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## Clinical Outcomes of Home Telemonitoring in Severe COPD

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### Abstract

**Introduction:** Aim of this study was to sum up clinical evidence about telemedicine programs in severe COPD patients.

**Methodology:** We conducted a clinical review about telemedicine programs in severe COPD patients. Our search strategy was based in selected all clinical trials published since 2000 about this topic.

**Results:** Finally, we include 13 articles. In telemedicine group the number of Accident and Emergency Department visits and number of hospitalizations were lower than usual care group.

**Conclusions:** Home telemonitoring appears to have a positive effect in reducing respiratory exacerbations and hospitalizations and improving quality of life.

Different programs have been designed to avoid hospitalizations due to AECOPD and to improve follow-up of these patients.

In recent years, several articles have focused on models of home monitoring for early detection and treatment of AECOPD to prevent hospitalizations and emergency room visits. Telemedicine is part of these programs, gathering useful information that can be used for an early intervention should an AECOPD occur [6].

Telemedicine have applications in different scenarios: tele-consultation [7], tele-rehabilitation [8], tele-spirometry [9] and home-telemonitoring programs (HT) [10].

HT program has become increasingly important in light of recent results showing a reduction of income and emergency room visits and high patient satisfaction [11].

So far, however, there has been little discussion about the results of telemedicine programs in severe COPD.

In this context, our work will focus on review recent evidence on the usefulness of telemedicine in patients with severe COPD, defined as number of Accident and Emergency Department (A&E) visits, number of hospital admissions and number of consult in Primary Care and Pneumologist avoided.

**Keywords:** Telemedicine; Severe chronic obstructive pulmonary disease; Remote consultation; Clinical study; Controlled clinical trial

### Introduction

Chronic obstructive pulmonary disease (COPD) is a leading but under-recognized cause of morbidity and mortality worldwide [1]. One of the most important aspects in the natural history of the disease are episodes of acute exacerbation (AECOPD) [2]. AECOPD is a major contributor to worsening lung function, impairment in quality of life, need for urgent care or hospitalization, and cost of care in COPD [3].

Moreover patients who suffer frequents AECOPD have lowest pulmonary function, more comorbidities and daily activities limitation [4]. An American Thoracic Society statement has emphasized the need of a strict follow-up of these frail patients [5].

### Methodology

A review study was conducted. Our search strategy is done in two steps.

First step an electronic literature search in Medline was conducted from January 2000 to January 2015, using the following keywords: tele(\*) (telemedicine OR telemonitoring OR telecare OR tele-home care) and [severe chronic obstructive pulmonary disease].

The inclusion criteria required that the studies: (1) have an experimental design involving direct data collection from patients with severe COPD, (2) be published in English language and appear in peer-reviewed journals, and (3) document telemedicine effects. Randomized and non-

randomized controlled trials were included. Conference and poster abstracts, which do not present detailed studies, were not considered in this review.

All patients included had a diagnostic of severe COPD defined as [12]: respiratory symptoms (dyspnea, cough or sputum), smoker history and severe spirometric obstruction ( $FEV_1/FVC < 0.7$  and  $\%FEV_1 < 50\%$  of theoric value). We also excluded articles that focused on several comorbidities groups of patients or not explain telemonitoring experiments.

Second step was based on reviewing all studies included in Clinical Trials database (<https://clinicaltrials.gov>), using the following terms: [telemedicine] and [severe COPD]. The last update took place on 1st February to prevent data loss.

We did this search because we thought that information about present clinical trials could give us dates about telemedicine platform, clinical characteristics of COPD patients included and actually investigation in telemedicine (cost-effectiveness, clinical outcomes, patient adherence, barriers and facilitators, etc.).

## Variables Used in this Review

We summed up all variables in 4 groups: clinical variables, quality of life and other questionnaires and telemedicine platform and telemedicine outcomes.

### Clinical variables

We were interested in clinical variables related to age, comorbidities (Charlson index), Barthel index and COPD severity (% forced expiratory volume in 1st second, previous AECOPD in the previous year, treatment with domiciliary oxygen therapy and GOLD stage).

### Quality of life and other questionnaires

Main questionnaires reported were: COPD Assessment Test (CAT) [13], St. George questionnaire [14], EuroQOL-5D [15] and CCQ [16].

