How will telemedicine change clinical practice in chronic obstructive pulmonary disease?

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Abstract: Within telehealth there are a number of domains relevant to pulmonary care: telemonitoring, teleassistance, telerehabilitation, teleconsultation and second opinion calls. In the last decade, several studies focusing on the effects of various telemanagement programs for patients with chronic obstructive pulmonary disease (COPD) have been published but with contradictory findings. From the literature, the best telemonitoring outcomes come from programs dedicated to aged and very sick patients, frequent exacerbators with multimorbidity and limited community support; programs using third-generation telemonitoring systems providing constant analytical and decisionmaking support (24 h/day, 7 days/week); countries where strong community links are not available; and zones where telemonitoring and rehabilitation can be delivered directly to the patient’s location. In the near future, it is expected that telemedicine will produce changes in work practices, cultural attitudes and organization, which will affect all professional figures involved in the provision of care. The key to optimizing the use of telemonitoring is to correctly identify who the ideal candidates are, at what time they need it, and for how long. The time course of disease progression varies from patient to patient; hence identifying for each patient a ‘correct window’ for initiating telemonitoring could be the correct solution.

In conclusion, as clinicians, we need to identify the specific challenges we face in delivering care, and implement flexible systems that can be customized to individual patients’ requirements and adapted to our diverse healthcare contexts.

Keywords: chronic care, e-health care, telecare, telemonitoring

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Introduction

Chronic obstructive pulmonary disease (COPD) is associated with a high cost burden. Modern information communication technologies offer new options for delivering remote specialized healthcare, amongst which telemonitoring, a complex intervention that includes both the electronic transmission of patient information to the healthcare system and the follow-up response by a healthcare professional. Telehealth has been defined as the use of information and communication technologies (ICT) to deliver healthcare services and transmit medical data over long and short distances. It encompasses a wide variety of technologies such as videoconferencing, internet platforms, store-and-forward devices, streaming media, and terrestrial and wireless communication. Telehealth may be used for a wide range of purposes: to decrease the demand on existing hospital and healthcare services; reduce the cost of care; measure treatment adherence; identify disease worsening; improve accessibility to services; and to extend the reach of services to remote locations. Telehealth is therefore a broad concept that involves diagnosis, treatment, monitoring, education and prevention. Within telehealth there are a number of domains relevant to pulmonary rehabilitation:
(1) Telemonitoring: the use of ICT to monitor patients at a distance.
(2) Teleassistance: the provision of clinical care at a distance using ICT.
(3) Telerehabilitation: the use of ICT to provide clinical rehabilitation services at a distance.

**Rationale for telehealth in COPD**
The rationale for telemonitoring development in patients presenting with COPD with or without chronic respiratory failure is related to progressive aging of the patient population, carrying with it an increased burden of care at home; technological advances; increased healthcare consumption and the need to cut costs; difficulties associated with hospital discharge; early remote detection of signs and symptoms of COPD chronic respiratory insufficiency decompensation; tailoring and monitoring at a distance of mechanical ventilation and providing education reinforcement for the patient and caregiver; and an opportunity to improve the access to pulmonary rehabilitation for aging populations in many developed countries and reduce patient-related barriers to attendance.

**Telehealth opportunities**
There are several opportunities related to e-health: telemedicine (TM) with diagnosis at a distance based on spirometry tracing, teleconsultation, telemonitoring of biological signals, decision support systems, teletherapy, teleevaluation, telecare, telerehabilitation, telecoaching/mentoring, teleconference and second opinion calls. The different generations of e-health, as they have evolved, have proposed the following: measurements transferred to the care provider asynchronously (by store-and-forward protocols) (first generation); synchronized data transfer (automated algorithms can recognize important changes but delays can occur if the systems are not active 24 h/day) (second generation); and constant analytical and decisionmaking support in which monitoring centers have full therapeutic authority 24 h/day, 7 days/week (third generation). The level of technology for an optimized e-health is available, but so far no one platform has proven its superiority over another. For this reason, the correct level of technology to use needs to be determined according to each individual patient, and it should be safe, feasible, effective, sustainable and flexible to the patient’s condition.

**Clinical findings**
To date, the evidence as to whether telemonitoring is really effective in COPD seems inconclusive and contradictory. For this reason authors have proposed an ‘authors review’ based on a search of EMBASE, CINALH, PubMed, PsychINFO and Scopus databases using the following keywords: telemonitoring and COPD, TM and COPD. Papers published between 2003 and 2017 in English language were considered. The first author assessed the identified RCT studies for appropriateness. Among 395 papers, 46 randomized controlled trials (RCTs) were considered as appropriate for analysis.

