Integrated software suite for diagnosis of respiratory diseases

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Abstract— Respiratory diseases can be very difficult to diagnose because their symptoms are sometimes very similar to each other. If we analyze asthma and COPD (Chronic Obstructive Pulmonary Disease), diseases which are targeted in our research, we come to the conclusion that early detection of airway impairment can greatly assist in an early diagnosis.

In this paper we present an integrated software suite that can help doctors make correct diagnosis of diseases such as asthma and COPD, using lung function tests. The software is based on object oriented methodology. The parameters of spirometry, IOS (Impulse Oscillometry System) and body plethysmography, used in the diagnosis of respiratory disease, will be included in the neuro-fuzzy system in order to help the software suggest proper diagnosis of asthma, COPD or normal lung condition. In order to meet all the conditions that are necessary for the proper and complete diagnosis of respiratory diseases, there is also information about the symptoms, allergies and auscultation of the patient included. In cases where it is not possible to determine the diagnosis on the basis of symptoms, spirometry and IOS test, the software indicates BDT (bronchial dilation test) and BPT (bronchial provocation test), after which new tests are required for spirometry, IOS and body plethysmography in order to get a complete diagnosis.

Keywords: Asthma, COPD, spirometry, body plethysmography, IOS, BDT, BPT

I. INTRODUCTION

Major respiratory diseases that affect mankind are COPD and asthma. About 75% of COPD patients do not have established diagnosis, most of them in mild degree, but also 4% in severe and 1% in very severe degree of COPD. The reason for that is slow progression of symptoms as cough and exercise intolerance, as well as development of disease in the elderly. It is estimated that in Croatia COPD affects up to 10% of the adult population. Approximately 200,000 to 300,000 people die due to COPD in Europe every year [1], which is more than from lung cancer and breast together [2], [3]. By mortality the COPD is on 4th place in the world, after myocardial infarction, malignant diseases and cerebrovascular insults. There are around 600 million patients with COPD today in the world, which is double than diabetics. Predicted to 2020, COPD will become the world’s third biggest „killer” [4], and thus the main growing public health problem.

International Professional Association (GINA "Global Initiative for Asthma"), in its research shows that 55% of patients with asthma in Europe does not have this disease under control, 70% of them feel dyspnea 3-6 times per week, 80% use relievers 2-3 times per week and 58% wake up at least one night in week due to asthma attacks. The prevalence of asthma in Croatia is not exactly known, but based on data from Glaxo Smith Kline, it is estimated that asthma affects between 4-5% of the Croatian population, which means about 220,000 patients. The average family doctor’s surgery in Croatia has a 60-110 patients with asthma [5].

The pulmonary function test that is most commonly used for detection of COPD and asthma is spirometry, which measures the volume of air that can be moved in or out of the lungs as a function of time with rapid and maximal inspiratory and expiratory efforts [6].

In contrast to forced spirometry, IOS measures respiratory impedance using short pulses of air pressure [7]–[10].

Based on all the facts developed in the previous we implemented an integrated software suite that can help doctors to make correct diagnosis of diseases such as asthma and COPD. The parameters of spirometry, IOS, body plethysmography, information about the symptoms, allergies and auscultation of the patient, used in the diagnosis of respiratory disease, will be included in the neuro-fuzzy system, in order to help the software suggest proper diagnosis of asthma, COPD or normal lung condition. In cases where it is not possible to determine the diagnosis the software will indicate user to do BDT and/or BPT, after which new tests are required for spirometry, IOS and body plethysmography, in order to get a complete diagnosis.

II. RESPIRATORY DISEASES

In normal individuals, breathing takes minimal effort from the body but the pulmonary system is sensitive to multiple agents that can trigger reactions or diseases. The most
disabling disorders are chronic obstructive pulmonary diseases (COPD), asthma, lung cancer and restrictive lung diseases.

COPD is a respiratory disorder characterized by chronic and recurrent airflow obstruction, which increases airway resistance [11]. Most COPD is caused by long-term smoking [12]. Two main examples of them are obstructive emphysema and chronic bronchitis.

Asthma is a respiratory disorder characterized by single or combination episodes of coughing, dyspnea, wheezing and chest tightness. Although it may be classified as COPD because it is an obstructive disorder, asthma is marked by acute exacerbations followed by symptom-free periods [13].

The bronchial diameter reduces more during expiration rather than during inspiration in an asthma episode. Sometimes the symptoms of asthma are similar to other lung conditions and thus hard to be diagnosed, but early detection and proper treatments would be very helpful in lives of people with this disorder.

