



## Predicting the risk of exacerbation in patients with chronic obstructive pulmonary disease using home telehealth measurement data



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### ABSTRACT

**Background:** The use of telehealth technologies to remotely monitor patients suffering chronic diseases may enable preemptive treatment of worsening health conditions before a significant deterioration in the subject's health status occurs, requiring hospital admission.

**Objective:** The objective of this study was to develop and validate a classification algorithm for the early identification of patients, with a background of chronic obstructive pulmonary disease (COPD), who appear to be at high risk of an imminent exacerbation event. The algorithm attempts to predict the patient's condition one day in advance, based on a comparison of their current physiological measurements against the distribution of their measurements over the previous month.

**Method:** The proposed algorithm, which uses a classification and regression tree (CART), has been validated using telehealth measurement data recorded from patients with moderate/severe COPD living at home. The data were collected from February 2007 to January 2008, using a telehealth home monitoring unit.

**Results:** The CART algorithm can classify home telehealth measurement data into either a 'low risk' or 'high risk' category with 71.8% accuracy, 80.4% specificity and 61.1% sensitivity. The algorithm was able to detect a 'high risk' condition one day prior to patients actually being observed as having a worsening in their COPD condition, as defined by symptom and medication records.

**Conclusion:** The CART analyses have shown that features extracted from three types of physiological measurements; forced expiratory volume in 1 s (FEV<sub>1</sub>), arterial oxygen saturation (SPO<sub>2</sub>) and weight have the most predictive power in stratifying the patients condition. This CART algorithm for early detection could trigger the initiation of timely treatment, thereby potentially reducing exacerbation severity and recovery time and improving the patient's health. This study highlights the potential usefulness of automated analysis of home telehealth data in the early detection of exacerbation events among COPD patients.

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### 1. Introduction

Chronic obstructive pulmonary disease (COPD) is characterized by incompletely reversible airflow obstruction. Patients with COPD

may experience exacerbations of their disease, which are associated with significant morbidity and mortality as well as reduced quality of life [1]. An acute exacerbation of COPD has been described as an acute worsening of respiratory symptoms associated with a variable degree of physiological deterioration [2]. Exacerbations of COPD typically require a patient to seek medical assistance or to change his or her treatment and are one of the most common medical conditions requiring hospital admission [3].

Lung Foundation Australia reported annual health system costs of more than \$750 million in the management of COPD in Australia in 2008, with hospital admission being the largest contributor [4]. Higher rates of hospitalization and length of stay occur among patients with COPD when there is delay in treatment of an

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exacerbation episode [5]. Unfortunately, recognition of the start of an exacerbation is not a straightforward task, but early detection may result in reductions in both exacerbation recovery time and risk of hospitalization [5–7].

A study conducted by Trappenburg et al. used a clinical COPD questionnaire as a tool to detect exacerbation events. The patients in the study were asked to answer the self-administered questionnaire weekly, for six consecutive weeks. The study concluded that the questionnaire assessment method can detect exacerbations. However, the method was not designed for real-time exacerbation detection [8].

As a means of detecting exacerbation earlier, and at the resolution of a single day, it has been proposed that patients with COPD might use a home telehealth service daily to evaluate their health status [7]. Existing home telehealth services offer a range of vital sign monitoring modalities, for measurements including lung function, pulse oximetry, weight and temperature [9]. The resulting longitudinal physiological records could prove useful in determining the stability of a COPD patient and in predicting an exacerbation event, which is significant enough to require hospital admission, before it occurs.

Although spirometry is key in diagnosing COPD, data are sparse with respect to changes in lung function parameters during acute exacerbations, which are usually diagnosed on clinical grounds. However, Parker et al. described worsening airflow obstruction and hyperinflation in a group of 20 individuals with moderate exacerbations of their COPD, when compared to test results obtained at recovery, some two months after the event [10]. Seemungal and colleagues described small changes in peak expiratory flow rate (PEFR), forced expiratory volume in 1 s ( $FEV_1$ ) and forced vital capacity (FVC) at exacerbation onset, with median time to recovery of PEFR (6 days) being similar to that of symptomatic recovery (7 days) [2].