In the last decade, several studies have been published on the effects of various telemangement programs for patients with COPD. Table 1 summarizes the RCTs on TM which showed positive results. Studies have been conducted in Europe (n = 18), the USA (n = 4), Australia (n = 1) and China/Taiwan (n = 2). A total of 4366 patients (mean age 71 ± 4 years) were studied with a mean forced expiratory volume in 1 s (FEV1) of 45 ± 10%; 12 ± 20% of the patients were on long-term oxygen therapy (LTOT), and all were frequent users of healthcare with a history of relapses and hospitalizations. In the majority of cases, the control groups were on the usual general practitioner (GP) care while the COPD groups were on a second-generation TM platform in 60% of cases and on a third-generation TM platform in 40% of cases for a mean time of 9 ± 7 months. Reduction in hospitalizations and use of other acute healthcare services, improvement in the quality of life and patient satisfaction were reported in the majority of studies providing chronic home care interventions and patient education at a distance (Table 1). These programs were based on a strict adherence to care interventions to enhance symptom self monitoring by patients and their caregivers, through increasing their understanding of drug therapy, monitoring symptoms and treatment, and acting as a liaison between primary care providers and hospital services. This involved the delivery of time-intensive education by nurses and other personnel such as a respiratory therapist.

Table 2 reports RCTs which showed contradictory results (both positive and negative according to the different outcomes). The studies were conducted in Europe (n = 5), the USA (n = 2) and Australia/New Zealand (n = 2). A
| Ref.         | Pts, n | Inclusion severity | Country | Control group | Experimental group | TM generation | Study time | Outcomes                                                                 |
|-------------|--------|--------------------|---------|---------------|-------------------|---------------|------------|--------------------------------------------------------------------------|
| Bernocchi et al.⁸ | 112 y = 70; FEV₁ = 66%; LTOT = 47%; exacerbation history | Italy | Standard care | Nursing and physical therapy program. Call once a week | Third generation | 6 months | + exercise tolerance; + PA; - hospitalizations; + QoL; - dyspnea; - fatigue |
| Tsai et al.⁹ | 36 y = 74; FEV₁ = 64%; LTOT = 0% | Australia | Standard care | Exercise training + videoconferencing three times a week | Third generation | 2 months | + exercise capacity; + QoL = PA; = physical performance;= health status; + psychological status; + self efficacy |
| Gellis et al.¹⁰ | 115 y = 79; FEV₁ = NA; LTOT = 0%; 3 or more home visits/week | USA | Standard care (physical therapy, social services, nutrition) | Telehealth nurse reviewed patient data daily. Alerting system to the central station | Second generation (daily vital signs to the central station) | 12 months | + general health and social functioning; + depression symptoms; + visits to ER for the control group |
| Billington et al.¹¹ | 73 y = 72; FEV₁/FVC <70%; FEV₁ = 50%; LTOT = 0% | UK | Self-management plan | Two contacts by a nurse; scheduled phone calls | Second generation (phone calls + data control) | 3 months | + CAT; = exacerbations; = satisfaction |
| Demeyer et al.¹² | 343 y = 66; FEV₁ = 56%; LTOT = 0%; smoking history of at least 10 p/y | Greece, UK, Switzerland, The Netherlands | Physical activity + medical treatment | Telecoaching (step counter; text message; activities goal review) | Second generation | 3 months | + PA; + functional capacity; = health status |
| Ho et al.¹³ | 106 y = 80; exacerbation history; FEV₁ = 62%; LTOT = 0% | Taiwan | Usual care + a phone line for medical counseling | Phone line + electronic diary of symptoms each day. Alerting system | Second generation (oximeter, temperature, blood pressure) (8 am–8 pm) | 2 months | + time to first readmission for COPD exacerbation; + all-cause readmissions; + COPD-related ER visits |
| McDowell et al.¹⁴ | 110 y = 70; FEV₁ = 44%; LTOT = 26%; exacerbation/hosp./ER/urgent GP history | Ireland | Respiratory team and GP + home visits. Alerting system to team | Home-based program + home telehealth system | Second generation (daily transmission of data to a nurse) | 6 months | + SGRQ-C; − HADS; − exacerbations and ER visits; + satisfaction |
| Segrelles Calvo et al.¹⁵ | 59 y = 73; FEV₁ = 37%; LTOT = yes | Spain | Two visits at home + monthly telephone calls | PROMETE telehealth program. Alerting system to nurse and pulmonologist | Second generation (blood pressure, oxygen saturation, HR on a daily basis and PEF three times/week) | 7 months | − ER visits; − hospital length of stay; − hospitalizations; − need of NIV |

