Chapter 3

Telemedicine Programs in Respiratory Diseases

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Additional information is available at the end of the chapter

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Abstract

Telemedicine programs are widely used in respiratory diseases, more often in patients with chronic obstructive pulmonary diseases (COPD). Telemedicine platforms use several devices to measure vital signs such as heart rate, respiratory rate, pulsioximetry or blood pressure between others. It is not unusual that patients could do questionnaires about clinical situation or communicate with their nurses via telephone, videocalling and/or Skype. The majority of results has been positive, with reduction in the number of emergency visits, hospitalizations and noninvasive ventilations. Despite their promising results, telemedicine programs/platforms are slow to implement. In this chapter, we reviewed some of the factors related to telemedicine implementation such as patients' adherence, impact of telemedicine design and professionals' resistance to change between others.

Keywords: COPD, eHealth, home telemonitoring, telemedicine, telemedicine platforms

1. Introduction

Chronic obstructive pulmonary diseases (COPD), asthma and lung transplantation have been, by far, the respiratory diseases or conditions more studied, in terms of telemedicine. However, the interest of telehealth providers in new areas also related to neurologic conditions, such as neuromuscular diseases in need of home noninvasive ventilation (NIV) due to chronic respiratory failure, or sleep-related breathing disorders, has arisen in recent years.

Existing evidence reveals promising results regarding reliability and validity of measures across all pulmonary conditions, and patients usually show a positive attitude toward telecare technologies. Other positive effects, for instance, detection of complications, better disease control, immediate feedback, and adequate medication use, have also been addressed [1]. Yet, there is still somewhat decreased adherence within time, possibly secondary to poor health status, time conflicts, device problems, and lack of ability to operate the system [2]. Furthermore, there is no solid evidence about the utilization of healthcare resources, as well as cost-effectiveness, paramount scenarios to advocate in favor of this new way of approaching chronic respiratory patients.

In the following section, current evidence apropos specific respiratory diseases (COPD, asthma, lung transplantation, neuromuscular diseases, and SRBD) will be disclosed, focusing on the positive results, along with the pitfalls found so far.

1.1. Telemedicine

Telemedicine (TM) has several definitions and all of them emphasize the role of telemedicine to enable the completion of the medical act at distance (**Table 1**) [3–5]. Norrit et al. define TM as a scientific area that uses information and communication technologies (ICT) to share medical information [6]. Thanks to ICT development, TM clinical opportunities are increasing. The information provided by TM programs can be useful for diagnosis and treatment of several diseases, as well as for enhancing their follow-up.

	Ref	Definition
WHO	[3]	The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities.
ATA	[4]	Telemedicine is the use of medical information exchanged from one site to another via electronic communications to improve a patient's clinical health status. Telemedicine includes a growing variety of applications and services using two-way video, email, smart phones, wireless tools, and other forms of telecommunications technology.
Bashur R	[5]	Telemedicine is conceived of as an integrated system of health-care delivery that employs telecommunications and computer technology as a substitute for face-to-face contact between provider and client.

WHO: World Health Organization; ATA: American Telemedicine Association, Ref: Reference.

Table 1. Telemedicine's definitions.

Historically, Dr. Graham Bell performed the first TM experience, when he used the telephone calling for help when he was sick. Also, in 1923, Sahlgrenska University (Gothenburg) used the Morse code to provide medical advice. TM programs were funded by the privacy industries in 1990 for the first time, and in 1993, the first telemedicine symposium was celebrated. Over 50 years, TM has been used for different programs such as: monitored surgeries, remote assistance in rural zones of Arizona, or vital signs monitoring of astronauts in space, just like

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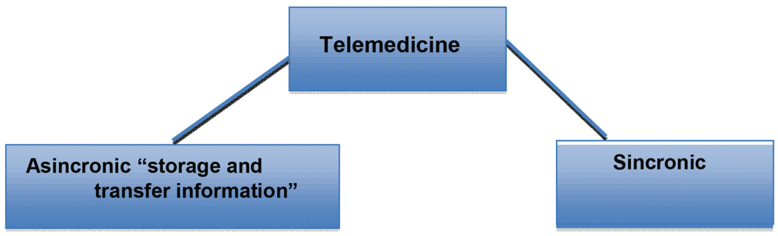
Bashur et al. demonstrated [7]. In fact, aerospace technology development has been one of the most important factors in TM evolution. In 1976, the Hermes satellite was put into orbit with the main objective of improving communications in remote areas of Canada. Since then, the Western Ontario University has been using it for telemonitoring of vital signs, sharing medical information between hospitals and, finally, sharing radiographies [8]. Moreover, the National Aeronautics and Space Administration (NASA) also has used TM to give medical assistance if a disaster takes place.

