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Management of Chronic Obstructive Pulmonary Disease (COPD) using Digital Health Technology

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Abstract:

Chronic obstructive pulmonary disease (COPD) is an irreversible life-threatening lung disease that interfere with normal breathing, causing persistent and progressive airflow limitation that is associated with an enhanced chronic inflammatory response in the airways and the lungs to noxious particles or gasses. Early identification and prompt treatment of COPD can delay lung function decline, reduce its economic and social impact, and improve patients' quality of life. Consequently, telehealth for COPD has been introduced recently to offer solutions for early COPD detection, long- distance consultation and emergency medical assistance. This article will review the incorporation of sensors for the management and early detection of this condition. In addition, it will go through some commercial systems on the market for this purpose.

Keywords: Chronic obstructive pulmonary disease, telehealth, connected health solution, continuous remote monitoring.

Introduction

Chronic obstructive pulmonary disease (COPD) is a common chronic condition which describes a group of conditions including chronic bronchitis and emphysema and results in gradual lung damage and progressive airflow limitation. The warning signs of COPD including breathlessness, cough, and sputum production that may exacerbate at certain times over the course of a year, impose current and future challenges which require concerted actions to avoid the economic and social burden associated with medical treatment and disabilities related costs. There is no doubt that early identification and prompt treatment of COPD can delay lung function decline, reduce its economic and social impact, and improve patients' quality of life. Consequently, telehealth for COPD has been introduced recently to offer solutions for early COPD detection, long- distance consultation and emergency medical assistance.

Telehealth is the use of internet and other technologies to support and improve clinician-patient interaction to be the main ingredient in medical care. It removes geographical and physical barriers and play a useful role in helping to deliver a useful service to a wider range of patients with COPD in an equitable way. This article will review the significant of connected health solution for the management and early detection of this condition. In addition, it will go through some commercial systems in the market for this purpose.

Definition and overview

Chronic obstructive pulmonary disease (COPD) is an irreversible life threatening lung disease that interfere with normal breathing, causing persistent and progressive airflow limitation that is associated with an enhanced chronic inflammatory response in the airways and the lungs to noxious particles or gasses. The overall severity in individual patients may be related to some extrapulmonary effects including exacerbations and comorbidities. COPD is a blend of small airway disease (obstructive bronchiolitis) characterized by structural changes and narrowing of the small airways, and parenchymal destruction (emphysema) characterized by loss of alveolar attachments to the small airways and reduction in lung elastic recoil. The relative contribution of each condition in the overall chronic airflow limitation vary from person to person (Global initiative for chronic obstructive lung disease, 2015).

According to the world health organization statistics, COPD is the third leading cause of death worldwide after ischemic heart disease and stroke, killing 3.1 million people in 2012. It is also one of the common cause of morbidity, with 65 million people have moderate to severe chronic obstructive pulmonary disease (COPD) worldwide resulting in substantial economic and social burden and disturb the quality of life of a remarkable percentage of people all over the world (World health organization, 2014). An international survey on the impact of chronic obstructive pulmonary disease (COPD) on a working age population estimated the annual cost of healthcare utilization (excluding treatment costs and diagnostic tests) per individual, being

£1,500. In addition, lost time from work costs the individual an average of £556 per annum, not to mention the income losses due to early retirement (Fletcher et al., 2011).

Cigarette Smoking is the most important factor for COPD, because it inflames and irritates the lining of the airways. This inflammation lead to thickening of the airway's walls and mucus production and consequently, respiratory symptoms associated with COPD including breathlessness, cough and phlegm may occur. About 40-50% of lifelong smokers will develop COPD, compared to only 10% of never-smokers. Secondhand smoke exposure may also contribute to respiratory symptoms and decreased lung function in infants and children. Moreover, prolonged and sufficiently intense exposure to airborne pollutants such as occupational dust, chemicals and fumes are an underappreciated cause of COPD (European lung white book, 2015).