(Continued)
| Ref. | Inclusion severity | Country | Control group | Experimental group | TM generation | Study time | Outcomes |
|------|-------------------|---------|--------------|------------------|---------------|-----------|----------|
| Bourbeau et al. | 16 | 70% FEV1; 0% LTOT; history | Canada | Usual care with GP | Third generation (education, supervised training + weekly telephone calls) | 12 months – hospital admissions; – ER visits; – unscheduled physician visits; – QoL | – relapses; – hospital admissions; – health costs; – clinical outcomes |
| Pedone et al. | 17 | 74% FEV1; 38%; LTOT = 0% | Italy | Standard care | Second generation (pulse oximeter + telephone) | 9 months – relapses; – hospital admissions | – QoL |
| Puig-Junoy et al. | 18 | 71% FEV1; 46%; LTOT = 0% | Spain | Conventional care without nurse’s support | Third generation (clinical data to nurse and physician) | 6 months – home visits of nurse; – hospital admissions; – hospital stay outcomes | – QoL |
| Paré et al. | 19 | 72% FEV1; 39%; LTOT = 0% | Canada | Regular home care | Second generation (clinical data to nurse and physician) | 6 months – QoL; – hospital anxiety; – hospital depression | – QoL |
| Lewis et al. | 20 | 71% FEV1; 39%; LTOT = 0% | UK | Standard care | Second generation (clinical data to a server) | 6 months – home visits of nurse; – hospital admissions; – hospital stay outcomes | – QoL |
| Chau et al. | 21 | 73% FEV1; 38%; LTOT = 0% | China | Standard care + education on self care | Second generation (clinical parameters three times/day) | 12 months – QoL; – hospital anxiety; – hospital depression | – QoL |
| Jódar-Sánchez et al. | 22 | 72% FEV1; 37% LTOT = 0% | Spain | Conventional medical care | Second generation (system generated an alarm) | 6 months – hospital admissions; – QoL | – QoL |
| Trappenburg et al. | 23 | 79% FEV1; 43%; LTOT = 0%; exacerbation history | The Netherlands | Usual care | Second generation (daily questions; immediate feedback from service. A nurse reviewed answers) | 6 months – hospital admissions; – QoL | – QoL |
| Ref.                  | Pts, n | Inclusion severity | Country | Control group | Experimental group | TM generation | Study time | Outcomes                                                                 |
|----------------------|--------|--------------------|---------|---------------|--------------------|---------------|------------|--------------------------------------------------------------------------|
| Vitacca et al. 24    | 220    | y = 69; FEV1 = 36%; LTOT = 69%; HMV = 40%; hosp./exacerbation history | Italy   | Outpatient visits every 3 months | Clinical score, pulse oximeter Telenursing and doctor on demand | Third generation (40 h/week, real-time teleconsultation + free calls 24/24 h) | 12 months | – hospitalizations; – urgent GP calls; – acute exacerbations; – costs    |
| Steventon et al. 25  | 315    | y = 69; FEV1 = NA; LTOT = 0% | UK      | NA            | NA                 | NA            | 12 months | – mortality; – ER visits; – length of hospital stay; = costs              |
| Abak et al. 26       | 24     | y = 63; FEV1 = 43%; LTOT = 0%; exacerbation/hosp. history | The Netherlands | Usual care + physiotherapy sessions | Teleconsultation, web-based exercising, self management, activity coach | Second generation | 9 months | + satisfaction                                                             |
| Au et al. 27         | 123    | y = 74; FEV1 = NA; LTOT = 0% | USA     | Usual care    | Healthy buddy device | Second generation | 36 months | – hospital admissions; – exacerbations                                  |
| Hernandez et al. 28  | 222    | y = 71; FEV1 = 42%; LTOT = 16% | Spain   | Standard care | Five nurses access + nonlimited phone calls | Third generation | 12 months | – hospitalizations; – ER admissions; + HRQoL; + patient satisfaction; + knowledge of the disease |
| Casas et al. 29      | 155    | y = 71; FEV1 = 42%; LTOT = 18.5%; hospital stay > 48 h | Spain + Belgium | GP visits scheduled every 6 months | Self management specialized nurse weekly phone calls | Third generation | 12 months | – readmissions; less % of patients without admissions; = no. of deaths |
| Farrero et al. 30    | 122    | y = 69; FEV1 = 27.5%; LTOT = 11.5% | Spain   | Conventional care | Monthly phone call, home visits every 3 months, home/hospital visits on demand | Third generation | 12 months | – ER visits; – hospital admissions                                      |
| Wang et al. 31       | 120    | y = 70; FEV1 = 35.5%; LTOT = NA | China   | Routine care  | Nurses’ calls every 2 weeks, home follow-up visits at 1, 3, 6, 12 months | Third generation (web-based coaching program) | 12 months | + lung function; + SGRQ; + 6MWT                                        |
| Witt Udsen et al. 32 | 1225   | y = 75; FEV1 = NA; LTOT = NA; MRC >3; CAT >10; exacerbation history | Denmark | Usual practice | Daily vital signs sent to the team. Alerting system | Second generation (blood pressure; pulse oximeter) | 12 months | + cost effectiveness; – hospital admissions; – primary care costs       |

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| Ref. | Pts, n | Inclusion severity | Country | Control group | Experimental group | TM generation | Study time | Outcomes |
|------|--------|--------------------|---------|---------------|-------------------|---------------|-----------|----------|
| Vasilopoulou et al. | 147 | y = 65.8; FEV1 = 50%; LTOT = 25%; exacerbation history | Greece | Usual care education | 2 months of PR + home telerehabilitation; access to call center 5 days/week, 10 h/day; psychological support; dietary and self management; telephone or videoconference | Third generation | 12 months | – exacerbations; – hospitalizations; + ER visits; + functional capacity; + HRQoL; + daily physical activity |