Generally speaking, TM applications could be classified into three groups: (a) normal clinical activity (teleconsult, telediagnosis, teletreatment, etc.), (b) remote assistance, and (c) administration labors and patient management.

1.1.1. Clinical activity

Almost all studies are aimed for telemonitoring patients or sharing medical data, where this medical act at distance needs a TM platform and a clinical response. We could classify the clinical response into two groups: synchronic or asynchronic response (**Figure 1**). The main difference is the time to response [9]. While in the first group, the clinical response is immediate and allows performing a live medical act, the second group clinical response is deferred (minutes or few hours). Asynchronic response is useful in telepatologhy or teleradiology, or in other telediagnosis programs.



	Asincronic	Sincronic
Time to response	Minutes or few hours.	Consultation in live. Usefull to medical emergency or consultation that need urgent decision.
Patient's interaction	It's not necessary	It's necessary as habitual medical consult.
Applications	Radiology, Citology, home-telemonitoring, etc.	Any medical act.
Advantages	Economic and easy telemedicine platform.	Allow to take medical decisions with other specialist. Quickly medical response.

Figure 1. Telemedicine classification.

1.1.2. Remote assistance

In this group, several medical actions are included such as online records for consulting previous medical charts, establishing a direct communication between patients and physicians, or teleconference between primary and specialized care doctors, useful for discussing difficult cases and take decisions for complex patients (terminal disease, multiple comorbidities, social exclusion, impossibility to attend the hospital, etc.).

1.1.3. Patients' management

Nowadays, patients manage their medical events via Internet more often, and their doctors can use the same way to give medical recommendations (rehabilitation, nutritional care, tobacco information, or health life recommendations). Obviously, TM is a helpful tool for health care personnel as well. In this case, TM is used to access scientific information or as a type of communication for multicentric and international clinical trials.

1.2. Telemedicine: barriers and benefits

According to the Europe Institute of Technologies findings, only 14.2% of citizens had used the Internet to solve their health related doubts. The more frequent searches regarding these issues were: disease description, clinical trials, medical literature, or patients' disease associations (**Table 2**).

	Information related to	EEUU (% total)	EU-15 (% total)
Patients	Disease description	68,49	55,78
	Clinical Trials	33,14	21,93
	Medical literature	81,51	58,74
	Disease associations	27,81	30,11
Professionals	Disease description	65,91	57,23
	Clinical Trials	39,94	50,21
	Medical literature	90,58	89,36
	Disease associations	18,18	16,17

Table 2. Search topics by patients and healthcare professionals.

There are several studies that have showed important barriers for applying TM programs. Segrelles-Calvo et al. suggested that healthcare policy, lacking studies about economic burden and cost-effectiveness of TM, no laws regarding the handling of information in TM programs and the resistance to change "usual medicine conception," are some causes that explain slow TM implantation [10]. According to the concept of "resistant to change usual care," Mira-Solves et al. presented the results of the ValCrònic program [11], in which authors discussed the causes to leave a TM program. The main reasons were: (1) difficulty to use the devices, (2) complex measures, (3) nonadherence with TM program, (4) technical problems, and (5) caregivers preferences.

Another important barrier not well studied is the opinion of health professionals toward TM programs. Telemedicine collects a lot of information and their belief is that TM increases workload. However, this belief is not displayed in scientific studies. Jódar-Sánchez et al. [12] showed indeed that a specialized nurse could solve most of the clinical urgencies detected, where only 8 of 40 cases needed a pneumologist intervention. Similar results were published by Vitacca et al. [13] reporting that in 63% of alerts, these could be resolved only by a nurse, and in the rest of them both physician and nurse gave the clinical response. As conclusion, it seems that there are external factors acting as barriers in the TM implantation, and further works are required to establish them. Motulsky et al. [14] and Cresswell et al. [15] pooled those external factors in three groups: (1) healthcare institutions policy, (2) the urge of guidelines about TM, and (3) the need of specific formation and educational resources.

