Use of a SmartPhone/Tablet-Based Bidirectional Telemedicine Disease Management Program Facilitates Early Detection and Treatment of COPD Exacerbation Symptoms

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Abstract

Introduction: *Early treatment of worsening chronic obstructive pulmonary disease (COPD) symptoms speeds recovery, improves quality of life, and reduces the need for hospitalization. Patients may fail to recognize worsening symptoms leading to delays in treatment. A telemedicine application could facilitate detection and treatment of worsening symptoms. To work, such an application requires consistent use by patients and quick responses from healthcare providers. We conducted a quality assurance assessment of our system to see if we were meeting these goals.* ***Materials and Methods:*** *Thirty patients were provided a smartphone application for daily COPD symptom reporting. Reports between November 2012 and September 2013 were reviewed. Symptoms reports and interventions were time-stamped by the application. Adherence reporting was calculated as the number of reports made divided by the number of days enrolled in the program for each patient. Time to intervention was calculated as the time a report was submitted to the time a treatment recommendation was sent to the patient.* ***Results:*** *There were 4,434 symptom reports made over 5,178 patient-days of observation for an average reporting compliance of 85.6%. Median reporting compliance was 90.7% (interquartile range, 83.8–98%). Four hundred seventy-five symptom reports resulted in an alert. The average response time for all alerts was 6.64 h, with a median response time of 5.75 h.* ***Conclusions:*** *From this quality assessment we were able to conclude that patient adherence to the reporting system exceeded 90% for over half of the participants. Furthermore, over 50% of worsening COPD symptom reports were responded to in less than 6 h with patient-specific treatment recommendations.*

Key words: *home health monitoring, telecommunications, telemedicine, technology*

Introduction

Chronic obstructive pulmonary disease (COPD) is a lung disease characterized by reduced airflow, inflammation, and progressive worsening of disease symptoms.[1] Even when COPD treatments are optimized, few patients are totally symptom free, and worsening symptoms (i.e., exacerbations) often lead to unscheduled office visits, emergency department interventions, and hospitalizations.[2,3] Shortening the time from symptom onset to treatment reduces the severity of these events but requires that patients recognize worsening symptoms, contact a healthcare provider, and start an appropriate treatment regimen.[4,5] This process could be potentially facilitated through telemedicine.

We offer a telecommunication option to our patients for COPD symptom reporting. Reports can be made using a smartphone application or by logging in to a restricted-access Web site through a home computer. Both the smartphone application and Web site are encrypted and Health Insurance Portability and Accountability Act (HIPAA) compliant. The patient's only responsibility is to report his or her symptoms on a daily basis. The application compares the patient's daily COPD symptom report with symptoms recorded when in his or her usual state of health. If worsening symptoms are detected, the application informs the patient and places an alert in the queue for review by the nurse. As part of our continuous quality improvement program, we assessed patient compliance with daily reporting and our ability to provide timely responses to reports of COPD symptom worsening.

Materials and Methods

TELEMEDICINE SYSTEM

COPD patients at high risk of acute exacerbation of COPD were given the option of using a smartphone application for

symptom reporting. The smartphone application is uploaded onto the phone and is password protected. Details of the telemedicine system have been described in an earlier publication.[6] In brief, the application consists of eight screens where patients record their respiratory symptoms (dyspnea, sputum [quantity, color, and thickness], coughing, wheezing, nasal congestion, fever, and sore throat) and peak flow. Three peak flow measurements are obtained using a hand-held peak flow meter and entered into the smartphone application. Three measurements are obtained to ensure they do not vary by more than 20%, and the best of the three measurements is used to compare with the patient's initial value. Sample screens are shown in *Figure 1*.

Initial values for each of these parameters were obtained when patients were in their usual state of health and served as the comparator to detect symptom worsening. Patients reported their symptoms daily prior to 12 p.m. Patients who did not report their symptoms by 12 p.m. received a single reminder from the system.

Symptom reports were converted to a symptom score by a computer algorithm, which compared the daily reported score with the patient's initial score. The algorithm is shown in *Table 1*. An algorithm score that exceeded the initial score by a value of 1 or more resulted in an "alert." The alert, along with the score, was immediately conveyed to the patient and stored on the system for the nurse to review.