Genetic factors including α1-antitrypsin deficiency and α1-antitrypsin deficiency are documented as a cause of COPD and related to decline in lung function. Lung growth and development is another factor that increase the risk of developing COPD. For example, birth weight is associated positively with FEV1 in adulthood. In addition, it is found that there is an association between a history of severe childhood respiratory infection and reduced lung function. Other factors such as Outdoor and indoor pollution, socioeconomic status, and early life environmental factors may also contribute to COPD. However, cigarette smoking is the main contributor and the best studied COPD risk factor (Global initiative for chronic obstructive lung disease, 2015).

Data needed for continuous remote monitoring

It is important to assess the severity, impact and risk of disease before starting treatment. This assessment should be based on patient's signs and symptoms, detailed medical and family history, and tests results. Moreover, early detection of COPD is key to successful treatment and will help in stopping or slowing the progression of the disease.

Symptoms: the characteristic symptoms of COPD are shortness of breath (dyspnea), chronic cough, production of a lot of sputum, and wheezing. Dyspnea is the major symptom of COPD described as a shortness of breath while doing everyday activities and daily routines. A large international survey was carried out by asking COPD patients if there had been any period of 3 months or more in the previous year when they had experienced symptoms for a few days a week, or every day. The results showed that the frequency of cough, breathlessness and phlegm were 70 % (46% daily), 67 % (45% daily), 60 % (40% daily) respectively (Rennard et al., 2002). This mean that experiencing any of these symptoms entails contacting the doctor as soon as possible to prevent the progression of the disease and receive valuable treatment.

Medical history: a detailed medical history is an important part of diagnosis. It provides information about family history of COPD which can be a risk indicator of the disease. Presence of comorbidities such as osteoporosis and cardiovascular disease should be declared as it benefit in assessing the severity of COPD. Occupational exposures and smoking are also part of the medical history that should be taken into account while diagnosing patients with respiratory disorders.

Physical examination: it is essential to perform some tests to patients with suspected COPD to evaluate the condition and exclude alternative diagnoses. One of these tests is Spirometry which is fundamental to making a diagnosis of COPD and a confident diagnosis of COPD cannot be made without spirometry. In this test, a spirometer device is used to diagnose airflow obstruction by measuring how quickly and effectively the lungs can be emptied and filled. FEV1/FEV ratio, which indicates the percentage of forced vital capacity expelled in the first second of a forced expiration, of less than 70% implies obstructive disease. Chest X-ray test, which is a very common non-invasive radiology test that produces an image of the chest and the internal organs, is helpful in ruling out other conditions with similar symptoms, such as lung cancer (WebMD, 2014).

Pulse oximetry is performed to measure the oxygen saturation in the blood. Normal spo2 reading range from 95 to 100 percent, under most circumstances. This test may be done to find out if oxygen treatment is needed. However, arterial blood gas test provides more valuable information about the need for such treatment. Moreover, electrocardiogram is needed to find certain heart problems that can cause shortness of breath. Other tests including alpha-1 antitrypsin and CT scan are rarely done to diagnose patients with suspected COPD (WebMD, 2014).

The importance of sensors in connected health solution

Long term monitoring of patients with COPD is needed for management of the disease, exacerbation prediction, and reducing the burden of the disease by reducing the number of hospitalization and length of hospital stay. This can be achieved by using external devices and wearable T-shirt integrating several sensors to collect patient data before delivering them to a personal digital assistance (PDA) to evaluate the health status and central system which performs data collection and extended analysis.

Bellos et al. (2012) proposed CHRONIOUS system to effectively manage and assess the health status of patients suffering from COPD. This system is based on the acquisition of several vital signals using wearable sensors including ECG sensor, respiratory sensor, acceleration sensor, body and ambient temperature sensors, humidity sensor, spo2 sensor and audio sensor. Additional external devices are integrated including spirometer, weight device, and other devices to measure blood pressure and blood glucose. Moreover, static information stored in the existing database (e.g., questionnaire, dietary, lifestyle, or demographic data. All acquired information is used to assess the patient and classify the severity of disease based on feature selection algorithms which identify the most important clinical-pathological information for individualized health status identification.