Telemedicine offers four fundamental benefits [4]:

a. *Improved access:* Telemedicine has been used to bring healthcare services to patients in distant locations.

b. *Cost efficiencies*: Telemedicine reduces the number of hospitalizations and the cost related to these events. Telemedicine program reduce patient displacement to Hospital and reduced travel times.

c. *Improved quality*: Studies have consistently shown that the quality of healthcare services delivered via telemedicine is as good as those given in traditional in-person consultations.

d. *Patient demand:* The greatest impact of telemedicine is on the patient, their family and their community. Telemedicine could reduce travel time and related stresses for the patient. Almost all studies have shown that patient and caregiver's satisfaction is very high.

1.3. Telemedicine platforms

In general, there is a common objective in telemedicine programs; however, there are several platforms in which TM could be offered. Telemedicine platforms are related to ICT. The most common scheme in telemedicine (**Figure 2**) is the one that includes devices to measure different vital signs or questionnaires, in order to perform a teleconsultation or to send educational resources to patients. Those measures could be made by the patients, anywhere and anytime. Clinical information is sent to a call center or a health professional by different means (telephone, Internet, etc.), and the clinical response is made according to all information regarding.

Some of the ICT used in telemedicine platform are as follows:

Videoconference. Possibly this ICT was one of the most important technological advances as a telemedicine platform. Mahmud et al. [16] made a follow-up platform of patients with chronic diseases (heart failure, COPD, cerebrovascular disease). In seven cases, the number of emergency department visits and hospitalizations were reduced, and the authors did not found complications in the use of the videoconference platform. These results were confirmed in 2000 by Johnston et al. [17] and by Nakamura et al. [18]. Johnston determined a reduction of 17% of home visits as well as a 27% reduction of costs in the telemedicine group. Moreover, Nakamura reported an improvement of daily activities in the telemedicine group. Recent studies have used videoconference to improve adherence to a telerehabilitation program [19], to follow-up patients with bipolar disorder [20] or to monitoring tuberculosis therapy compliance [21], among other topics. According to these studies, in our view the videoconference is a remarkable technology, facilitating the follow-up of patients to improve their adherence to treatment.

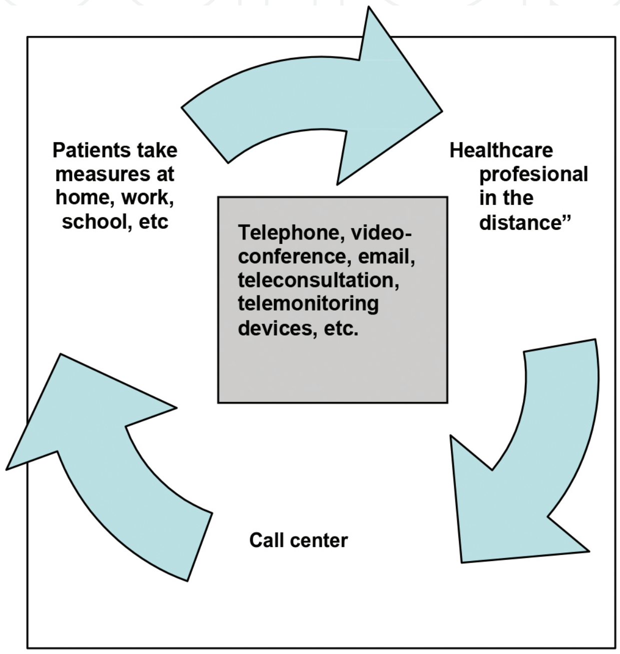


Figure 2. Telemedicine platform.

Telephone. Mainly, studies have focused in the telephone as a device to follow-up of patients but Balas et al. [22] described five possible actions that we could also do via telephone: (1) follow-up, (2) videoconsultation due to interactive telephone, (3) telephonic reminders of taking a medicine or doing an exercise, (4) calling health professionals if case of clinical deterioration, and (5) clinical investigation.