In others studies, investigators used a clinical questionnaire based in answer about symptoms related to AECOPD: sputum color, wheezing, cough, fever, dyspnea, chest pain, etc.

In this review, we only explain what questionnaire was used, but didn't report these results because were not an endpoint of this study.

### Telemedicine platform

We were interested in describe telemedicine platform. For this reason we have analyzed the methodology of all studies included.

Variables collected were: (1) Telemedicine design: Telemedicine devices, data transmission via, parameters telemonitoring, frequency of the measurement and kind of clinical response. (2) Existence of call center. (3) Existence of specialized nurse.

In this report we did not add dates about other telemedicine variables as: patient and health professional adherence, causes of withdrawal, % of alerts that needed medical respond and % of them that could be resolved by nurse and causes of technical alerts.

### Telemedicine outcomes

We collected all results about A&E visits, hospitalizations in both groups (telemedicine or usual care group), visits to Primary Care or Pneumologist avoid. Other variable that include in this analysis was time to first AECOPD. We reported p-value in each category as best mark to know clinical impact of telemedicine programs.

## Review Procedure

Two members of the study team independently screened the titles and abstracts. Full papers were obtained if either reviewer did not exclude the paper based on the abstract or title. Full texts of papers were obtained and read by one author. The relevance of each study was assessed according to the predefined inclusion criteria.

## Data Analysis

A narrative synthesis of the data, primarily in terms of study design, population, type of intervention, telemedicine design and clinical outcomes was carried out. Thematic analysis was used to identify the most important and recurrent themes relating to telemedicine design across the multiple studies. The analysis was developed in an inductive manner, without a set of a priori themes to guide data extraction and analysis.

## Results

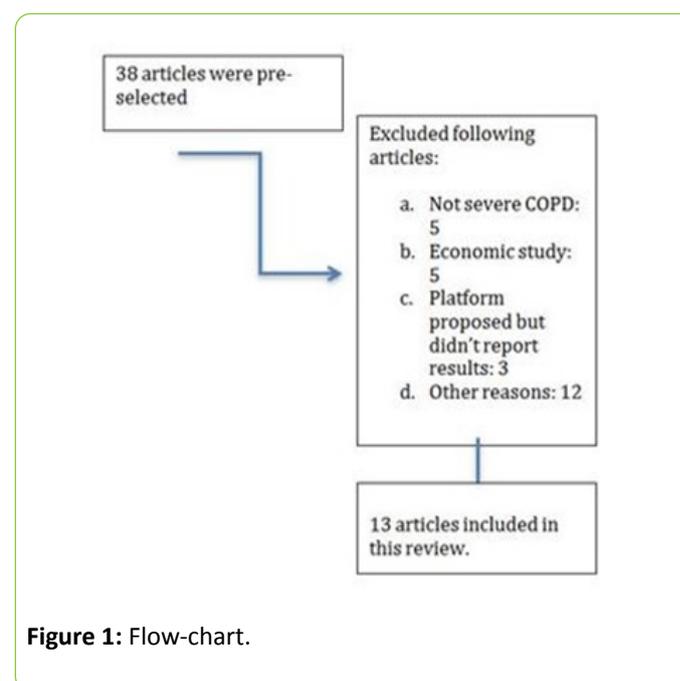


Figure 1: Flow-chart.

Thirty eight studies were selected and 13 of them were included (Figure 1). Telemedicine programs duration varied from 16 weeks to 14 months. The main characteristics of the studies that were included are summarized in Table 1.

