

Feasibility of connected health solutions for the management of COPD

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Abstract:

Chronic obstructive pulmonary disease (COPD) is one of the lung diseases. This disease describes a series of conditions including emphysema which affects the air sacs at the end of the airways, and chronic bronchitis which is occurred when the airways were inflamed and narrowed. Also, the person who suffers from chronic bronchitis usually produces sputum. Moreover, COPD causes difficulties in breathing because the airways have been narrowed. In addition, this disease will reflect on the patient's quality of life. Also, it has an economic impact on the healthcare system.

According to the British Lung Foundation (2018), COPD caused 5.3% of the total number of deaths in the UK in 2012 and COPD was the second-highest lung disease that caused death. Therefore, the improvement of diagnostic techniques and treatment methodologies for COPD is an important issue that faces the healthcare system.

This article will review the definition and symptoms of COPD, the data and signals required for the diagnostic procedure, and the sensors and devices that are currently used in the diagnostic procedure. Also, the incorporation of sensors/devices into a connected health solution for the management and early detection of COPD will be considered. Finally, this article will illustrate some commercial systems on the market that are used to diagnose COPD and the future trends of diagnosis COPD.

KEYWORDS

COPD, oxygen concentration, ECG, First Second of Forced Breath (FEV1), Forced Vital Capacity (FVC), Spirometry.

1. INTRODUCTION

COPD is a group of chronic conditions that affect the lung and cause irreversible narrowing in the airways and damage in the lung that causes a limitation in the airflow from and into the lung and a decline of expiratory volume. Also, the patient with COPD will suffer from emphysema and/or chronic bronchitis. COPD is associated with exposure to harmful gases or particles in the polluted air which induced an abnormal inflammatory response of the lung[1].

In addition, COPD is the third highest reason for deaths in the world. Therefore, COPD is one of the challenges that is faced by the healthcare systems in the world due to the high spread and inability to estimate the real number of patients with COPD in the different countries due to use the of different concepts to describe COPD. Also, the causes of COPD depend on lifestyle. Therefore, each country has several reasons that cause COPD. In most developed countries tobacco smoking is considered the main cause of COPD so the rate of COPD in men is higher than in women. On the other hand, in low income and middle-income countries, biomass fuel is one of the main reasons for COPD which reflects on the high rate of COPD in the women in these countries[1].

Furthermore, some genetic disorders can increase the susceptibility to develop COPD. For example, Alpha-1 antitrypsin deficiency is a genetic disease that may result in liver or lung diseases. Also, COPD is one of the complications of this genetic defect[2]. Also, COPD is associated with other diseases such as cardiovascular diseases. Where a third of patients with cardiovascular diseases have difficulties in breathing. Therefore, the rate of death by COPD is higher than the expected value and causes a high challenge for the healthcare system[1].

2. METHODS AND MATERIALS

2.1. Signals/ data required for diagnosing and managing COPD

COPD is a wide-ranging concept. Therefore, the assessment of a patient with COPD includes diagnosing the patient's symptoms, reviewing the patient's medical and family history, and performing several clinical tests.

Firstly, diagnosing the patient's signs and symptoms is the starting point. Several signs appear on the patient with COPD such as shortness of breath, cough, and sputum production. In addition, the patient with COPD may suffer from weight loss which results from the reduction in the metabolism process in the body due to a reduction in oxygen concentration. Also, the reduction of oxygen concentration which is associated with COPD can result in a bluish discolouration of the skin of the patient[3].

Secondly, the medical and family history is an important part of the assessment of the patient case because COPD is associated with the exposure of the patient to harmful gases and particles, and it is associated with different diseases. Therefore, the medical and family history can provide details about the history of diseases that can be associated with COPD such as cardiovascular diseases and the lifestyle such as the smoking background of the patient and family.

Finally, the diagnosis of COPD includes several clinical tests that are used to identify the signs and symptoms of the patient that are resulted from COPD and to determine the stage of the disease. firstly, Spirometry is one of the essential tests to diagnose COPD which is based on using a mouth flow sensor to measure the amount of air exhaled during the first second of forced

breath (FEV1) and the total amount of air exhaled during the forced exhaled breath which is described by the forced vital capacity (FVC). Therefore, if the ratio of FEV1/FVC is less than 70% this provides an indicator that the patient has obstructive lung disease. In addition, the percentage of FEV1 is used to identify the level of riskiness associated with COPD. Therefore, spirometry is one of the most important examination tests for the diagnosis of COPD[3].