E-mail. Email is a rather quick tool for the patients to communicate with health professionals, making it easier for the latter to perform questionnaires so any given doubt of the patient or caregiver could be cleared up.

2. Chronic obstructive pulmonary diseases

It is now consensually agreed that an estimated number of 328 million people have COPD worldwide, that is, 168 million men and 160 million women. Moreover, COPD causes the death of 2.9 million people annually and it is projected to be the third cause of mortality by 2020 [23].

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Whereas the three most important factors in individual patients that determine the economic and social costs of COPD are disease severity, presence of frequent exacerbations of disease and the presence of comorbidities, which are common (30–57%) in COPD patients [24], the current short-term and long-term strategies to reduce the burden of COPD comprise the triad of smoking cessation, minimizing acute exacerbations and management and prevention of comorbidities [25].

Hence, a high priority should be given to interventions aimed at delaying the progression of disease, preventing exacerbations and reducing the risk of comorbidities in order to alleviate the clinical and economic burden of COPD in Western countries [26]. Among these interventions, telemedicine has shown some promising results although no conclusive evidence has been accomplished. The effects of telemedicine in COPD have been addressed in previous systematic reviews [27, 28]; however, their conclusions are not consistent since the types of tested interventions have been rather heterogeneous. These interventions range from simple telephone or video interviews to daily telemonitoring of physiological parameters or symptoms data, and that is why comparativeness of one study to the other does not come along easily.

So far, there is moderate evidence of the benefit of telemedicine in COPD, in terms of increasing quality of life and reducing hospital admissions. Basically, the problem has been that in previous years the studies included in systematic reviews were underpowered, had heterogeneous populations and had lack of detailed intervention descriptions and of the care processes that accompanied telemonitoring [29]. Another issue is the clinical scenario where patients are usually recruited. For instance, telemedicine can be offered to those patients prone to exacerbations that are in stable condition [30], or right after admission regardless of the number of previous exacerbations or FEV_1 obstruction severity [31].

Regarding telemonitoring (understood as retrieving periodically clinical data such as oxygen saturation, heart rate, symptoms, etc.), recent data including randomized clinical trials of good quality are now available; however, some of them are still underpowered. In terms of hospital admissions, one of the latest systematic reviews on the matter, which included eight studies with 486 patients randomized to home telemonitoring or usual care, determined a significant lower risk of hospitalizations in the telemonitoring group. However, healthcare utilization in general was similar in both groups, since it was not clear whether the utilization was due to respiratory events specifically, and the lower range of compliance to telemonitoring reported by some studies may have influenced the ability of detecting clinical deterioration [32]. Moreover, even between this data retrieved on a daily basis there were different clinical features measured, which end up inevitability in being quite difficult to integrate quantitative variables because of missing or noncomparative data. Thus, the extrapolation of these results to the general population should be carried out with absolute caution. The usual problem with these systematic reviews is that, due to the heterogeneity of outcomes and the way the studies have assessed them, it is troublesome to determine the true effect of telemonitoring on COPD patients. For instance, adding a closer approach to patients with videoconsultations to the usual telemonitoring, which would be ideal in order to obtain higher rates of compliance or reduction of the use of healthcare resources in general, failed to demonstrate differences in hospital admissions or time to first admission or all-cause hospital admissions [33].

Detection and management of COPD exacerbations in early stages is an important step in order to reduce hospital admissions and the consequent increase of quality of life and reduction of health costs in general. So far, telemedicine has proven to be a useful tool to achieve this.

Physical activity, one of the strong mortality predictors in COPD patients, if not the strongest, has not been properly issued. Although no conclusive evidence of telemedicine benefit exists on this regard, the use of telehealthcare may lead to increased physical activity level [34]. A recent study that evaluated the feasibility of a telerehabilitation program compared to a regular outpatient program, showed an increase of physical activity measured by steps/day in the telerehabilitation group, with acceptable rates of satisfaction with the service, although no differences were found when the 6-minute walking test, dyspnea measured by the Medical Research Council or quality of life measured by the St. George's Respiratory Questionnaire were compared [35].