**Table 1:** Characteristic of the studies included.

First author, year of publication	Reference	Journal	Country	Primary aim	n
Berkhof FF, 2015	[17]	Respirology	Norway	Telemedicine consisting of provider-initiated telephone contacts in addition to traditional outpatient management would reduce health-care utilization in comparison to usual care and increase the health status of COPD by timely detection of incipient exacerbations.	101
Blumenthal JA, 2015	[18]	Psychosom med	USA	To evaluate the efficacy of telehealth coping skills training intervention for improving QoL and medical outcomes in COPD patients by helping them develop skills for coping more effectively with their disease.	326
Tabak M, 2015	[19]	International Journal of COPD	Norway	To improve self-management in COPD exacerbations.	29
Segrelles Calvo G, 2014	[20]	Respir Med	Spain	To reduced number of COPD exacerbations and hospitalizations in telemedicine group.	59
Jehn M, 2013	[21]	Environ Health	Germany	To reduced number of COPD exacerbations and hospitalizations in telemedicine group.	62
Sorknaes AD, 2013	[22]	J Telemed Telecare	Denmark	To reduced number of COPD exacerbations and hospitalizations in telemedicine group.	266
Jakobsen AS, 2013	[23]	Trials	Denmark	To reduced number of COPD exacerbations and hospitalizations in telemedicine group.	57
Pinnock H, 2013	[24]	BMJ	UK	To reduced number of COPD exacerbations and hospitalizations in telemedicine group.	256
Jódar-Sánchez F, 2013	[25]	J Telemed Telecare	Spain	To reduced number of COPD exacerbations and hospitalizations in telemedicine group.	45
Chau JP, 2012	[26]	Int J Med Inform	China	To reduced number of COPD exacerbations and hospitalizations in telemedicine group.	40
Vitacca M, 2009	[27]	Eur Respir J	Italy	To reduced number of COPD exacerbations and hospitalizations in telemedicine group.	240
Trappenburg JC, 2008	[28]	Telemed J E Health	USA	To reduced number of COPD exacerbations and hospitalizations in telemedicine group.	
de Toledo P, 2006	[29]	IEEE Trans Inf Technol Biomed	Spain	To reduced number of COPD exacerbations and hospitalizations in telemedicine group.	157

COPD: Chronic obstructive pulmonary disease.

## Patient characteristics

**Table 2:** Patients characteristics.

Reference	Age	% FEV1	GOLD stage	Comorbidities (Charlson Index)	Domiciliary oxygen	Previous AECOPD
17	68 y	40	Undescribed	Undescribed	17.3%	44.2% study cohort
18	66.1 y	45.4	Undescribed	CI 2	37%	Undescribed
19	66.1	50	Undescribed	Undescribed	Undescribed	Undescribed
20	75.9 y	37.1	Undescribed	CI 3.7	100%	1.9
21	64.1 y	50	II-IV	Undescribed	Undescribed	Undescribed
22	74.5 y	0.665 litres	Undescribed	Undescribed	Undescribed	Undescribed
23	Undescribed	Undescribed	III-IV	Undescribed	Undescribed	Undescribed

24	69.4 y	44	Undescribed	>1 comorbidity 61%	Undescribed	2.3
26	72.9 y		Undescribed	Undescribed	Undescribed	Undescribed
27	61.2 y	39	IV	CI 1.7	64%	1.7
28	69	42	Undescribed	Undescribed	Undescribed	1.45
29	71	42	Undescribed	Undescribed	Undescribed	Undescribed

CI: Charlson index; AECOPD: acute exacerbation of COPD, y: years old.

A total of 1,498 patients were included had in account all studies. Average age was 68.7 years old. Older patients were included in studies of Segrelles-Calvo et al. (75.9 y), Chau JP et al. (72.9 y) and de Toledo P et al. (71 y).

In this review patients with more severe obstruction were reported to Segrelles-Calvo et al. (%FEV1 37.1%). %FEV1 ranged between 37.1% and 50%. The average number of AECOPD in previous year was 1.5.

Only in 7 studies (Blumenthal JA et al., Pinnock H et al., Vitacca M, Trappenburg et al., Segrelles-Calvo G et al., Jódar-Sánchez F et al., de Toledo P et al.) are mentioned comorbidities, Charlson index or Barthel index, Table 2.

### Primary and secondary endpoints

The most frequent endpoint was clinical impact of telemedicine (number of A&E visits, number of hospitalizations, time to first AECOPD and visits to Pneumologist or Primary Care).

Moreover, secondary endpoints included impact of telemedicine in quality of life, patients' preference, adherence to telemedicine program and economic burden.

### Telemedicine platform (TP)

Design of TP platform was distinct between studies.

In nine studies were monitored several clinical parameters at patients' home. One of the most frequent parameters registered was oxygen saturation (SpO<sub>2</sub>) alone (Vittacca et al. and Pinnock et al.) or together with other parameters

(Segrelles Calvo G, Jódar Sánchez F, de Toledo P, Trappenburg JC, Farmer A and Sorknaes AD). Those parameters were: SpO<sub>2</sub>, heart rate, respiratory rate, peak-flow or spirometry.