CAT, COPD assessment test; COPD, chronic obstructive pulmonary disease; EQ-5D, Euro QOL five Dimensions Questionnaire; ER, emergency room; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; GP, general practitioner; HADS, Hospital Anxiety and Depression Score; HMV, home mechanical ventilation; HR, heart rate; HRQoL, health-related quality of life; LTOT, long-term oxygen therapy; MRC, Medical Research Council; 6MW, 6-min walk test; NA, not applicable; NIV, noninvasive ventilation; PA, physical activity; PR, Physical Rehabilitation; PEF, peak expiratory flow; Pt, patient; p/y, pack years; QoL, quality of life; RCT, randomized controlled trial; SGRQ-C, St George Respiratory Questionnaire; TM, telemedicine.
Table 2. Summary of RCTs on TM with positive and negative results.

| Ref. | Pts, n | Inclusion severity | Country | Control group | Experimental group | TM generation | Study time | Outcomes |
|------|--------|--------------------|---------|---------------|--------------------|--------------|------------|----------|
| Ringbæk et al. 34 | 281 | y = 69; FEV1 = 34%; LTOT = 37.5%; hospitalisation and exacerbation history | Denmark | Respiratory nurses at home or in outpatient clinic | Symptom control by a call center; video consultation. Alerting system, second opinion specialist | Second generation (symptoms, saturation, spirometry) | 6 months | = hospital admissions; experimental group had more moderate exacerbations |
| Kenealy et al. 35 | 171 | y = 65; FEV1 = 27.5%; LTOT = 11.5% | New Zealand | Usual care | Health hub, telephone | Second generation | 3–6 months | – anxiety and depression; = QoL, self efficacy and disease-specific measures; = hospital admissions and outpatient visits |
| Vianello et al. 36 | 334 | y = 76; FEV1 = 41%; LTOT = 40% | Italy | Transmitted parameters daily + alerting system to GP and specialist | Transmitted parameters daily + alerting system to TM team [8–18 Monday–Friday] with specialist | Second–third generation (HR and SpO2) | 12 months | = HRQoL; = HADS; = no. and duration of hospitalizations; + readmissions; + specialist visits; + visits to ER; + deaths |
| Chatwin et al. 37 | 72 | y = 61.8; FEV1 = 0.9 liter; LTOT = 38; hospitalization history | UK | Standard care + contact number with medical team + access to respiratory care nurse | Daily data to healthcare team. Alerting system with staff action | Second generation (HR, SpO2, blood pressure) symptoms | 12 months | = time to first admission for an acute exacerbation; – hospital admissions; = GP consultations; + home visits by nurse; + QoL; – HADS |
| Cordova et al. 38 | 67 | y = 63.5; FEV1 = 31.5%; LTOT = 68%; hosp./exacerbation history | USA | GP care plan | Phone calls if alerting to nurse or GP. Visits at 6–12–18–24 months | Second generation | 24 months | = hospitalizations and mortality; + fewer and more moderate symptoms; + lower symptom index score; = QoL; = dyspnea |
| De San Miguel et al. 39 | 71 | y = 71.5; FEV1 = NA; LTOT = NA | Australia | Usual educational book + telemonitoring alerting to nurses | Educational book | Second generation (vital signs and health status) | 6 months | = hospital admissions; = ER visits; = length of stay; = costs |

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Table 2. (Continued)

| Ref.         | Pts, n | Inclusion severity | Country | Control group | Experimental group                                                                                  | TM generation                                                                 | Study time | Outcomes                                                                 |
|--------------|--------|--------------------|---------|---------------|----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------|--------------------------------------------------------------------------|
| Koff et al.  | 40     | y = 66; FEV1 = 32%; LTOT = 95% | USA     | Usual care    | Education + self management + remote home monitoring                                                | Second generation (Mon. to Fri. 9 am to 5 pm)                                   | 3 months   | QoL; healthcare costs; exacerbations; satisfaction                         |
| Jakobsen et al. | 57 | y = 70; FEV1 = 0.7 l; LTOT = 5% | Denmark | Usual care    | Daily ward rounds (touch screen for nurse visit)                                                     | Third generation (unscheduled calls 24/24 h 7/7 days)                           | 6 months   | hospital readmissions; need of NIV; hospitalizations for >5 days; lung function; QoL; satisfaction; nurses’ satisfaction |
| Farmer et al. | 166    | y = 69.8; FEV1 = 48.5%; LTOT = NA | UK      | Usual care + education + EDGE system platform                                                       | EDGE system platform + education + video education + tablet + daily monitoring of symptoms, mood, biological signs + red flags | Second generation (twice/week vision of vital signs and health status)          | 12 months  | specific QoL; hospital admissions; GP visits; generic QoL; fewer nurse visits |

ER, emergency room; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; GP, general practitioner; HADS, Hospital Anxiety and Depression Score; HR, heart rate; HRQoL, health-related quality of life; LTOT, long-term oxygen therapy; NA, not applicable; NIV, noninvasive ventilation; QoL, quality of life; Pt, patient; RCT, randomized controlled trial; SpO2, pulsed oxygen saturation; TM, telemedicine.
total of 1259 patients (mean age 68 ± 5 years) were studied with a mean FEV1 of 36 ± 8% and 42 ± 31% of cases were on LTOT; similarly to the positive studies, all patients with COPD were frequent users of healthcare and had a history of relapses and hospitalizations. Also in these studies, the control groups were mainly based on usual GP and home nurse care (sometimes with structured educational programs) while the studied groups were on second-generation TM platforms in 78% of cases and on third-generation TM platforms in 22% of cases for a mean time of 9 ± 7 months.