Furthermore, measuring oxygen saturation by using pulse oximetry is an important parameter in diagnosing COPD and provide a sign for the level of oxygen in the body. Also, the examination tests could include performing an X-ray imaging for the chest to analyse the presence of fluid bubbles. Moreover, a completed blood count (CBC) test can be performed which measures the concentration of Red Blood Cells (RBC) and Hemoglobin in the blood which provides an indicator for the reduction in the oxygen level in the body[3].

In addition, more specialized tests can be used to analyze the patient case when the symptoms are common with other diseases. For example, an electrocardiogram (ECG) and echocardiogram can be used to diagnose the cardiovascular problems that are associated with COPD. Also, laboratory tests can be used such as sputum culture and Alpha-1 antitrypsin concentration that provide information about the infection source and the genetic defects[3].

2.2.Commercial systems

The continuous monitoring of the patient signs is an important parameter in managing COPD. Also, this monitoring will help in reducing the rate of hospitalization and the cost which is associated with the healthcare of COPD. In addition, the real-time controlling of patient physiological conditions will assist in improving the life quality of the patient. Therefore, several technologies are used in monitoring and managing COPD.

In general, several commercial medical devices are used in monitoring and management of COPD such as SPIROMETER as shown in figure (1) which is manufactured by CONTEC Medical Systems. This portable system has several features that make it suitable to use in monitoring COPD patients. The system provides a friendly user interface, measurement of several lung parameters such as FVC, FEV1, FEV1%, and Peak expiratory flow (PEF). Also, it has an internal memory for data storage. In addition, it provides the ability to review the storage data and to transfer the data through Bluetooth[4].

Furthermore, the level of oxygen saturation is an important sign which helps in monitoring the state of a patient with COPD. Therefore, several medical systems are used to provide a real-time controlling of oxygen saturation such as the MightySat Fingertip Pulse Oximeter as shown in figure (2) which is manufactured by Masimo. This portable and lightweight pulse oximeter provide a user-friendly touchscreen, the measurement of SPO₂, the pulse rate, the perfusion index, and the respiratory rate. Also, it has an integrated Bluetooth system that enables to sharing and view of data through a specific application. Therefore, the clinician can monitor the signs of the patient through a mobile application or the web[5].

In addition, monitoring the changes in ECG is very important in reducing the rate of hospitalization. Therefore, several portable ECG devices are used to record the ECG of the patient such as PC-80B as shown in figure (3) which is approved by the FDA and provides the ability to record and transfer ECG signals through Bluetooth or USB port[6]. In general, there are wide ranges of medical systems that can be used for monitoring and management of COPD

based on the signs that can be measured by these systems. Therefore, the ability to develop the monitoring and management of COPD is based on the ability to understand the relationship between physiological conditions and COPD.

3. RESULTS AND DISCUSSION

3.1. Incorporation of sensors/devices into connected health solution

The diagnosis and management of COPD as one of the chronic diseases focus on inhibiting the exacerbation of the disease and reducing the disease development. Therefore, the management of COPD is based on real-time monitoring of patient signs and functions that are associated with COPD such as lung functions, electrocardiogram, and oxygen concentration[3].

In addition, the high-cost burdens of diagnosis and management of COPD that are resulted from frequent hospitalization and the effect of COPD on the patient's life quality increase the need to develop advanced and effective methods for managing and monitoring the patient[7]. Therefore, several connected health systems that aim to supply accurate information to the right person at the right time are used in the management of COPD [8].

In addition, the diagnosis and treatment of most chronic diseases such as COPD require real-time monitoring for the patient's physiological signs, the patient daily activities, and environmental conditions. Therefore, several health solutions were developed such as the CHRONIOUS system which provides real-time monitoring and management of the patients' signs. In general, the CHRONOS system consists of a wearable jacket which contains several integrated sensors such as an ECG sensor, respiratory sensor, audio sensor, the acceleration sensor, which is used to monitor the patient conditions, the personal digital assistants (PDA) system which uses a series of algorithms to provide the medical assistance for the patient, and central system which is used to collect and analyze the data. Also, several external devices can be used in parallel with this system for monitoring additional signs such as a glucometer and blood pressure monitor[9].