The cost-effectiveness of telemedicine in COPD is yet to be determined. In fact, a recent study carried out in the United Kingdom, which recruited 3230 patients where both at baseline and follow-up participants with COPD made up the largest telehealth intervention group, showed that costs of self-reported service use, combined with telehealth intervention costs, were greater for the group randomized to telehealth in addition to standard care than for the group randomized to usual care alone [36]. However, the validity of this conclusion may be biased for two reasons. First, the trial recruiters had foreknowledge of the allocation groups in many cases [37], and second, its transferability to other healthcare systems was not taken in consideration since the trial did not include all community and healthcare resources. Thus, a recent Danish trial (TeleCare North) will determine the real benefit of telemedicine in COPD in terms of health-related quality of life and the incremental cost-effectiveness ratio through a large-scale, pragmatic, cluster-randomized trial with nested economic evaluation [38].

Quality of life, a paramount feature in COPD and a strong predictor of mortality, has been analyzed irregularly. Once again, the instruments used to determine the health related quality of life vary greatly among the telemedicine studies (i.e., Chronic Respiratory Disease Questionnaire, Chronic Respiratory Questionnaire, St. George's Respiratory Questionnaire (SGRQ), Clinical COPD Questionnaire, EURO-QOL-5D Questionnaire, Medical Outcome Study Short-Form 36 Questionnaire), so comparative data is deficient. Overall, no significant differences have been found between a home telemonitoring group and the usual care group [32].

The aim of telemedicine toward COPD patients should be to keep this population outside the hospital or the emergency rooms. Although there is evidence that this aim has been achieved in some studies, we are still in need of larger clinical trials which include a rigorous cost-effectiveness analysis in terms of use of healthcare resources separated by respiratory diseases or not, quality of life, and mortality. Furthermore, a 6- or 12-month follow-up is insufficient to determine conclusive differences in favor of telemedicine.

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3. Asthma

Asthma is a worldwide disease affecting 300 million of people, and its economic and social costs are mostly related to emergency visits and hospital admissions. Self-monitoring of symptoms and peak flow, following a written action plan and attending regular visits to their physician, have demonstrated to improve asthma control [39], and that is why approaches through telemedicine have been done to increase its control and follow-up. It has been hypothesized that providing self-monitoring tools such as easy-to-use handheld electronic monitoring devices or symptom questionnaires, patients can gain insight into their level of asthma control which gives them suggestions for subsequent treatment adjustment [40]. This is why telemedicine for asthma appears to be a promising tool to achieve this so wished for self-control and management of the disease.

However, there are some pitfalls regarding telemedicine for asthma. If noncomparative data due to the different sort of interventions is a main issue for COPD, the problem is probably more serious for asthma. One of the most relevant systematic reviews in the matter included 21 studies, of which nine consisted in telephone calls, two in videoconferences, two in using the Internet, one in short text messaging, one in a combination of short text and Internet, and six more using other networked communications. This study demonstrated no improvement of quality of life and even a nonsignificant increase of emergency room visits in the telemedicine group, although a significant reduction of hospitalizations was observed [41]. However, some authors have stated some concerns about these meta-analysis conclusions. First of all, there were only few examples of a comprehensive telemanagement approach in asthma (defined as a treatment plan, self-monitoring of lung function by FEV_1 and asthma control with feedback and e-communication with a professional to support this self-management), and second, patients in the control strategies often received an enhanced form of usual care, which makes it difficult to draw final conclusions on the effectiveness of telemanagement in asthma [40]. A more recent meta-analysis of 20 trials involving 10,406 asthmatic patients where common outcomes employed were healthcare utilization, quality of life and symptoms, concluded that the median effect of telemedicine was weakly positive, and that there were not differences between the types of interventions (telemonitoring, routine voice contact or videoconferencing). But the problem with this positive effect is that a publication bias exists due to the tendency of more positive results reported in earlier studies, which contained heterogeneous outcomes measurement and assessment [42].

Regarding cost-effectiveness we are still in need of studies addressing the topic specifically, situation that withholds the use of telemedicine for asthma unquestionably. Probably the only evidence of cost-effectiveness of Internet-based self-management compared with usual care, showed no significant differences during a follow-up of one year. However, this study had several limitations, acknowledge by the authors. First, the quality adjusted life year estimates were calculated out of only two measurements throughout one year. Second, patients were inevitable conscious of the allocated group, which may have influenced their utility ratings. And third, the economic evaluation was limited to one year only [43]. Regarding a specific feature of telemedicine, another study showed that telephone consultations led by experienced nurses enabled a greater proportion of asthma patients to be reviewed at no additional cost to the health service, although these findings should not be extrapolated as a thorough cost-effectiveness analysis, compared to the comprehensive telemanagement as explained before [44, 45].

