

Home-based spirometry in the self-management of chronic obstructive pulmonary disease

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It is estimated that more than 3 million people die from chronic obstructive pulmonary disease (COPD) annually. Acute exacerbation of COPD (AECOPD) leads to an irreversible decline of pulmonary function, an increase of emergency visits, hospitalization and length of stay in hospital, and an increase of the mortality. However, many exacerbations are not reported to healthcare professionals for therapy and yet these events, although often in short durations, have a significant impact on health status.^[1] Early detection and intervention of AECOPD as well as reducing of unreported episodes of AECOPD will potentially improve the prognosis.

Traditionally, COPD patients accept medical evaluations in hospitals or clinics periodically. The advice from physicians based on those measurements may not always be appropriate because the state of a disease like COPD varies frequently during follow-up. Whether a dynamic instant monitoring and feedback system improves the outcomes of chronic disease is an interesting question in the era of booming technology of remote, portable, and smart monitoring equipment and applications.

Mobile devices, for instance, pedometer, smart bracelet, blood pressure meter, glucose meter, pulse oximeter, spirometry, and smartphone, have been widely used by healthy or ill people. For COPD patients, long-term home-based self-management is an important part of maintaining health status and reducing the frequency of AECOPD. Home-based mobile spirometer that satisfies the needs of self-monitoring fluctuations in pulmonary function at home will be applicable for the home-based managements.

It is known that with the progress of COPD disease, the lung function of patients gradually decreases. Though data are limited, some studies indicate there is a significant fluctuation in lung function, especially forced expiratory volume at 1 s (FEV₁) or peak expiratory flow rate, observed before AECOPD develops. Daily pulmonary function monitoring, therefore, has potential in detecting the changes of pulmonary function earlier before AECOPD symptoms develop.^[2,3] Watz *et al*^[4] analyzed FEV₁ data measured with a remote spirometry at least once per week for 8 weeks from 360 COPD patients who participated in a clinical trial of comparing triple and dual therapy. It was found that the decreasing trend of daily FEV₁ could be observed 2 weeks before the onset of clinical symptoms of AECOPD (from 0.907 L in usual to 0.860 L on the day of symptom onset). This study provides the possibility of early detection of a decrease of FEV₁ and intervention 1 to 2 weeks before the clinical apparent deterioration of AECOPD.

Sund *et al*^[5] observed 18 patients for 6 months who used a mobile spirometry and mobile-enabled personal digital assistant. Spirometry and a symptom score questionnaire covering the degree of breathlessness, fatigue, sputum, and sputum color were used. Sund *et al*^[5] defined AECOPD as the following: (1) a decline of FEV₁ ≥ 10% from baseline, or an increase of at least 1 degree of two symptoms out of four, for 2 successive days or more; (2) a patient visited the clinic because of suspected AECOPD and was given a course of antibiotics or oral steroid. Out of 75 AECOPD events, there were 55 (73%) AECOPD events detected via remote monitoring system. Among those 55 events,

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37 (67%), six (11%), and 12 (22%) were detected by symptom score only, FEV₁ only, and symptom score plus FEV₁, respectively. The study suggests spirometry should be used in combination with symptom questionnaires to increase the detection rate of AECOPD.

Shany *et al*^[6] reported a randomized trial of a telemonitoring with spirometry, oximetry, temperature, electrocardiogram, blood pressure, weight, etc. They found telemonitoring was related with reducing of emergency visit, hospitalization, and hospital bed days. The potential of mobile spirometry in reducing AECOPD was demonstrated in this randomized trial with a small sample size of 42 subjects.

In the aspect of life quality and clinical symptoms, a randomized trial of 281 COPD patients compared the quality of life and COPD assessment test (CAT) in patients on telemonitoring to usual care group.^[7] The group that spirometry, oximetry, and symptoms were telemonitored showed improved health-related quality of life scores after 6 months. There was no significant difference in CAT scores as well as the number of AECOPD events between the two groups after 6 months.