Aqarwal et al. (2008) studied the diagnostic values of ECG among patients with COPD. It is found that fifty percent of COPD patients had ECG changes and more than one third of them had peaked p-waves and abnormal p-waves axis suggesting that COPD patients should be screened electrocardiographically to as a part of the diagnosis. Respiratory sensor is used to measure respiratory frequency, amplitude, and inhalation-exhalation duration. A pilot study was performed by monitoring the respiratory frequency of a cohort of patients with severe COPD for 3 months until they had an episode of COPD exacerbation that required hospitalization. The results showed that mean respiratory frequency increases by about 15% to 30% at least 48 hours before the patient requires hospitalization because of ECOPD. This means that it is possible to detect the exacerbation of COPD early by monitoring the breathing rate and this may offer an opportunity for early intervention (Yanez et al., 2012).

Physical activity is reduced in patients with COPD. This is associated with an increased risk of hospital admission and higher risk of mortality, and also places patients at risk of developing comorbidities. Accelerometer sensor can be used to measure daily physical activity of patients with COPD. Then, a combination of individualized pulmonary rehabilitation programs and pharmacotherapy in conjunction with behavioral modification may be the way forward to help patients adopt a more active lifestyle and consequently lower risk of hospitalization, comorbidity and mortality associated with COPD (Troosters et al., 2013). Automatic cough detection based on an audio microphone is important as a predictor of decline in patients with established airway obstruction. However, cough may be associated with other diseases and a patient may have a form of COPD, even without an annoying cough (Smith et al., 2006).

In stable patients with severe disease (FEV1 < 50% predicted), and in patients with worsening symptoms or other signs of an acute exacerbation, pulse oximetry is useful as a tool for patients to use at home to assist with their management under physician guidance. This device provides a method for rapid assessment especially of short-term respiratory compromise. Since spirometer is the gold standard for diagnosis and staging COPD, pulse oximetry is helpful as a complement rather than competent with spirometry in this process (Nonin, 2015).

Monitoring of some environmental signals such as ambient temperature, and environmental humidity is important in managing COPD. High temperature in summer together with smog and other pollutants may exert additional stress to patient and cause a greater level of shortness of breath. High humidity is another problem that causes COPD symptoms to worsen and increases the risk of a COPD flare-up. Thermometer and humidity sensors are helpful in monitoring the environmental signals and allow for better management of COPD by providing the patient with some advices to mitigate the effect of environmental conditions such as drinking plenty of fluids, staying indoor, and using air conditioner and dehumidifier to control the climate in the home (The lung association, 2010). Blood pressure and blood glucose measurement using external devices may be helpful because of their potential relationship with the COPD exacerbation as some studies revealed (Lung institute, 2015 ; Baker and Bell, 2009).

Level	0	1	2	3	4	Accuracy
Heart Rate (HR)	<90	90-100	100-110	110-120	>120	39.45%
Systolic Pressure	120	120-140	140-160	160-190	>190	Not enough data
Diastolic Pressure	70	70-90	90-100	100-110	>110	87.16%
SpO_2	>92%	90-92%	<90% with room air	<90% with O_2	<80%	68.81%
Respiratory Frequency	<14	14-16	16-20	20-25	>25	17.43%
Inspiratory Time	1.6-1.8	<1.6 and >1.2	<1.2 and >1.0	<1.0 and >0.8	<0.8	87.16%
Expiratory Time	3.0-3.4	<3 and >2.5	<2.5 and >2	<2 and >1.6	<1.6	15.60%
Respiratory Frequency/Tidal Volume (f/Vt)	<80	80-95	95-110	110-120	>120	33.95%

Table 1: Rules that are indicated by clinicians characterizing five levels of severity. (Bellos et al., 2014).

Depending on the collected data and based on several rules and limits provided by clinicians as shown in table 1, the system classifies the patient health status in 5 levels of severity. Any abnormal

health episode recognized by the system entails an action (alerts, reminders, etc.) that should be sent to the appropriate recipients (patient, health professional, etc.). A simple recommendation or an alert is presented to the patient monitor or mobile phone if the severity is being assessed to a low level (level 0, level 1, level2). However, a higher level assessment requires web service triggering in order to send a respective notifications and alarms

to the clinician in the form of an SMS or an email. Following that, the clinician will assess the case and take the appropriate action such as asking for administering some medications, oxygen therapy, hospital admission or referral for advice, specialist investigations or treatment, etc. (Bellos et al., 2014).