Despite the similar moderate evidence either for asthma or COPD, there are some differences when telehealthcare main purposes are compared between the two diseases. While in COPD telemedicine aims to reduce exacerbations or their early detection in order to avoid emergency rooms visits or hospital admissions, in asthma these objectives are usually directed at assuring a better symptoms self-control and adherence to treatment, considering that undertreatment is the most common problem in European asthmatic subjects [46], and its usual presentation at early stages of life. A fitter control of asthma has been reported possibly secondary to the opportunity of register symptoms continually, thus, the patient obtained a more accurate picture of his disease severity and complied to treatment with a closer and efficient self-monitoring. However, this severity awareness led to an increased number of unscheduled visits and a harmful consumption of inhaled corticosteroids, which increased their adverse effects [47]. In a similar fashion, another study revealed that 43 patients under a mobile telephone interactive self-control system and compared with a control group, presented significantly higher mean daily dosage of either inhaled or systemic corticosteroids during the study period. Nonetheless, this system also demonstrated fewer unscheduled visits to the emergency department; higher peak expiratory flows at 4, 5, and 6 moths; higher FEV_1 at 6 months; and better quality of life at 3 months after inclusion [48].

Compliance to new technologies is a relevant feature of telemedicine since not all of public health systems can afford them, and there are still underprivileged groups who are not familiar to these sorts of interventions. It seems that telemedicine for asthma is feasible, although when compared to a web based self-management, patients presented higher rates of adherence to the classic paper based strategies of self-control of symptoms and action plans, though other critical feature such as lung function data was not reliable when the patient wrote it down on his own [49].

In the pediatric population there is also lacking evidence of telemedicine benefit. Telemonitoring of lung function on daily home spirometry in 44 children with professional feedback did not reduce the frequency of exacerbations significantly when compared to conventional treatment, nor the number of unscheduled visits, FEV_1, quality of life or use of inhaled corticosteroids [50]. This finding could be explained by the fact that a highly variable peak expiratory flow and FEV_1 values at time of symptoms and a complete overlap in distributions between symptoms-free days and at times of symptoms [51], and also by the underpowered nature of the study.

In conclusion, even though telemedicine for asthma seems to be a useful and promising tool for empowering the asthmatic patients in order to guarantee the self-control of the disease, the evidence of its benefit is still unclear. The short follow-ups, the heterogeneity of subjects and the insufficient evidence of its cost-effectiveness, are paramount aspects that restrain the use of telemedicine for asthmatic patients. We advocate for the tailoring treatment to the individual

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needs as the cornerstone of telehealthcare, although more studies are called for so the real effect of this new technologies can be elucidated.]

4. Sleep-related breathing disorders and obstructive sleep apnea

Speaking of sleep-related breathing disorders, obstructive sleep apnea (OSA) is a prevalent disease that affects approximately 6–7% of global population, although these figures probably underestimate the real OSA prevalence. OSA is a sleep disorder in wich breathing repeatedly stops and starts, which lead to hypoxemia, subsequent arousals, sleep fragmentation, thus, a poor sleep quality in general. The main symptom is excessive daytime sleepiness, and is now acknowledge as an independent cardiovascular risk factor, increasing the probability of presenting hypertension, coronary artery disease, congestive cardiac failure, and stroke [52]. Attended full in-lab polysomnography (PSG) is the gold standard for OSA diagnosis, an expensive test that demands plenty of time as well as fully trained technicians, and that is why simplified sleep data recollection systems have been approved by the scientific societies for patients with high or low pretest probability of OSA, in order to reduce the waiting list for PSG [53]. Despite the increase of accredited sleep units, the demand of sleep studies has also increased over the years considering the prevalence of the disease. Therefore, waiting lists remain long [54]. Finally, continuous positive airway pressure (CPAP) is by far the recommended treatment for symptomatic or severe OSA, and it is known to reduce cardiovascular death and non-fatal cardiovascular events [55], however, adherence to treatment has been a troublesome factor in such a way that the first year of long-term treatment usually between 25 and 30% of patients drop out the device [56]. Having said this, there have been some efforts to reduce the long waiting lists and increase the rates of CPAP adherence through telemedicine.