Upon receipt of their daily symptom score patients had the option of contacting the clinic; however, in most cases patients waited to be contacted by a clinic nurse with specific recommendations as to how their symptoms should be managed. The clinic nurse used a real-time, HIPAA-compliant application and Web site to view symptom reports and patient messages on a daily basis.

Table 1. Electronic Diary Scoring

CATEGORY	SCORING
Breathlessness	Score 1.0 if ≥3 increments above initial value
Sputum quantity	Score 0.5 if change to greater amount from initial value. Choices: <1 tablespoonful, >1 tablespoonful, >¼ cupful
Sputum color	Score 0.5 if color change from initial value. Choices: If initial value was none or white, and the change is to yellow, green, or brown, score 0.5. If initial value was none, white, brown, or yellow, and the change is to green, score 0.5.
Sputum consistency	Score 0.5 if change from initial values of none, watery, or thin to thick. Score is 0.0 if thick is not a change from baseline.
Peak flow	Score 1.0 if ≤80% of baseline
Temperature over 100° F	Score 0.5 if answer is "Yes"
Cough	All minor symptoms. If two or more minor symptoms are "yes" and a change from baseline, score 0.5.
Wheeze	
Sore throat	
Nasal congestion	

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ALERT RESPONSE PROCESS

For those patients who alerted, the nurse reviewed the report and determined the symptom or combinations of symptoms that triggered the alert. Based on the symptoms the patient reported, an evidence-based treatment recommendation was suggested by the nurse and forwarded to a pulmonologist for approval. A standardized, symptom-based approach to treatment ensured that the suggested treatments were consistently applied across our COPD patient population. Once a treatment recommendation was approved by a pulmonologist, the nurse transmitted the recommendation to the patient in real-time texts and e-mails. Each step of the process (patient symptom report, nurse treatment recommendation, physician approval of recommendation, transmission of treatment to the patient, and patient acknowledgement) was time-stamped by the application.

Fig. 1. COPD-CO-PILOT Diary report sample screens.

DEFINITION OF END POINTS AND DATA ANALYSIS

For this quality improvement project the intervention time to an alert was defined as the time from when a patient submitted a daily report to the time a treatment recommendation was sent to the patient. Because symptom worsening often extends over several or more days, consecutive days with continuous symptoms were combined into episodes. The first day of an alert was considered the start of an episode. An episode ended the day a symptom score of 1 was followed by 7 days of reports below a score of 1.

Daily symptom reporting compliance was calculated as the number of reports received from each patient divided by the expected number of reports. Patients were instructed not to report symptoms if hospitalized for an exacerbation because treatment decisions were being made by a local physician, but some patients reported anyway. These reports were not included in the analysis. Age, gender, race, COPD severity, and pulmonary function test results were extracted from the patient's medical record and obtained as part of the patient's clinical care. Continuous data are reported as mean (standard deviation) except where noted. Categorical data are reported as number and percentage. Symptom reports made between November 2012 and September 2013 were included in the analysis.

Results

Thirty patients used the smartphone system for symptom reporting over the period of 320 days. Symptom reports for 24 patients generated an alert. The demographics and clinical characteristics of these patients are shown in *Table 2*. There were no differences in the clinical characteristics between those patients who generated an alert and those who did not. The period of observation was shorter for those patients who did not alert compared with those who did. The median number of days enrolled in the program was 184 days (interquartile range [IQR], 84–215 days), resulting in 5,178 patient-days of observation. During this time 4,434 symptom reports were made for a mean reporting compliance of 85.6%. The median reporting compliance was 90.7% of days (IQR, 83.8–98%).