Commercial systems

Several commercial systems and gadgets aiming to monitor and support patients suffering from chronic obstructive pulmonary disease has been developed recently. They help in stabilizing patients and reduce the risk of complications while improving their quality of life. In addition, they significantly reduces the number and length of hospital stays.

SHL Telemedicine's chronic disease monitoring program is one example of these commercial systems. Easy to use SHL telemedicine monitoring devices are provided to each patient depending on their condition. Data recorded and tests results are automatically transmitted to the telemedicine center without patient intervention. Then, SHL center performs a comparison between new data and past tests for that patient. Subsequently, an alert will be triggered at the telemedicine center, and a call will be made to patient if any turning point in any vital signs is recognized. Adjusting medications or carrying out other interventions may be consequently

Figure 1: TeleBreather device that can be used at home to test how well patient's lung is working. (SHL Telemedicine, 2015)

prescribed by the physician at the center to stabilize patient condition. SHL telemedicine's central communication module (CCM) is an innovative telecommunication device that work with many devices from SHL's product line, including breath exhalation (TeleBreather), blood pressure (Telepress), Spo2 (TelePulse Oximeter), and sugar measuring devices. CCM transmit medical data measured by the connected devices over an internet connection, cellular platform, or regular landline to telemedicine centers (SHL Telemedicine, 2015).

TeleBreather (figure 1) is a remote, electronic, handheld device that can be used at home to measure various volumes and speed of air expelled from lung during forced exhalation. It is small, lightweight, battery operated device that require no special training or user adjustment. It provides healthcare provider with the most important medical data needed to assess users who are suffering from COPD. TelePulse oximetry which is shown in figure 2, is another device developed by SHL to be used at home for accurately measuring the saturation level of oxygen in the blood (SPO2) and pulse rate. Breathlessness symptom of patients suffering from COPD can lead to lowering the saturation level of oxygen in blood. Consequently, it is required to monitor SPO2 level in patients with COPD to keep track of their condition. There are other devices that can be used to acquire patient vital signs at home including TelePress which is used to monitor patient blood pressure, Teleweight to measure patient body weight, and Cardiobeeper to measure ECG (SHL Telemedicine, 2015).

Figure 2TelePulse oximetry device that can be used at home to measure spo2 and pulse rate (SHL Telemedicine, 2015).

Philips Healthcare also developed a wearable gadget inside a disposable adhesive patch for COPD patients to continuously gather patient vital signs such as respiratory function, heart rate and physical activity and transfer them to patient's mobile device and healthcare center. It also developed a

propeller health inhaler sensor which is a small device that attaches to the top of existing inhaler to allow patient to keep track of his medication use. It is wirelessly syncs with smart phone using Bluetooth technology (How to use inhalers interactive guidance & management, 2013).

Future perspectives

Telehealth is increasingly playing an integral role in the management of COPD. Several pilot studies and research have proved that telehealth is an effective, feasible and usable choice for management of COPD. Cost effectiveness, reduced unscheduled hospital appointments, reduced inappropriate home visits and improved care pathways are benefits that lead healthcare systems to consider further investment into the number of telehealth monitors for COPD services. It is also suggested that telehealth services can be used to monitor patients with multiple comorbidities such as COPD, congestive heart failure and diabetes (Innovation health & wealth, 2015).

The use of autonomous mobile system for the management of COPD is expected to rise in the near future. This requires doing as much as possible for the COPD patients in their own home with the support of hospital resources. In addition, healthcare processes to be done at home and the devices needed to facilitate action at home must be defined. Furthermore, it is required to integrate the telemedicine approach into the current healthcare system.

It has been recently proved the efficacy of connected health programs in COPD management. In the future, it is expected a wide availability of these programs not only for patients, but any average internet/smart phone user. . Connected health programs for COPD management have the potential to exist in people's life with little effort on their part, by tracking physiologic data, motivating and affecting change in the most natural and sustained manner, that preventive programs to date have been unable to achieve (Innovation health & wealth, 2015).

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