Interpretation of the results of lung function tests for the purpose of classification of diseases of the respiratory system using an integrated software package

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I Introduction

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 asthma, chronic obstructive pulmonary diseases (COPD), lung cancer, bronchitis, emphysema, pneumonia and inflammation of respiratory tract [1-6]. Pulmonary function tests are the most commonly used to detect asthma and COPD are spirometry and Impulse Oscillometry System (IOS). Spirometry as a test of lung function is most commonly used in the diagnosis of chronic obstructive pulmonary disease and asthma. Spirometry is running by measuring forced maneuver [7]. In contrast to forced spirometry, the forced oscillation technique (FOT) superimposes small air pressure perturbations on the natural breathing of a subject to measure lung mechanical parameters. IOS measures respiratory impedance using short pulses of air pressure [8-9].

The most successful diagnosis is achieved by combination of IOS and spirometry. In this way we obtain a static assessment of the patient. In order to get patient’s dynamic assessment of pulmonary function, it is also necessary to take into account the patient’s symptoms and allergies, perform auscultation of patient and do bronchial dilatation (BTD) and bronchial provocation tests (BPT). BPT is not necessary for COPD, but for diagnosis of asthma and other diseases of the respiratory system is essential.

The actual benefit of the integrated software suite is to help the clinical utilization of impedance oscillometry, and at the same time to assist in the diagnosis of asthma and differentiation of Chronic Obstructive Pulmonary Disease (COPD). Data which are first entered to software are related to a directory, symptoms and risk factors drawn from two major benchmarks for COPD and asthma. Global Initiative for chronic obstructive Lung Disease (GOLD) and Global Initiative for Asthma (GINA). The parameters of IOS, spirometry, information about the symptoms, allergies and auscultation of the patient, are included in the neuro-fuzzy system, in order to help the software to suggest proper classification of asthma, COPD, or normal lung condition. In the cases where it is not possible to determine the diagnosis the software will indicate to do BTD and/or BPT, after which new tests are required for IOS and spirometry, in order to get a complete diagnosis. This software increases the percentage of correct interpretation of data obtained by measuring tests of impedance oscillometry and spirometry, and friendly guides the user to quickly obtain data to be used in evaluation of lung function.

II Integrated software suite

This chapter is showing the user 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 used to develop this software is Microsoft Visual C++. Also there is used MATLAB for fuzzy reasoning, neural networks and reading PDF files. The procedure of using the integrated software suite will be explained from the beginning of starting to get the final results.

A. Starting program and input data

With opening and debugging the file “LungDiseaseDetection”, a Microsoft window shown on Figure 1 will appear on the screen.

As it can be seen from the Figure 1, first must be entered data in Patient Info. The reasons lie in the fact that is necessary before proceeding by loading and analyzing the results of these tests, spirometry and/or IOS, we must review the patient. This review is the fulfillment of the form shown in Figure 2.

Selecting the types of test leads to changes in the variables that will be stored values of these reports. Based on them, the diagnosis is made. Window to identify and analyze test report is presented in the figure 3. For every report we need to select the file in PDF format that includes a specific report. Reading from PDF 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 it is based on only one test clearly concludes which disease is concerned. For this purpose, the principle of fuzzy reasoning is used. One example of diagnosis based only on IOS results is shown on the Figure 4, where it is diagnosed as Normal air tight obstruction with the same values.

The main diagnostic report is obtained by pressing the button “Diagnose after the Test Only” which changes depending on the selection of the test. The button according to the artifact of neural network, which is pre-trained to recognize the diseases based on the diagnosis or suspicion of a diagnosis with a recommendation to do BTD or BPT. In order to be able to give a sure diagnosis.

If upon completion of the second step, which involves the BDT, the software cannot 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 shown on the Figure 6.

III Materials and methods

We enrolled 541 patients who previously visited departments for lung diseases in 10 European clinics. In this study, first all patients were asked by physician to respond to questions regarding symptoms, allergies and risk factors of asthma and COPD. Second step was measuring lung function with spirometry and IOS. Using spirometry, forced vital capacity (FVC) and forced expiratory volume in one second FEV1 were measured, while ratio FVC/FEV1 was calculated. Using Impulse oscillatory system (IOS), total respiratory resistance Rs, proximal resistance R20, distal capacitive reactance Xc and resonant frequency Fres, were measured. Subjects were divided into two groups, healthy and diseased, based on their medical history, physical examination, GINA and GOLD guidelines.

Patients with positive symptoms and Rs 150%, R20>150%, Xc>15, FEV1/FVC<0.8 were diagnosed with asthma. Patients with different test results were evaluated for bronchial hyper reactivity (BHR), first with BDT, and then with BPT. If Rs increases by more than 25% (ΔRs), Xc increases by more than 20% (ΔXc) and FEV1 decreases by more than 12% of baseline value and 200 mL, those patients are diagnosed with asthma. In cases where BDR didn’t achieve any improvement for final diagnosis, patients have done methacholine BPT. Of 541 patients who were enrolled in this study, 72 (13.30%) were grouped as asthmatics. COPD was diagnosed by having a positive history of dyspnea, chronic cough, chronic spumon and history of exposure to tobacco, occupational dusts, chemicals or other smokes after the age of 40. The diagnosis of COPD was confirmed by a positive history, Rs150%, Xc15 and FEV1/FVC<0.7. Patients with these test results were evaluated for bronchial hyper reactivity (BHR) through BTD, to check in case of group of COPD B, C or D [10]. Total sum of 541 patients who were enrolled in this study, 252 (46.99%) were grouped as COPD, while 217 (40.11%) were grouped as healthy controls.

IV Discussion and results

Results of this study showed a high efficiency of integrated software suite in the classification of asthma (97.22%), COPD (96.41%) and healthy patients (98.61%). The Table I contains hits and misses of the integrated software suite in the classification of asthmatics, COPD and healthy patients who were involved in this study.

From Table I we can see that software showed a small percentage of false positive results in the case of patients affected with asthma (2.79%), COPD (1.59%) and healthy patients (1.39%) as compared to physician diagnosis.

Testing the efficiency of integrated software suite at each single step of classification of asthma and COPD patients were obtained from the results of this study. These results are presented in Table II and Table III, respectively.

Based on the study results shown in Table II it’s clear that the software classify the most patients with asthma in a second step, i.e. after bronchial dilatation test (BTD). In this test, 85% of patients Rs increased by more than 25%, Xc increased by more than 20% and FEV1 decreased by more than 12%. In first step, i.e. after the results of IOS and spirometry test has classified 11.43% of patients with asthma, while in the third step, i.e. after bronchial provocative test, classified 27.14% of patients with asthma. These patients have done methacholine bronchial provocation test and Rs increased by more than 35% and Fres increased by more than 30%.

Based on the study results shown in Table III is clear that the software classify the most patients with COPD in the first step, i.e. after BDP and spirometry test results (73.8%). In these cases of patients, Rs was more than 150%, Xc more than 0.15 and FEV1/FVC less than 0.7. In the second step, i.e. after making BDT, the software has classify 26.62% of patients with COPD. For these patients we needed to do BDT to confirm is their FEVI/FVC less than 0.7.

V Conclusions

In this study we present results of classification of asthma, COPD and healthy patients using integrated software suite. Based on the total number of 541 patients involved in this study, the software correctly classified asthma in 97.22% and COPD 96.41% of cases, whereas in the case of healthy subjects correctly performed the classification in 98.61% of cases. Also, it is shown that for classification of diseases integrated software suite takes into account the complete dynamic picture of patients. In this study we also presented that the clinical evaluation of lung function is a more comprehensive developed software.

References


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