Table 343–53 shows RCTs with negative results for TM use. These studies were conducted in Europe (n = 8), the USA (n = 2) and Australia (n = 1). A total of 5699 patients (mean age 69 ± 5 years) were studied with a mean FEV1 of 41 ± 4%, in 3 ± 8% of cases on LTOT, all frequent users of healthcare with a history of relapses and hospitalizations. The control groups were in the majority of cases based on usual GP care with stronger home care support (home visits, nurse availability, social services) compared with the positive studies. The experimental groups were on second-generation TM platforms in 73% of cases and on third-generation TM platforms in 27% of cases for a mean time of 8 ± 3 months.

The literature has shown that the best telemonitoring outcomes are expected in programs dedicated to aged and very sick patients with severe symptoms, frequent exacerbations, multimorbidity, on LTOT and with limited community support; long-term interventions; programs using third-generation telemonitoring systems providing constant analytical and decisionmaking support with monitoring centers led by a physician, staffed by specialist nurses, and have full therapeutic authority 24 h/day, 7 days/week; countries where home care is not widely available (if an extensive home care package with strong community links exists, telemonitoring may add little additional benefit); and zones where ICT and rehabilitation can be delivered directly to the patient’s location, regardless of physical proximity to a rehabilitation center. Whilst only a few pulmonary rehabilitation programs worldwide are currently offering telerehabilitation,57 this is likely to grow as telehealth applications become increasingly accessible to patients and clinicians.

**Legal issues**
The legal problems associated with teleassistance and TM are still controversial. Given that many processes of teleconsultation are patient specific and unique, the legal principles applying to conventional, face-to-face, doctor–patient relationships may be equally as valid in the context of the practice of medicine at a distance.58,59 Important system precautions need to be used by e-health users:60,61

1. **Data security and confidentiality.** Suppliers and users must ensure the confidentiality, the authenticity of the data and their reporting, the authorized certification of procedures with digital signature, the protection of confidentiality, the security and privacy of the assisted persons, and the storage and transfer of sensitive data in real time between one unit and the other without manipulation.

2. **Responsibilities and potential obligations of health professionals.** Three key aspects need to be specified: the responsibility of the physician (teleconsultant) and the patient at distance (teleconsulted); the relationship and coresponsibility between specialist consultant and the requesting physician; the responsibility and the relationship between the applicant, consultant and service supplier or suppliers.

3. **Interoperability.** Mutual exchange of ICT-enabled solutions and of data are necessary for better coordination and integration across the entire chain of healthcare delivery to offer personalized solutions.

**How will TM change clinical practice?**
In the near future it is expected that TM will produce changes in work practices, cultural attitudes and organization, which need to be ‘negotiated’ among all the professional levels involved in the provision of care. Table 4 summarizes the possible change of scenarios in COPD care using TM. Table 5 summarizes barriers and difficulties to TM development in terms of work organization, cultural and technical concerns.62–64

**Discussion**
A ‘one glove fits all’ approach in offering telemonitoring for COPD appears too simplistic for a heterogeneous population such as these patients.
| Ref            | Pts, n | Inclusion severity | Country            | Control group                      | Experimental group                                      | TM generation                                                                 | Study time | Outcomes                                                                 |
|----------------|--------|--------------------|--------------------|------------------------------------|--------------------------------------------------------|-------------------------------------------------------------------------------|------------|--------------------------------------------------------------------------|
| Schou et al.43 | 44     | y = 71.5; FEV1 = 42%; LTOT = 0 | Denmark            | Usual medical treatment            | Daily ward rounds videoconference                     | Third generation (pulse oximeter + spirometer + thermometer)                  | 3 months   | = HRQoL; = daily activity; = anxiety and depression; = self-assessed cognitive decline |
| Lilholt et al.44 | 1225   | y = 70; FEV1 = 48%; LTOT = 0; MRC >3; CAT >10; >2 exacerbations | Denmark            | Usual practice                     | Daily vital signs sent to healthcare personnel. Alerting system | Second generation (blood pressure monitor, pulse oximeter)                    | 12 months  | = QoL                                                                     |
| Berkhof et al.45 | 101    | y = 68; FEV1 = 40%; LTOT = 7.5% | The Netherlands    | Outpatient visit T0, T6 by a pulmonologist + visit at T2 and T4 with a pulmonary nurse practitioner | Every 2 weeks phone call by nurse. Alerting system for pulmonologist | Second generation                                                            | 6 months   | = QoL; + visits to the pulmonologist                                      |
| Pinnock et al.46 | 256    | y = 69; exacerbation history; FEV1 = 42%; LTOT = 0 | Scotland           | Clinical care                      | Clinical care + telemonitoring                         | Second generation (daily symptoms saturation)                                | 12 months  | = no. of exacerbations; = time to hospital admission; = no. and duration of admissions; = QoL; = anxiety and depression; = self efficacy; = knowledge; = adherence to treatment |
| Moy et al.47    | 238    | y = 66.8; FEV1 = NA; LTOT = 28% | USA                | Pedometer without plan goals       | Pedometer every day, upload daily step counts and access to a website | Second generation                                                            | 12 months  | = QoL; = daily steps count                                               |
| Antoniades et al.48 | 44     | y = 69; FEV1 = 0.8 liter; LTOT = 0; hospitalization history | Australia          | Patients could call the nurse if they felt unwell | Daily clinical data. A nurse reviewed 5 days weekly. Alerting system for the GP | Second generation, Unscheduled calls                                          | 12 months  | = hospital admissions; = inpatient bed days; = QoL                         |
| Dinesen et al.49 | 105    | y = 68 FEV1 = 0.91 liter; LTOT = 0 | Denmark            | Physical activity by themselves    | Physical activity and clinical parameters monitored by GP and nurses | Second generation (clinical values, no. of steps) web-based portal GP or nurses could assess data video meeting | 10 months  | + rate of admissions                                                        |
### Table 3. (Continued)