Though great opportunities have been revealed, conflicting results were reported in the randomized controlled studies that compare remote monitoring and usual care in the management of COPD. Remote spirometry (FEV₁) was usually performed 2 to 7 days a week. In some studies with relatively large sample sizes, the reduction of AECOPD events was not observed.^[8,9] Emergency visits and hospital admissions were commonly used in studies instead of AECOPD as study endpoints. However, data of mild or moderate AECOPD were not well investigated. The heterogeneous results could be due to following reasons: (1) variability in baseline of patients and management; (2) different strategies of remote monitoring used, for example, questionnaires and other devices used; (3) different outcomes used, even the definitions of AECOPD were not the same; (4) different feedback mechanisms when abnormal readings appear. Further studies are required to clarify who can benefit from the remote monitoring, when they should use it, and how the remote monitoring systems are properly implanted into self-management program of the patients.

Using remote monitoring is probably cost-effective. Achelrod *et al*^[10] performed a population-based study including 651 patients on telemonitoring and 7047 patients on usual care. Spirometers were provided for patients with FEV₁ ≥ 35% and spirometers and oximeters were provided for patients with FEV₁ less than 35%. Both measurements were required at least twice a week. Other questionnaires and patient education were sent from the platform. Any queries from patients were responded at any time. Based on the study for 12 months, mortality hazards were significantly lower in the remote monitoring group. The direct cost reduced also because of less emergency visits, hospital admission, and the duration of hospital stay.^[10]

Forced oscillation technique, an alternative of spirometry for home-based monitoring, has an advantage to measure

pulmonary function during smooth breathing. In a multicenter, randomized clinical trial to investigate telemonitoring with forced oscillation in 312 COPD patients for 9 months, no benefit was found for home-based daily measurement with forced oscillation technique in extending the time to the first hospitalization.^[11] In a recent study on 15 COPD patients for 8 to 9 months, high adherence (95.4%) of forced oscillation technique was observed.^[12] The variability of inspiratory reactance measured by 5 days running window was quite good in reflecting symptoms and potentially detected AECOPD 3 days earlier before symptoms developed. Remote monitoring of airflow limitation with a peak flow meter can also be used in the self-management of COPD.^[13]

There are advantages of mobile spirometry in many aspects such as portable, affordable, easy to operate, timesaving, etc. More importantly, it provides instant information on airflow limitation, reflecting disease fluctuation. Early detection of AECOPD and instant intervention are potentially feasible. However, several issues of these applications exist: (1) The accuracy of unsupervised spirometry is a major concern. Fortunately, the criteria of acceptability and usability of the maneuvers can be instantly reported. Patients should be trained to use the devices correctly and follow the instructions from the system before they start to use. Soler *et al*^[14] found that the use of FEV₁/forced expiratory volume in 6 s, instead of FEV₁/forced vital capacity, was better in stratifying COPD severity and gave an appropriate treatment regimen to help the patient's self-management. (2) The second is the calibration. Calibration requirements for diagnostic measurements are heavily dependent on the design of spirometer. Some mobile spirometers use different mechanisms other than volume-sensing in measurement. Long-term calibration stability has been designed for certain types of spirometers following long-term use. (3) The third is the cleaning of the devices. A study suggested that the pneumotachometers remained accurate for 5 to 9 disinfections but began to drift toward inaccuracy after the first disinfection, and all the pneumotachometers had become inaccurate after ten disinfections.^[15] (4) The interaction and online support from the health care providers should be instant and 24-h uninterrupted. After monitoring data are received in a cloud data center, an artificial intelligence-based data analysis system will be valuable in sending alert to patients and support center instantly. Interaction between patients and health care providers should be smooth. Such a system is extremely important for patients who use telemonitoring devices.

As illustrated in Supplementary Figure 1; <http://links.lww.com/CM9/A569>, home-based remote monitoring of pulmonary function and symptoms facilitates self-management of COPD via smart-phone and support center. In contrast to early generation of portable monitoring without data transmission, current remote monitoring is powerful in instant data analysis and decision-making support. Clinical studies in this area, however, are extremely limited. Although data currently available are not consistent, remote monitoring of pulmonary function is potentially beneficial in reducing the episodes of AECOPD, early alert of AECOPD, and improving

pulmonary function and quality of life in the self-management of COPD. Rapid development of cloud-based data interaction via smart devices is changing the clinical practice in COPD.

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Conflicts of interest

None.

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