Patrick Fischer*, Keywan Sohrabi, Osman Ashraf, Henning Schneider, Andreas Weissflog and Volker Gross

# Home monitoring of nocturnal cough in COPD patients

**Abstract:** Telemedicine approaches in the treatment of COPD can be useful for the detection of upcoming exacerbations. Specifically productive cough can serve as an effective monitoring parameter. By using modern technologies, we developed a smartphone application to record and analyze nocturnal cough in an outpatient environment. All results will be displayed through a web interface by patients, physicians and relatives. Monitoring cough could lead to an individual therapy and an increased quality of life.

**Keywords:** Cough, COPD, Monitoring, Sputum, Exacerbation, Smartphone Application

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## 1 Introduction

The aim of telemedicine and home monitoring devices for the treatment of COPD is to decrease days and costs of hospitalization and to increase Health-Related Quality of Life [1]. Chronic cough is a common symptom of COPD. The frequency of coughing increases significantly before and during an exacerbation [2]. Current cough monitoring devices focus on counting cough, but not on whether the cough is productive or not [3–6]. Several symptoms, including cough and sputum production can be used to detect an upcoming exacerbation with a high sensitivity [7, 8]. By knowing these details, our aim was to develop a smartphone application to record and analyze nocturnal cough in an outpatient environment. Furthermore, we developed a web interface that enables relatives and physicians to review the patients' results. Patients can monitor their own symptoms and can record their current condition.

## 2 Concept

### 2.1 Recording and analysis

After a pseudonymized authentication process, the patients receive a unique ID to identify their recordings in the Online-Therapy-Viewer. Before starting a recording, patients need to answer a question about their general condition once a day. Afterwards, the smartphone starts to continuously record and sends sound data in small packages, with a duration of 30 seconds each, to a data server. A Wi-Fi signal is needed to transfer the recorded data. The recording is performed by using the build in microphone. A data management software installed on the data server moves the received files to a storage system and starts the analysis by the evaluation server. Algorithms based on an established cough monitoring

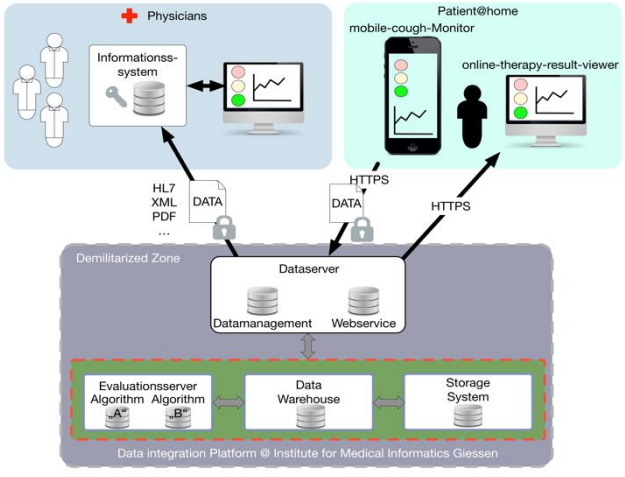


**Figure 1:** Concept of home monitoring of cough using a smartphone and Data-Integration-Platform.

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device are used to detect and classify cough events. The amount of cough events, productive cough and the number of cough epochs are returned as result. The data management software stores the patient's results in the database. The app requests the results of the previous package while sending the next one to the server. All results can be viewed during the recording and in the next morning. For therapy monitoring purpose, a doctor can review the results through a web interface. The outcomes can also be included in the information-system of the physician or clinic (see **Figure 1**).

### 2.2 Security

To ensure privacy, all information is stored by using a unique patient ID, which is only known by the patients, their doctors and their relatives, if desired. Physicians need a German Health Professional Card to get access to the web interface. To provide a secure communication between server and app, the encrypted data is transferred using HTTPS. All servers represent a Demilitarized Zone and are hosted by the Institute of Medical Informatics of the Justus-Liebig-University Giessen (Germany). The storage system can only be accessed by servers and clients inside the firewall and through the data management software of the data server. The evaluation server and database are also inside a firewall to deny access from external devices. The data packages are deleted from the smartphone once the data server successfully received them.

## 3 Implementation

### 3.1 Smartphone application

Due to the limited number of different microphones, the focus of our development was to provide an Application for Apple iOS (min. iOS 8.0). We used Apples Programming Language Swift (Version 3.1), as well as Objective-C and their Integrated Programming Environment Xcode (Version 8.3.1). The following frameworks were used to implement all functions:

- CoreData (Apple Inc.)
- AudioToolbox (Apple Inc.)
- AVFoundation (Apple Inc.)
- CoreAudio (Apple Inc.)
- UIKit (Apple Inc.)
- Chart (Daniel Cohen Grindi)

Patients can start recordings at any time. The question about their general condition can be answered several times each day. Figure 2 provides a screenshot of the developed smartphone application.

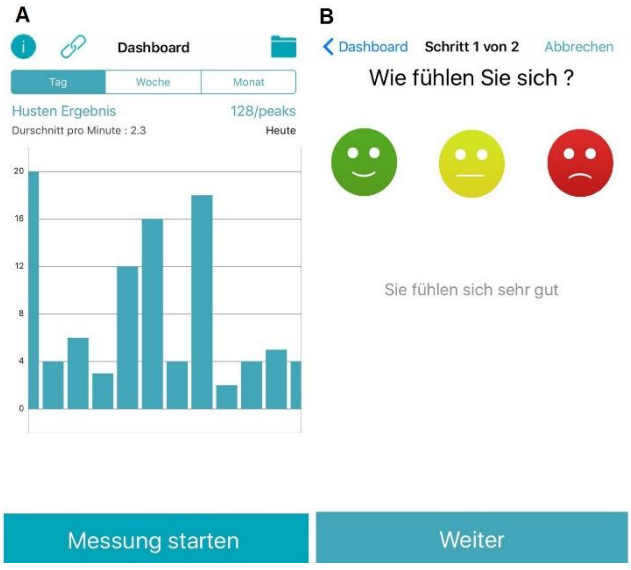


**Figure 2:** Screenshot of the Dashboard (A) and the question about the general condition (B)

### 3.2 Algorithms

Based on an established cough monitoring device, we developed an algorithm to detect and classify cough. For the development, we used MATLAB R2016b and the Signal Processing Toolbox (Version 7.2). Beside the number of cough events, the algorithm also returns the amount of cough epochs, which are defined as at least two consecutive cough events with a maximum distance of two seconds. The cough events are also analysed whether they are productive or not.

### 3.3 Web interface

To implement the web interface, common web technologies such as HTML, JavaScript and PHP (Version: 5.6) are used. Smarty (Version 3.1) was used as the template engine. The web interface can be accessed by patients, physicians and relatives, who can get involved in patient's care.

## 4 Discussion

There are several telemedicine approaches in the treatment of COPD, including continuous cough monitoring [6]. Our

approach focuses on nocturnal cough and its distribution, but also the productiveness of the detected events. Increasing sputum production and highly increasing coughing can help to detect severe exacerbation, which require hospitalization [8]. The novel idea of getting relatives involved in patient's care can help to keep the patients motivated to monitor their symptoms. Monitoring of changes in coughing could lead to an individual therapy, which helps to increase the heath-related quality of life. Questionnaires such as Leicester Cough Questionnaire or the Breathlessness, Cough and Sputum Scale can be included to the app to provide an easy way of performing clinical trials with the end-point cough. Problems during the recruitment, like the ones reported by Crooks et. al. need to be considered [6].

Validation of the algorithms and security concept need to be completed in order to prepare the app for a certification as a medical device.

### Author's Statement

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