| Ref            | Pts, n | Inclusion severity | Country        | Control group | Experimental group | TM generation | Study time | Outcomes                                                                 |
|----------------|--------|--------------------|----------------|---------------|--------------------|---------------|------------|--------------------------------------------------------------------------|
| Coultas et al. | 151    | y = 69; FEV1 = NA; FEV1 = 35%; LTOT = 0; exacerbation history | USA            | Educational booklets | Nurses reviewed symptoms, medications, intervention + 1/month call | Second generation | 6 months | = health status; = self-reported healthcare utilization                   |
| Sorknaes et al. | 266    | y = 71.5; FEV1 = 35%; LTOT = 0 | Denmark      | Conventional treatment; nurse outpatient consultation (spirometry, oximetry) | Conventional treatment + teleconsultation by video 7 days a week starting within 24 h of discharge | Third generation | 6.5 months | = hospital readmissions; = mortality; = time to readmission; = mean no. of readmission days with AECOPD |
| Cartwright et al. | 3225   | y = 70; FEV1 = NA; LTOT = NA | UK            | Usual healthcare and social services + whole system redesign (WSR) | WSR + synchronous data transfer and automated algorithms interpreted data. Alerting system | Second generation | 12 months | = QoL; = psychological outcomes                                         |
| Schou et al.   | 44     | y = 71; exacerbation history; FEV1 = 42%; LTOT = NA | Denmark      | Hospitalization until discharge criteria were fulfilled | Education plan to familiarize themselves with the videoconferencing system. Daily ward rounds of patients' parameters were performed by the physician. Patient could connect with the call center 24/24 h 7/7 days | Third generation | 1.5 months | = cognitive performance                                                  |

AECOPD, acute exacerbation of COPD; CAT, COPD assessment test; COPD, chronic obstructive pulmonary disease; FEV1, forced expiratory volume in 1 s; GP, general practitioner; HRQoL, health-related quality of life; LTOT, long-term oxygen therapy; MRC, Medical Research Council; NA, not applicable; Pt, patient; QoL, quality of life; RCT, randomized controlled trial; TM, telemedicine.
Factors that will be important for the successful implementation of telemonitoring are an individually tailored approach, flexibility and a service that is locally responsive.

There are a number of possible explanations why the telemonitoring approach may not be superior to standard management carried out at home, which may be synthesized as follows:

1. Patients with COPD who may benefit most from telemonitoring have not yet been identified. In fact, it is not clear which patients would benefit from specific types of care delivery and, more importantly, what preferences patients have. Although many studies have included patients with severe disease, they vary in terms of the inclusion and exclusion criteria regarding baseline diagnosis, history of exacerbations, previous use of healthcare services such as home visits, hospitalizations, or rehabilitation, as well as requirements for supplemental oxygen or home mechanical ventilation. Patients with severe symptoms, frequent exacerbations, multimorbidity and limited community support might well benefit from telemonitoring. In another study across the range of COPD severity, patients with severe COPD (GOLD 3 [Global Initiative for Chronic Obstructive Lung Disease] classification but not GOLD 4) and patients younger than 60 years are likely to be the most cost-effective group.65 It is also common experience that, in patients with more severe disease, their clinical condition is such that hospital admissions are often inevitable: in any case, telemonitoring does not have the unique aim to avoid hospitalization per se but rather to control the progression of the disease, which sometimes will mean accelerating

Table 4. Changes and impact in scenarios for chronic obstructive pulmonary disease under telemedicine.