III. PULMONARY FUNCTION TESTS

Pulmonary function tests evaluate how well the lungs work. They are a group of procedures that measure how much air the lungs can hold, the speed of inspiration and expiration, and how well the lungs exchange oxygen and carbon dioxide in blood. Pulmonary function tests can help doctors diagnose a range of respiratory diseases which might not be obvious to the doctor or the patient. The tests are also used to measure how a lung disease is progressing, and how serious the lung disease has become. Pulmonary function tests can also be used to assess how a patient is responding to different treatments.

A. Spirometry

Spirometry is the most common pulmonary function test to measure the changes in the volume of lungs during breathing. The general respiratory parameters that can be measured by spirometry are: Forced vital capacity (FVC), Forced expiratory volume in one second (FEV1), FEV1 divided by FVC (FEV1/FVC). Other parameters that can be calculated from the spirogram are vital capacity (VC), tidal volume (Vt), breathing rate and ventilation rate (tidal volume x breathing rate). Spirometry measurements may vary in different cases based on age, height, sex and body size of subjects. With a simple spirometer, neither the FRC nor the residual volume can be measured.

B. Body plethysmography

One way to measure Functional Residual Capacity (FRC) is by using a body plethysmograph device. It resembles a telephone booth, a large airtight box that the person sits in. After a normal expiration, a shutter closes the mouthpiece and the person is asked to take a deep inspiration. In the inhalation step, the person takes the air inside the box into his lungs so the lung volume increases and the box pressure rises since its volume is decreased. By using Boyle’s law and knowing the pressure in the box before and after inspiration and the volume of the box before inspiration, the change in the volume of lungs can be calculated. With this information, FRC, which is the volume of lungs before inspiration, can be derived [14].

C. Impulse Oscillometry System (IOS)

The other technique, which requires minimum cooperation from the patient, is Forced Oscillation Technique (FOT). It evaluates the mechanical properties of the respiratory system and more specific information about resistive, inertive and elastic properties of the respiratory system, which cannot be obtained by a spirometric test [15]. It uses a superimposed pressure burst at the mouth to gain information about airflow obstruction by measuring the respiratory impedance (Z) and its two components, resistance (R) and reactance (X), over a wide range of frequencies. The IOS also provides useful guidance in clinical patient management [16], and it can be used to test older children and adults as well as younger children and aged people.

IOS measurements yield frequency-dependent impedance values which may be correlated with respiratory system models consisting of electrical components that are analogous to the mechanical resistance, inertance and compliance of the central and peripheral airways. Parameter estimations of these models can serve as reference values for the detection, diagnosis and treatment of various diseases/pathologies [17].

IV. INTEGRATED SOFTWARE SUITE AND RESULTS

This chapter shows interface interactions between the end user of the software package and the system. The designed integrated software suite is capable of distinguishing between the different kinds of the respiratory diseases. The programming language to develop this software is Microsoft Visual C# Express. Also there is used MATLAB for fuzzy reasoning, neural networks and reading PDF files.

Schematic diagram of integrated software suite is presented on the Figure 1.
First must be entered Patient Info data. The reasons lie in the fact that it is necessary to review the patient before proceeding with loading and analyzing the results of these tests, spirometry and/or IOS. This review is the fulfillment of the form shown in Figure 3.

Window to identify and analyze tested report is presented in the Figure 4. For every report we need to select the file in PDF format that includes a specific report. PDF reading is implemented in MATLAB.

B. Results

It is possible to get a diagnosis on the basis of individual tests. This feature was designed for cases where on the basis of only one test one can clearly conclude which disease it refers to. For this purpose, the principle of fuzzy reasoning is used. One example of diagnosis based only on IOS results is showed on the Figure 5, where it is diagnosed as Normal saturation with the same values.
The main diagnostic report is obtained by pressing the button “Diagnose after the (Test Type)” which changes depending on the selection of the test. The button according to the results of artificial neural network, which is pre-trained to recognize the disease, provide the diagnosis or suspicion of a diagnosis with a recommendation to do BDT or/and BPT, in order to be able to give a sure diagnosis, as it is showed on the Figure 6.

If upon completion of the second step, which involves the BDT, the software can’t make an accurate diagnosis, it will suggest the third step, which is the BPT. After that, software will give a clear diagnosis, as it is showed on the Figure 7.

V. CONCLUSION

This paper focuses on implementation of an integrated software suite based on the reports of IOS, spirometry and body plethysmography tests to provide a diagnosis of respiratory disease, such as COPD and asthma. A diagnosis, if possible, is realized in the software on the basis of the individual test reports. The ability to input allergies, symptoms and general condition of the patient is integrated in the software suite, as well as the progress after bronchial dilation and bronchial provocation tests, considering that in order to determine the diagnosis all the information are necessary for a complete dynamic image of the patient.

REFERENCES


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