COPD is a wide labelled disease, and it is associated with other diseases. Therefore, the identification of the severity degree of COPD requires monitoring of several bio-signals that are affected by this disease. Warner et al, 2013 studied the relationship between the abnormalities in ECG and COPD. This study is considered the first study which compares the characteristics of ECG for patients with and without COPD. In this study, the ECG abnormalities were compared between the two groups. The first group consists of patients with COPD, aged over 65 years, and who do not have any heart diseases[10].

On the other hand, the second group which is the reference group consists of patients without COPD, aged over 65 years, and who do not have any heart diseases. The measured ECG for each group were processed using a digital software system that aims to determine the mean corrected (QTc) interval, the QTc dispersion, the mean RR interval, and the heart rate variability (HRV). Moreover, the collected data showed that abnormalities in ECG significantly appeared on the ECG of the patients with COPD in comparison to the patients without COPD. In addition, the conduction noise was the most significant abnormalities which appeared in the ECG of patients with COPD in comparison with the ECG of patients without COPD. Also, the study showed a relationship between the degree of severity of COPD and ECG abnormalities. In general, the

study showed that the conduction abnormalities in ECG, QTc prolongation, QTc dispersion, and heart rate are increased as the severity level of the patient is increased[10].

Furthermore, the changes that are occurred in the physical activities of COPD patients are important parameters in the diagnosis and management of COPD. Therefore, several techniques are used to monitor the daily activities of patients such as heart rate monitoring, oxygen saturation monitoring, and accelerometer. The accelerometer is a piezoelectric transducer that is used to measure the rate of change of velocity (acceleration). Therefore, the accelerometer is used in several studies to monitor the daily activities of a patient with COPD. In one of these studies, the acceleration measurements of a group of patients with COPD were compared to acceleration measurements of the other group of patients without COPD. The measured acceleration is expressed in vector magnitude unit (VMU) and the results showed that the patients with COPD have lower activities than patients without COPD[11].

In addition, according to Global Initiative for Chronic Obstructive Lung Disease (GOLD), cough is one of the major signs of COPD. Therefore, GOLD classifies the stage of a patient who has a cough and without airflow obstructive as stage 0 because the problem can be developed into COPD. Moreover, several techniques were used to count cough for a patient such as using an audio detector to detect the waveform of the sound of a cough and counting the number of a cough. In general, cough waveform is affected by many variables such as the type of disease and the external noises that limited the application of a cough counting in COPD diagnosis. Therefore, several signals are measured in parallel with a cough waveform that is used to assist in the counting of coughs such as a plethysmograph and an electromyogram[12].

Also, real-time monitoring of respiratory rate and tidal volume for patients with COPD is an important method to detect the exacerbation of COPD (ECOPD) and to reduce the risk of hospitalization. In one of the studies for the role of the respiratory frequency to detect ECOPD, a monitoring system that consists of two sensors was used to detect and determine the respiratory rate for a patient with COPD. Moreover, the system was integrated with the oxygen generator system. One of the sensors were used to measure the change in the oxygen pressure and the other to detect the oxygen flow. The results showed an increase in the respiratory frequency of the patient by 15% to 30% two days before the hospitalization[13]. In addition, the respiratory rate increases as the level of severity of COPD is increases. The respiratory frequency of level 1 is less than 14 and for level 4 is higher than 25. Therefore, the monitoring of respiratory frequency is an effective indicator to avoid the exacerbation of COPD[9].

Furthermore, oxygen saturation and heart rate are important signs that can be used to monitor the stable patient with FEV₁<50% predicted. In general, the patient with COPD shows a decrease in the SPO₂ and an increase in the heart rate as the severity level of COPD increases [14], [15]. Therefore, portable pulse oximetry was used for monitoring the SPO₂ and heart rate of a patient. In addition, a motion sensor was integrated with pulse oximetry to monitor the activity of the patient. Therefore, the measured values of SPO₂ and heart rate that included changes in the patient activities were excluded[16]. In addition, the level of glucose in the blood is associated with pulmonary function. Therefore, the glucometer device is used to provide additional information which assists in diagnosing COPD[9].