Authors defined a normal range to each parameter. When a parameter exceeded these limits clinical alert was activated. Devices' installation was performed to specialist nurse at patients' home. In this first visit, nurse confirmed that patient was unable to use devices.

This information was transmitted telephone line via until the call center although other studies used video-call or Skype® to follow-up the patients. To diagnose early AECOPD authors not only collected clinical parameters but clinical questionnaire is adding too.

In other studies, authors used a test based on respiratory symptoms related to ACOPD as: color sputum, cough, wheezing, fever, dyspnea and it was used to classify COPD severity. Questionnaires were performed using Tablet, web platform or telephone. The more frequent questionnaires done were: COPD Assessment Test (CAT), Euroqol-5D or St. George questionnaire.

### Patients outcomes

Telemedicine program reduced A&E visits and number of hospitalizations in the follow studies: Jehn M et al., Segrelles-Calvo G et al., Vitacca M et al., Trappenburg JC et al. and de Toledo P et al. (Table 3).

Time to first exacerbation was about 141.97 days, significantly lower than usual care group (77.28 days p-value = 0.003).

**Table 3:** Clinical outcomes.

First author	Intervention	A&E visits	Hospitalizations
Berkhof FF	Telephone call twice per week.	No differences (p-value = 0.33)	No differences (p-value = 0.27)
Blumenthal	Telephone call twice per week.	Undescribed	Undescribed
Tabak M	Web-platform involved the following modules: teleconsultation, web-based exercise, self-management and activity coach.	No differences (5 vs 5 visits)	No differences (4 vs 5 hospitalizations)

Segrelles Calvo G	Telemedicine platform with home remote monitoring connected via telephone. Daily measures of blood pressure, pulse oximetry, heart rate and peak-flow.  Clinical alert was defined if anyone of parameters exceeds the limit settled down.  Dates were reviewed by specialized call center and Pneumologist.  Program was coordinated by Pneumologist and with Primary Care.	20 telemedicine vs 57 usual care (p-value = 0.001)	12 telemedicine vs 33 usual care (p-value = 0.001)
Jehn M	Telemedicine platform with home remote monitoring connected via telephone. Daily measures of pulse oximetry, 6 minutes walking test, spirometry and COPD Assessment Test.	Undescribed	7 income in telemedicine group vs 22 in usual care (p-value = 0.012)
Sorknaes AD	Telemedicine video consultation involved the followed equipment: computer with web camera, a microphone, saturation, spirometry, means of contacting a specially trained nurse at the hospital and alarm to send a short message to the nurse.	No differences between groups.	No differences between groups.
Jakobsen AS	Telemedicine program involved web-platform, webcam and devices to measure pulse-oximetry, spirometry and temperature.	Undescribed	Telemedicine group had 28.5% less readmissions.
Pinnock H	Telemedicine pulse-oximetry daily register and questionnaire based on respiratory symptoms.	No differences between groups.	No differences between groups.
Jódar-Sánchez F	Telemedicine platform with home remote monitoring connected via telephone. Daily measures of blood pressure, pulse oximetry, heart rate and peak-flow.  Clinical alert was defined if anyone of parameters exceeds the limit settled down.  Dates were reviewed by specialized call center and Pneumologist.	No differences between groups.	No differences between groups.
Chau JP	Online network platform with the followed equipment: pulse oximetry, heart rate and respiratory rate.	No differences between groups.	No differences between groups.
Vitacca M	Transmit arterial oxygen saturation information measured by pulse oximetry through home telephone lines. TA nurses provided real-time teleconsultation 40 h/week. The call center was able to receive data 24 h/day, addressing patients' needs or questions. When necessary, the pulmonologist on duty was contacted.	Reduced number of A&E visits (p-value = 0.04)	Reduced number of hospital admissions (p-value = 0.04)
Trappenburg JC	Received conventional care and used telemonitoring device Health Buddy, which provides access to a browser-based care management tool and communication tool. Monitored disease symptoms, medication compliance, and knowledge, and provider education about patients' conditions.	Reduced number of A&E visits (p-value = 0.04)	Reduced number of hospital admissions (p-value = 0.03)
de Toledo P	Patient attended a 1.5 h education session. They received a laptop-based mobile home visit unit, a device used by nurses when visiting patients at home. They also received a spirometer for respiratory monitoring at home and transmission to the telemedicine server.	TH 0.36 vs UC 0.54 (p-value = 0.15)	Patients that were not readmitted at least once (46.9% TH vs 65.2% UC, p-value = 0.03)
A&E visits: Accident and Emergency Department visits.			