Worsening hypoxaemia in acute exacerbations probably results from worsening ventilation–perfusion mismatching, possibly with modest increases in shunt fraction. Estimation of arterial oxygen saturation using pulse oximetry ( $SpO_2$ ) may be a useful parameter to monitor at home.

Other parameters such as fever, respiratory rate and heart rate, may also be useful signs to monitor in patients at risk of exacerbation of COPD. One study showed that more than one-third of exacerbations requiring hospitalization were associated with fever [11]. Heart rate and respiratory rate are reported to increase with the severity of COPD exacerbation [12]. A range of spirometric indices and vital signs were used in this study to identify possible exacerbation episodes amongst COPD patients.

This paper outlines the development of an algorithm to predict the onset of exacerbations in patients with COPD. The measurement data employed in the validation of this algorithm were collected from a previously reported home telehealth study [13]. During the study, patients with COPD performed their measurements using a home monitoring device that automatically returned acquired data to a remote database for analysis. These data were used to design a classification and regression tree (CART) classifier model to predict exacerbation events. The long-term aim is for this algorithm to be embedded in a decision support system for real-time remote management of COPD patients, using a home telehealth service.

## 2. Methodology

### 2.1. Data

#### 2.1.1. Database

The home telehealth database employed in the development of the algorithm consists of data from twenty-one patients with

moderate-to-severe COPD (six males, fifteen females, aged  $71 \pm 10$  years (mean  $\pm$  SD)). Data were acquired between February 2007 and January 2008, using a home monitoring unit (TeleMed-Care Health Monitor: TMC-Home, TeleMedCare Pty. Ltd., Sydney, Australia) placed in the patients' homes. The database was generated from a randomized controlled study comparing standard best practice care (SBPC) with SBPC plus remote monitoring-triggered intervention. Only data collected from the intervention group were used here. The study was conducted within the catchment area of Austin Hospital in the state of Victoria, Australia. The participant inclusion criteria were: (i) English fluency; (ii) finger dexterity to use a keyboard and mouse; (iii) willingness to use a computer in health self-management; (iv) living independently; (v) no major motor deficit that could prevent use of the home monitoring device; (vi) able to give informed consent; (vii) confirmed moderate/severe COPD; and, (viii) at least one hospital presentation in the last 12 months. Exclusion criteria were: (i) significant co-morbidities (e.g., cancer, renal failure); (ii) documented cognitive impairment; and, (iii) participation in another trial [13]. Each patient was asked to complete physiological measurements and questionnaires on a daily basis using the TMC-Home device, i.e., to measure blood pressure, lung function, pulse oximetry, body temperature and body weight. The questionnaire delivered by the TMC-Home device queried the patients on their respiratory symptoms and general feeling of wellbeing. Moreover, medication information relating to patient respiratory management was recorded in order to acquire a history of medication changes throughout the monitoring period.

During the data collection period, the patients could start, increase, or decrease their respiratory medication intake according to predefined actions included in their normal medication plan, or as instructed by healthcare professionals during the trial. Patients could consult healthcare staff via a telephone or by attending a health clinic. Consent for the execution of the aforementioned data collection was granted by the Austin Health Human Research Ethics Committee.

#### 2.1.2. Reference standard for subject health status

In order to construct a classification model to identify the prodromal stage of an exacerbation event, a reference standard containing each subject's health status was constructed. This reference standard was used in the training phase of the classifier design to fine-tune the performance of the classifier, before independent validation was performed. The process of generating the reference standard is described below.

The reference standard development was adapted from the definition of COPD exacerbation provided by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) strategy document and literature [14,15]. In the symptom questionnaires, patients were asked if there had been any changes in their symptoms, namely: increase in sputum amount; change in sputum colour or consistency; or, worsening breathlessness. Similarly, in the daily medication questionnaires, patients were asked if they had increased their dosage, or had started the use of a respiratory medication on that day. Examples of the questions asked are shown in [Appendix A](#).

Worsening in any one of the symptoms that warranted an increased dosage, or initiating the usage of a respiratory medication, indicated that the patient may have undergone an exacerbation episode on that particular day [14,16]. The three symptoms used below in the definition of risk of exacerbation for this study are:

- an increase in sputum volume;
- an increase in breathlessness; and,
- a darkening in sputum colour.

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