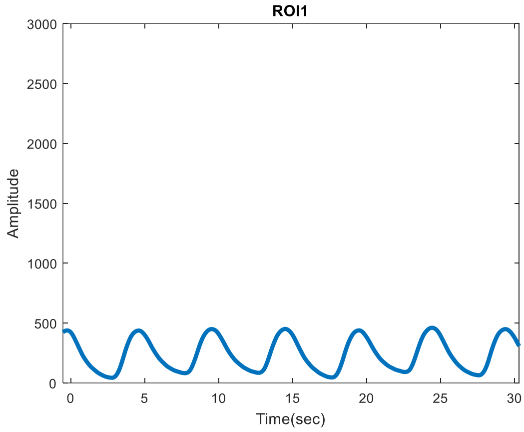
Figure 1 shows an image of this belt.

Fig. 1. Displaying the 16 electrode belt of EIT system [18]

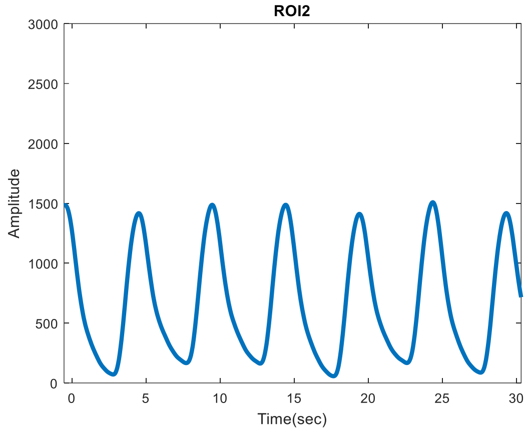
After attaching the belt to the patient's body, five signals are shown on the screen similar to figure 5. The duration of recording these signals is 30 seconds. The first signal (Figure 2-a) shows the overall changes in lung volume at any moment, as well as the duration of the entire registration period. The signal is composed of a sum of four other signals, including the first to the fourth region of interests, corresponding to Figure 2-b to Figure 2-e. The signal which is obtained from the sum of the region of interest (ROI) signals is called the global signal. To represent the signals better, all scales are considered the same to produce a better understanding of the signal strength in different parts of the lung.



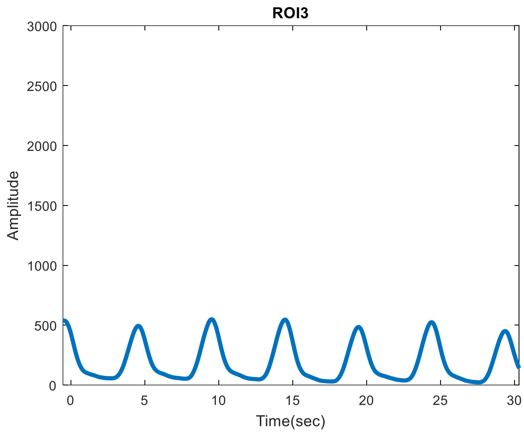
(a)



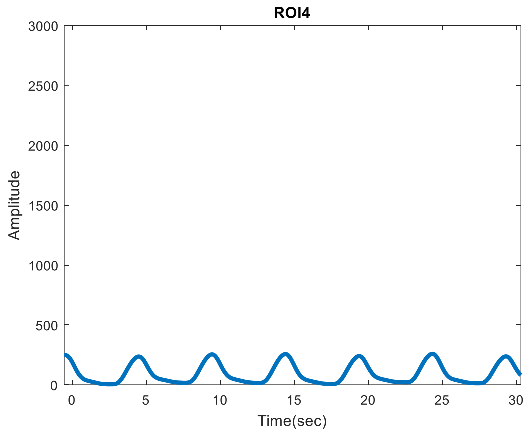
(c)



(b)



(e)



(d)

Fig. 2. Signals of lung volume changes. a) Global volume changes, b) Tidal volume changes of ROI1, c) Tidal volume changes of ROI2, d) Tidal volume changes of ROI3, e) Tidal volume changes of ROI4.

2.2 suggested method

In this paper, after recording the signal, in the preprocessing step a bypass filter between low and high frequencies of 50 and 100 Hz was used for noise elimination. According to the different durations of recorded signals, in this paper, for better analysis and achieving more accurate results, the signals which had short durations and lack of proper qualities due to improper selection of the location of the belt on the body, have been ignored. Therefore, 61 data whose registration time ranges were between 20 and 30 seconds, has been chosen. Then, in the next step, we identified the peaks of the Global, ROI1, ROI2, ROI3 and ROI4 signals using the windowing method and MATLAB software version R2018a. The results of peak extractions are shown in Figure 3.