| Work organization                  | Cultural changes required                              | Organizational changes required                      |
|------------------------------------|-------------------------------------------------------|-----------------------------------------------------|
| Staff workload                     | Staff experiences with the application                 | Need for a stakeholders network                     |
| Work distribution                  | Positive view of the technology                       | Patient empowerment                                  |
| Routines and patient pathways      | Interactions with patients                            | Patient self management                              |
| Constant interaction               | Face-to-face nursing work                             | Bidirectional message exchange                       |
|                                    |                                                       | for communications between the home of the patient   |
|                                    |                                                       | and the hospital                                     |
| Number of medical units working    | Interactions                                          | Reconfiguration of existing practices and relationships |
| together to provide service        |                                                       |                                                     |
| Time spent learning to use the     | Designing and implementation of                      | Access to healthcare                                  |
| application                         | follow-up plans at home                               |                                                     |
| Productivity                       | Specific clinical practice guidelines for each disease| Regionalization prospective                          |
| Organization of primary care and   | Structure (norms, rules, values, and resources)       | Linkages between rural district hospitals and the    |
| specialist care                    |                                                       | main national hospitals                              |
| Greater responsibility to nurses   | Skills required                                       | Training and education for healthcare professionals  |
|                                   |                                                       | in rural areas                                       |
| Renegotiation of professional      | Citizens consensus                                     | Implementation of national health policies           |
| roles                              |                                                       |                                                     |
| Reconfiguration of work practices   | Social influence                                       | New businesses                                        |
| [burden or empowerment]            |                                                       |                                                     |
hospitalization, face-to-face visits or home care visits. Early treatment of home exacerbations at distance is often useful to prevent a catastrophic clinical worsening and subsequent need for intensive care unit admission or mechanical ventilation.

(2) The use of different generations of the telemonitoring and e-health devices and platforms may have determined substantial differences in the findings across studies. Available telemonitoring devices range from basic first-generation systems to the far more complete third-generation systems. The role of the case manager/care manager during telemonitoring use may also vary among different countries depending on the current policy of each country’s health system.

(3) Previous results indicated that existing resource patterns of patients and variations in delivery-site practices might have a strong influence on cost effectiveness, possibly stronger than the included health or sociodemographic sources of heterogeneity. To evaluate the real cost effectiveness of new methods such as telemonitoring in this population it is important to understand what is meant by ‘standard care’ and ‘usual care’ in the papers published so far. In fact, standard care varies greatly not only among European countries, but also within each country. Some studies have also proposed health economic assessments but the findings were inconclusive. Unfortunately, this ‘standard’ care is not a common or mandatory care approach in all European Union (EU) countries. If an extensive home care package with strong community links exists, telemonitoring may add little additional benefit, whereas for trials in which less community support was available telemonitoring seems to show more benefit in terms of team expertise and the patient’s (or carer’s) self efficacy.

(4) Now, the question to evaluate is if the superiority of telemonitoring to the gold standard is really the goal. Equivalence between telemonitoring and the gold standard may be a more appropriate goal; indeed, an intervention that cost-effectively

Table 5. Barriers and difficulties to telemedicine development.

| Work organization | Cultural barriers | Technical concerns |
|-------------------|-------------------|--------------------|
| Short-term funding | Low level of interest | Preferred outpatient clinic visits |
| Sustainability | Poor user-friendly technology | Follow-up plan customized to each patient |
| Integration of new technologies into routine service delivery | Low acceptance | Complexity of the system |
| Time limitations | Person’s illness and health literacy | Many different software, hardware and telecommunication options |
| Requirements for technical competence | Too much responsibility for patients with chronic disease | Poor specification design for each condition |
| Poor uniformity for standards | Poor knowledge and culture | Legal/confidentiality problems between subjects involved (poor standard of care; manipulation, poor protection |
| Lack of interoperability among different solutions | Lack of knowledge of e-health among patients, citizens and healthcare professionals | The network may show difficulty to ascertain responsibilities and potential obligations of health professionals |
| Limited evidence of cost effectiveness | Skepticism from doctors | High startup costs |
| | | Absence of reimbursements |
improves a suboptimal service bringing it on a par with the gold standard would be a success. Cost effectiveness could be the ‘gold standard’ for each new health service. It is not important for each health organization to push for a ‘unique modality’ of continuity of care but to press for the ‘most efficient’ one respecting shared and standardized clinical and scientific targets for chronic care.

Last but not least, negative or positive results clearly depend on the expected outcomes of the study (e.g. healthcare use, patient-related outcomes, adherence, mechanical ventilation initiation and adaptation, need for palliative care) and corresponding methodological development, which differ from one study to the next.

As shown in Table 5, major barriers for TM implementation are lack of awareness/confidence in e-health, supposed e-health complexity and time consumption during the working day, necessity for complicated medical licensing, the risk for doctors to reduce the area of influence with a decreased chain of command, more cooperation requested between primary and secondary healthcare, risk of data protection and privacy, lack of structured best practices, solid public or private providers and dedicated call centers, the necessity for infrastructure accreditation with certification and labelling obstacles, and last but not least, regional differences in accessing ICT services.

**Future directions**

Another important aspect in telemonitoring studies is using advanced analytics or machine learning to optimize the patient’s condition, for example by early identification of COPD exacerbations. This is going to be an important future direction and challenge in patients with COPD breathing spontaneously.