Also, the changes in the environmental conditions have a significant factor in the exacerbation of COPD. Several studies showed an increase in ECOPD and hospitalization rate during the winter period. This change is related to many reasons such as the increase in respiratory viral infection

during the winter. Furthermore, several environmental parameters have a relationship with the exacerbation of COPD. For example, the decrease in temperature and humidity and the increase in atmospheric pressure were associated with the increase in the exacerbation of COPD. Therefore, the measurement of the temperature, humidity and pressure considers effective factors in reducing the rate of hospitalization[17].

Finally, the collected information and the measured results are analyzed based on a standard protocol to identify the stage of the disease. In general, the Global Initiative for Chronic Obstructive Lung Disease classifies the severity of COPD into five levels [18]. Therefore, based on the stage of the severity which is identified by the collected data the system will send a notification and reminder to the right person. In the case of the low levels of severity that include level 0, level 1, and level 2, the patient will receive a notification through a mobile message or be displayed on the patient monitor. On the other hand, at the high level of severity, the reminder will be sent to the clinician who diagnosis the case of the patient and tacks the decision based on collected data[8], [9].

3.2.Future Perspective

In general, COPD is one of the critical issues which faces the healthcare system due to the high prevalence rate and the high cost associated with the healthcare of COPD. Therefore, the fundamental understanding of the physiological signs and environmental conditions that are associated with COPD is an essential area to develop treatment methodology and to reduce the rate of the disease[1]. Also, the development of a monitoring and management system is an important factor in the reduction of the level of severity and rate of hospitalization. Therefore, several studies showed that the development in the field of telemedicine will play an effective role in improving the control of the state of COPD patients. In addition, telemedicine provides a flexible platform for monitoring several chronic diseases at the same time such as cardiovascular diseases and kidney diseases[19].

Furthermore, the development of several technological fields such as communication and biosensors will provide flexible options for monitoring and managing the patient signs at a low cost and faster time. Also, the development of a mobile-based system to transfer and manage patient conditions will help in improving the life quality of the patient in reducing the hospitalization rate. Therefore, several technologies were developed in this field to provide more flexibility to manage COPD[7].

4. CONCLUSION:

COPD is a group of chronic conditions that affect the respiratory system. Furthermore, this disease is related to several factors such as smoking and a genetic disorder. In addition, the diagnostic of COPD includes the measurement of several signs such as oxygen concentration, RBC concentration, haemoglobin concentration, and ECG. Also, the high prevalence rate and the high cost associated with the management of COPD are some of the challenges that face the healthcare system. therefore, the improvement of the diagnostic methods will have a significant effect in improving the management mechanism of COPD. Besides, the use of connected health solutions in the management of COPD will have a significant role in the reduction of the severity level and rate of hospitalization.

5. FIGURES:

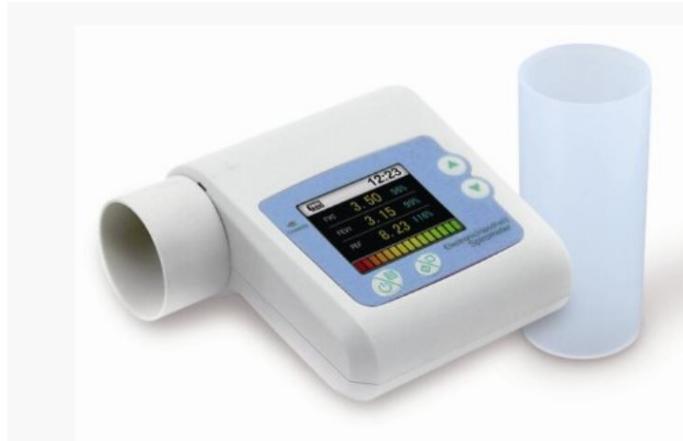


Figure 1: SPIROMETER by CONTEC Medical Systems [4]



Figure 2: MightySat Fingertip Pulse Oximeter [5]



Figure 3: PC-80B ECG monitor [6]

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