TIME FROM ALERT TO RESPONSE

Twenty-four patients submitted 518 symptom reports that generated an alert. Forty-three of these reports were not included in the analysis because they were made by patients who were hospitalized. The resultant 475 alerts were grouped into 83 distinct episodes of worsening COPD symptoms encompassing 692 patient-days. The median number of episodes

Table 2. SmartPhone/iPad Chronic Obstructive Pulmonary Disease Telemedicine Program Demographics ($n=30$)

	ALL ($N=30$)	ALERTED ($N=24$)	NO ALERT ($N=6$)
Age (years) [mean (SD)]	69.7 (5.4)	67.8 (7.0)	72.2 (5.7)
Male [*n* (%)]	11 (48%)	10	1
Race [*n* (%)]			
White	22 (73%)	17	5
Other	8 (27%)	7	1
GOLD stage [*n* (%)]			
0	1 (4%)	1	0
I	2 (8%)	2	0
II	1 (4%)	1	0
III	7 (26%)	6	1
IV	19 (52%)	14	5
FEV1%[a]	37.6 (20.4)	37.2 (20.1)	40 (25.3)
6 MWD (m) [mean (SD)][b]	244.5 (78.1)	246.4 (82.7)	235.5 (58.4)
Smoking pack-years [mean (SD)]	46.1 (32.1)	43.7 (26.8)	55.8 (50.2)
Supplemental O_2 use [*n* (%)]	16 (61%)	14 (58%)	2 (33%)
Days of observation [mean (SD)]	180 (91)	202.4 (78.3)	93.2 (92.3)[c]
Medications used (% of patients)			
SABA		95	66
SAMA		60	16
LABA		69	83
LAMA		39	16
Oral steroid		52	83
Inhaled steroid		73	50
Azithromycin		34	33
Roflumilast		47	16
Nasal steroid		34	0
Leukotriene antagonist		13	16
Theophylline		13	0

[a]Two no-alert patients did not have pulmonary function test data available.

[b]Two patients in each group did not have 6-min walk distance (6 MWD) available.

[c]$p<0.01$.

FEV1%, forced expiratory volume in 1 s percent predicted; GOLD, Global Initiative for Chronic Obstructive Lung Disease; LABA, long-acting beta-2 agonist; LAMA, long-acting muscarinic antagonist; SABA, short-acting beta-2 agonist; SAMA, short-acting muscarinic antagonist.

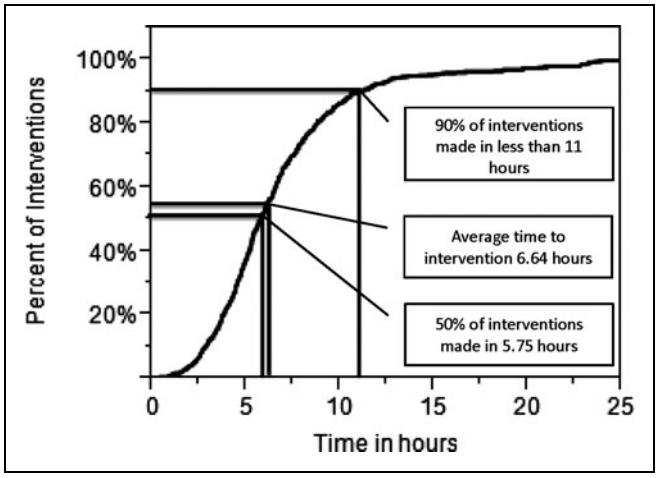

Fig. 2. Time to respond to an alert ($n = 475$).

was 2 (IQR, 1–6; range, 1–9). Median duration of episodes was 3.01 days (IQR, 1–9.9 days; range, 1–67 days).

The median time from the patient's transmission of a symptom report to the time a treatment recommendation was sent to the patient was 5.75 h (IQR, 4.23–8.02 h). Ninety percent of follow-up contacts were made less than 11 h after a report was submitted (*Fig. 2*).

The most common symptom that resulted in an alert was an increase in dyspnea, which was reported on 89% of alert days. This was followed by increased sputum production (56%), cough (31%), nasal congestion (30%), wheeze (15%), sore throat (5%), and fever (0.4%) (*Fig. 3*).

Discussion

Early intervention is an underlying management principle for many diseases. This is as true for a relatively asymptomatic condition like hypertension, where early interventions prevent target organ damage,[7] as it is for strokes and heart attacks, where the goals are to avoid death and chronic disability.[8,9] Unlike hypertension, COPD is a highly symptomatic disease, but patients may not recognize small day-to-day variations in their pulmonary symptoms. Unlike heart attacks and strokes, where symptoms frequently present with little warning, COPD patients most often experience worsening symptoms that peak over a period of several days.[10] These factors—lack of symptom awareness and the pace of symptom worsening—make daily COPD patient telemonitoring an attractive approach to facilitate early intervention. Even so, a daily telemonitoring application can only be effective if the system is used and the healthcare provider responds in a timely manner. This quality improvement assessment was conducted to determine if these goals were being met.