The ATS/ERS [American Thoracic Society/European Respiratory Society] statement on pulmonary rehabilitation states that ‘defining the role of telehealth and other new technologies’ is the key to addressing the research priority of ‘increasing the accessibility to pulmonary rehabilitation’. Critical future steps towards this will be achieving a consensus on what constitutes ‘usual care’, such that the additional benefits offered by telehealth can be quantified (standardizing models of telehealth in chronic lung disease for a more uniform implementation, thus allowing meaningful comparison across studies); defining the role of telemonitoring and teleassistance across the spectrum of chronic lung disease, that is determining in which diagnostic groups it is most useful, when it should be offered (including considerations of disease severity and acute versus stable disease) and when it should be stopped; and conducting robust cost-effectiveness studies to inform health policy. Telehealth can improve access to care, particularly for those living away from major centers. Simple yet innovative telehealth solutions to improve access and uptake have already been implemented in clinical practice, with good results. Such programs, including simple telerehabilitation models and teleconsulting, should be made more widely available. Where high-quality clinical care is already available it is less clear if telerehabilitation adds significant benefit. Current data do not yet justify the routine implementation of telehealth in such a setting, although individual patients may benefit. For future directions, more attention needs to be focused on how to accommodate the increasing number of patients with COPD in a postdischarge telemonitoring management program with real integration between hospital and primary care professionals according to quality standards. The self-management support must also become more integrated, with standardized decision support and outcome measures plus electronic information so that critical information is shared among the various health professionals involved in the home programs. In addition, more research is required on the organizational implications of introducing telemonitoring so that a new service does not duplicate the traditional system, resulting only in greater inefficiency and more costs. More research is also needed on the security and confidentiality of patient data, on the responsibilities and potential obligations of health professionals and on EU jurisdictional problems regarding e-health systems. Finally, we need to provide a useful benchmarking picture of different models of telemonitoring good practice around Europe as an aid to those who fund telemonitoring services in their decisionmaking regarding personnel investment, reduction of redundancy and duplication of care services, as well as prioritization of services. The ‘one glove fits all’ approach in offering telemonitoring for COPD seems too simplistic for a heterogeneous population such as these patients. Factors important for the successful implementation of telemonitoring are an
individually tailored approach, flexibility and a service that is locally responsive. Chronic diseases increase the burden on healthcare systems. Primary care needs to be sustained in the face of increasing demands: home care and telemonitoring may help primary care professionals and specialists to reduce the expected burden. Hospitalization of chronically ill patients is a ‘failure’ for healthcare systems and chronic diseases exemplify the need for the large-scale deployment of follow-up programs. For these reasons, home care programs and telemonitoring may provide an opportunity for health organizations to develop new strategies and clinical procedures. Another important aspect that might limit the effectiveness of telemonitoring studies is patient compliance and acceptance: in general telemonitoring is well accepted\(^2\) and patients are enthusiastic about this service.\(^7\)

Anyway, the patient’s perspective is not always the doctor’s perspective: in a recent survey\(^7\) about 50% of patients receiving home mechanical ventilation responded that they would refuse telemonitoring because it feels like ‘big brother’, and expressed concerns about privacy of personal information/data. They also felt it might increase anxiety as a result of fewer visits and fewer opportunities to enjoy personal contact, and finally that their actual home care settings ‘feels good and they don’t want it adjusted’. Home telemonitoring and telerehabilitation of chronic diseases seems to be a promising patient management strategy that could produce accurate and reliable data, empower patients, influence their attitudes and behavior, and potentially improve their medical conditions. Remote monitoring alone is not sufficient for successful disease management. A patient-centered design approach (continuous improvement allowed feedback from users) has been used in order to allow the personalization of interventions and encourage the completion of daily self-management tasks resulting in high compliance with self monitoring over a prolonged period of time (12 months).\(^7\)

The overall body of literature on this topic shows that the extent and significance of benefits to patients and economic organizational expectations are not always consistent and sometimes remain inconclusive. The impact on clinical effectiveness outcomes and economic viability likewise remains unclear. At the moment the fundamental prerequisite for the efficacy of telemonitoring in COPD management is to establish common standardized protocols rather than determine how to deliver the care.\(^7\) It is clear that telemonitoring alone is not sufficient in itself to yield a better outcome; telemonitoring could be a key element in the management of COPD, but it is difficult to evaluate its benefit without considering the other services received by patients (GP network, home care, access to hospital, social care). Considering the overall care ‘package’ received by the patient, telemonitoring may have a place as one of the services offered within the package. But other aspects, quality improvement, integration of programs and services, increase in collaboration and communication across the different care settings, and the development of a shared vision, goals and priorities, are needed to improve the efficiency of the healthcare services provided for patients with chronic disease.\(^7\) The key point in optimizing the use of telemonitoring is to correctly identify who the ideal candidates are, and at what time they should receive it and for how long.\(^7\) The time course of disease for each patient is different and a ‘correct window’ for personalized TM application could be the answer. Initiating a TM program too early might be useless and inefficient, while only the TM program in very advanced conditions might be insufficient due to the high level of disability and instability which cannot be completely managed and monitored at a distance.

In conclusion, TM will provide a framework for patient engagement and a new model of care delivery utilizing integrated practice units, both of which are needed to navigate the healthcare needs of the 21st century. As clinicians we need to identify the specific challenges we face in delivering care changing our future clinical practice implementing flexible systems that can be customized to individual patients’ requirements and adapted to our diverse healthcare contexts.

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