Average days of hospitalization were similar in all studies. Segrelles-Calvo et al. reported length of stay: telemedicine group 105 days versus usual care group 276 days (p-value = 0.018).

De Toledo et al. claim that telemedicine group has few readmissions that usual care group (46.9% vs 65.2%, p-value = 0.03). In this work number of readmission by patient was 0.9+/-1.28 in telemedicine group vs 1.33+/-1.73 in usual care group (p-value = 0.04).

Vitacca et al. observed that patients in telemedicine group had lower admissions per month (p-value < 0.01) compared as usual care.

Another important practical implication of telemedicine is the reduction of hospitalizations in COPD with frequent exacerbations [28].

## Clinical trials

Until 1<sup>st</sup> February 29 studies were included in Clinical Trials database. Total number of patients that participated in those works was 5711. Primary endpoint was related to home telemonitoring in 15 articles, tele-rehabilitation in 5 articles, self-management in 3 patients and other interested areas were: tele-spirometry, tele-hospitalization and non-invasive ventilation home monitoring.

In four studies, authors admitted severe COPD patients (%FEV<sub>1</sub> < 50%): Wandivier et al., Ancochea J et al., Winck JC et al. and Andersen FD et al.

## Discussion

There is increasing interest in the use of to assist in the management of diseases. possibilities for patients with include

medical consultations, in-home patient monitoring and remote rehabilitation [30].

The findings of this review show that telemedicine could reduce A&E Department visits and hospitalizations due to AECOPD. These results, although promising, present some usability problems that need to be considered in future research [10].

In severe COPD group, in some studies telemedicine reduced the number of AECOPD that need urgent assessment. In other case telemedicine showed that could be comparable alternative as usual care.

In this review, patients included had the following characteristics: average age was 68.7 years old, medium number of comorbidities measured by Charlson Index was ranged 1.7 [27] and 3.7 [20] and %FEV1 between 37.1% [20] and 50% [19,21]. It is important to note that it is unusual to highlight these features in the studies undertaken.

Kamel T et al. reported that exacerbations rates 3 months after started telemedicine program and number of hospitalizations were lower in telemedicine care group. Segrelles-Calvo et al. proved that 1<sup>st</sup> AECOPD was latter in telemedicine patient [20] and de Toledo P et al. evidenced that range of readmissions was lower in that group unlike that usual care group [29].

One of the most highlight points in this review is the different clinical response in telemedicine group. Main barriers that we found were: (1) Coordination between Primary and Secondary Care are rare. (2) A few publications describes a flow-chart to clinical response when patients needed medical attention. (3) Several of the selected studies used clinical questionnaires more frequently than respiratory parameters measurements or both dates. (4) Only in one of the studies medical home visit was performed.

Segrelles-Calvo et al showed that patients in telemedicine group have less severe COPD exacerbation. Patients included in the usual care group had more admissions with respiratory acidosis, needing of non-invasive ventilation and admissions in Intensive Respiratory Care Unit (p-value = 0.008) [20].

Trappenburg and et al. reported that patients in telemedicine group had less frequent exacerbations (> 2 ECOPD, p-value = 0.03). These results are consistent with those of other studies and suggest that telemedicine reduced number of readmissions (de Toledo [29] and Jakobsen [23]).

Our reviews suggest that COPD severity and comorbidities are associated with better outcomes in telemedicine group. Moreover telemedicine design with respiratory parameters measurement, call center with nurses and flow-chart to clinical response are probably related with better clinical results.

There are several possible explanations for those results. Probably, the telemedicine affect not only clinical outcomes, but also patients' perception of care.

We haven't got information about how should be clinical response. Studies don't offer information about if clinical response will be immediately or delayed.

Time of response is limited to call center organization. In Segrelles-Calvo [20], Jódar-Sánchez [25], de Toledo [29], Trappenburg [28] and Jakobsen [23] trials clinical response were active between 8-17h. Most of the AECOPD occurred during this time.

In conclusion, home telemonitoring appears to have a positive effect in reducing respiratory exacerbations and hospitalizations and improving quality of life. However, the evidence of its benefits is still limited and further research is needed to assess the effectiveness of home telemonitoring in COPD management, as there are still few studies in this area.

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