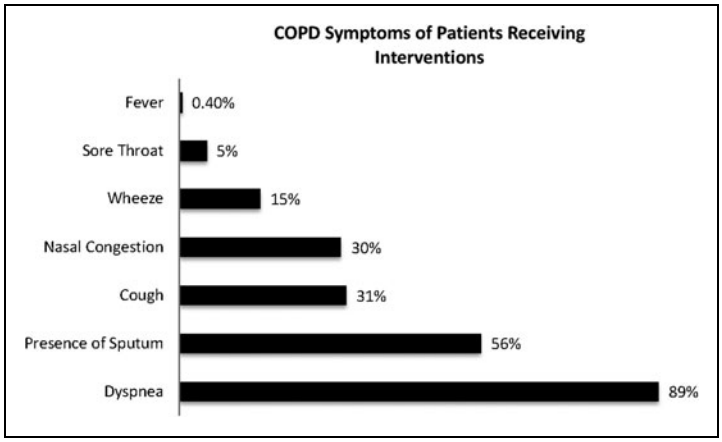

Fig. 3. Alert symptoms ($n = 475$). COPD, chronic obstructive pulmonary disease.

We observed a median reporting rate of 90.7%, indicating a high level of acceptance of the system. The high level of reporting compliance can be attributed to several factors. Among the reasons are that symptom reports could be made in less than 2 min once peak flow rates were obtained, which led to minimal disruptions in the patient's daily activities, that patients knew that reports would be reviewed quickly and that they would be contacted if their symptoms had worsened, and that after making their symptom reports, patients did not need to contact the office for a treatment recommendation.

If an alert occurred, 90% of interventions were made less than 11 h after symptom reporting, and over half were made in less than 6 h. Patients understood that symptom reports would be reviewed beginning after 12 p.m. each day. Despite this, some patients consistently reported their symptoms in the late afternoon or evening. When questioned about this, patients informed us that they had difficulty "getting started" in the morning. The response time would appear to be shorter if calculated from the time reports were first reviewed by the nurse (12 noon). We chose not to do this to reflect the actual time a patient waited for a response after an alert was generated. To improve overall response time, symptom reports could be reviewed twice daily. However, the number of reports involved did not justify the added burden on the nursing staff. Furthermore, to maintain patient safety, patients could contact the office directly if they felt their symptoms were severe. Even without adding a second review of reports, the overall timeliness of response was substantially better than that reported in an interventional study,[11] where it took 6–7 days after the onset of symptoms to start steroids, antibiotics, or both.

There are limitations to our findings. First, a small number of patients was enrolled in the program, and all

were quite ill. This may have provided a substantial motivation to make daily symptom reports. It is unknown if a less ill patient cohort would be equally responsive; however, this group at high risk for exacerbations is the one most likely to benefit from telemonitoring. Second, because of the small sample size, lack of a control group, and limited duration of follow-up, we cannot comment on whether or not we impacted healthcare utilization.

Conclusions

From this quality assessment we were able to conclude that patient adherence to the daily symptom reporting system exceeded 90% for over half of the participants. Furthermore, over 50% of worsening COPD symptom reports were responded to in less than 6 h with patient-specific treatment recommendations.

Disclosure Statement

G.J.C. has served on Advisory Committees for Astra Zeneca and Phillips-Respironics and as a consultant for Johnson & Johnson, Glaxo-Smith-Kline, Pulmonx, and Pearl. G.J.C. has received research grants from Astra Zeneca, Boehringer Ingelheim, Actelion, Forest, Glaxo-Smith-Kline, InterMune, the National Institutes of Health, Novartis, Pearl, Phillips-Respironics, PneumRx, Pulmonx, Roche Pharmaceuticals, and Spectral Diagnostics, Inc. Temple University and Criner have equity interests in HGE and those equity interests are managed by Temple University. All research grant monies are deposited and controlled by Temple University. H.S.S., D.F., C.L.G., and M.R.J. are consultants to HGE Healthcare Solutions. A.J.C. is an employee of HGE Healthcare Solutions.

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