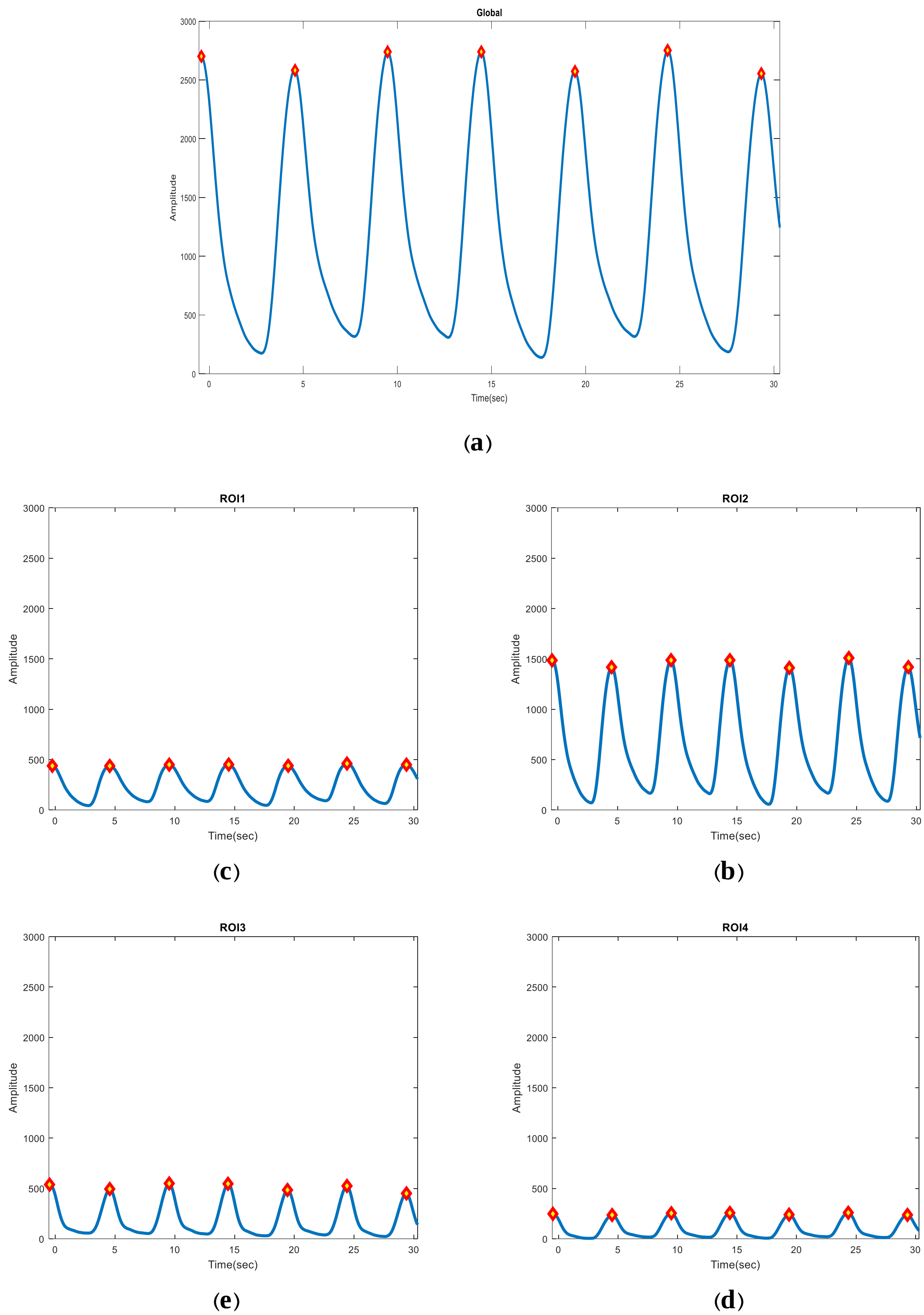


Fig. 3. Showing the peaks of lung volume signals

In the following, a certain amount was achieved by drawing each of the data available and specifying the signal peaks of each division and its ratio with the global volume signal peaks. Then, according to the signal lengths and the number of peaks, different ratios over time were determined and calculated to measure the percentage of the efficiency of the breathing volume per unit. This specifies the average percentage of responses of each part to the received oxygen in the entire lung. The lung volume due to the type of the segmentation (horizontal or quadrants as shown in Figure 4), has a standard amount which is presented in Table 1 that shows the standard amount of received oxygen in lung according to the quadrant segmentation type. By observing those percentages, doctors can have an accurate assessment of the function of each patient 's lungs in receiving oxygen levels and better decision making about the individual 's lung volumes and their disease. Figure 5 shows the block diagram of the different steps of the proposed method in this paper.

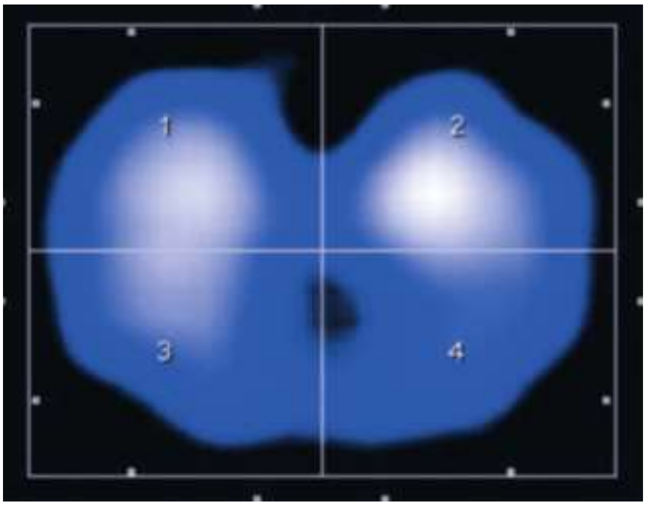


Fig. 4. The image of quadrant segmentation in lung

Table. 1. The amount of received oxygen in lung of a healthy person according to the type of the segmentation

Type of segmentation	Desired area			
	ROI4	**ROI3**	**ROI2**	**ROI1**
Horizontal	21%	25%	26%	28%
Quadrantes	25%	25%	25%	25%
Horizontal- Quadrantes	ROI2+ROI3		ROI1+ROI4	
	50±5%		50±5%	

Fig. 5. A block diagram of evaluating the lung function

3. RESULTS

The results obtained in this paper are appropriate criterions of pulmonary function by comparing standard values of a healthy lung volume. As each signal cycle represents a complete inhale and exhale, peaks represent the inhales and the valleys represent exhales. Comparison of gained percentages from each sector with the percentages of a healthy lung can determine the existence of a disease in every part of the lung or other words, the inefficiency of each sector. For example, in right side pneumonectomies, if we use quadrants sectioning, ROI2 and ROI4 absorb 100% of the ventilation in total, and practically the RIO1 and ROI3 nearly do not absorb any ventilation and are technically disabled.

4. CONCLUSION

Today, with the incensement of tobacco consumption and air pollution in advanced societies, the incidence of lung diseases has increased dramatically and are threatening the health of the community. Therefore, the need for accurate and quick identification, diagnosis can prevent subsequent dangerous consequences and reduce therapeutic costs. The use of computer diagnostic algorithms in different medical fields is a complementary way for better detect and quick diagnose illnesses and plays an important role in reducing medical diagnostic errors, medical costs and preventing undesirable treatment [19] to [21]. This paper, an electrical impedance tomography and volumetric signals are used to determine the effectiveness of each lung sectors. A computer diagnostic aid system introduced in this paper shows the acceptable performance of the proposed method. This method can, therefore, be used alongside traditional medicine recognition to determine the effectiveness of each lung sector. Another use of the diagnostic aid method is in operating rooms during and after surgery to help surgeons and specialists to inform the patient 's lungs and how to deliver oxygen to different departments. This idea can provide significant assistance to nursing and medical personnel to screen and allocate special facilities to acute patients. One of the important gains of the proposed method in this paper is that it can be used to determine the efficiency and ventilation of each lung sector at every breath, and to determine the health rate of each lung sector, and to determine the differences between each part of the lung.

List of Abbreviations

Chronic Bronchitis (CB)
Chronic Obstructive Pulmonary Disease (COPD)
Computed Tomography (CT)
Control and Prevention (CDC)
Electrical impedance tomography (EIT)
Intensive Care Unit (ICU)
Recruitment Maneuver (RM)
The region of Interest (ROI)
Tuberculosis (TB)
World Health Organization (WHO)

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