Regarding OSA diagnosis, the evidence of telemedicine usefulness is limited. So far, the American Academy of Sleep Medicine has classified the sleep recording devices into four categories. Full-attended in-lab PSG would be type 1; comprehensive portable unattended PSG with a minimum of seven channels (including electroencephalogram, electrooculogram, chin electromyogram, electrocardiogram or heart rate, airflow, respiratory effort, and oxygen saturation) corresponds to type 2; type 3 comprises modified portable systems with a minimum of four channels monitored, including ventilation or airflow (at least two channels or respiratory movement, or respiratory movement and airflow), heart rate or electrocardiogram, and oxygen saturation comprise; and finally type 4 includes continuous single or dual bioparameters with one or two channels, typically including oxygen saturation or airflow [57]. Despite the limitations of sensor losses that lead to technically inadequate recordings, the inability to assess sleep time duration or the distinction of apneas (central or obstructive), and the vast heterogeneity of sensors and recorders, the studies have confirmed the overall usefulness of type 3 devices, especially if they focus on the outcome which results in earlier access to treatment for the patient, specially those at high-risk of OSA. An alternative to type 3 devices is the home-polysomnography (H-PSG), which enables the home centered care for patients and a complete sleep evaluation allowing the possibility of diagnosing a large panel of sleep disorders. Thus, this H-PSG intends to perform as well as a full-attended PSG though in an unattended surrounding, without continuous supervision. A technician hooks-up the device, and this factor limits the wide us of this technique [58]. Since the loss of data is still a big issue with type 2 or 3 devices, potential future developments include the use of assistive technology and telemedicine to allow real-time remote monitoring.

To enhance the quality of H-PSG signal, real-time telematics data transmission has been tested generating successful and high-fidelity recordings through a cell phone for an easily deployed home monitor device [59], and a failure rate of 11% of telemonitored in-hospital unattended PSG compared to a 23% failure for unattended H-PSG was observed in another study [60]. Moreover, a pilot study, where 90% of recordings were of excellent quality, consisted in a wireless device to obtain real-time remote supervision of H-PSG from the sleep lab [61]. With this amount of evidence, it seems telemedicine for sleep studies recordings is feasible and may be an important step to reduce the failure rates of home devices; however, there are important barriers for implementing telemedicine for sleep studies regularly. Telemonitoring devices are complex as well as their software; hence, incompatibility problems with other computer programs should be expected. Furthermore, the cost-effectiveness of these systems is yet to be determined considering the fact that the home must be equipped with a computer and Internet connection, along with high specifications for computer programs. However, investigations using integrated circuits available on the market (mobile telephony) have been conducted to simplify access to these technologies [62]. Last but not least, there are also problems related to privacy protection and security of medical data transmission [58]. An ongoing telehealth out-of-laboratory "Fast Track for Sleep Apnea" program for veterans has been reported, that has helped to relieve clinical load at the central sleep program, improved local access to sleep care, and improved patient satisfaction with health care for sleep-related breathing disorders. Nonetheless, the following challenges have been acknowledged so far: the programs needed to be properly integrated with other data management systems and data storage devices must be interfaced with computers attached to the VA server; data loss; and maintaining quality control using metrics [63]. Either way, further research is required to determine the role of telemedicine in sleep-related breathing disorders diagnosis, especially for OSA.

CPAP has shown to wipe out the adverse effect of severe OSA, especially those effects related to cardiovascular diseases. However, the rates of adherence to CPAP are still far of being acceptable. That is way any measure to achieve CPAP adherence is needed, and new approaches such as telemedicine seems to be feasible and cost-effective. Compliance to CPAP is a complex process that involves the participation of the device itself, family support, physicians, health care personal, sleep unit, and government politics [64]. So far, low-quality evidence justifies the use of supportive interventions added to the usual clinical practice to increase CPAP adherence [65] and, similar to previous items, more clinical trials are called for to clear up the role of these interventions, where telemedicine is included. Earlier works presented contradictory results. A statistically significant higher adherence was found in a telemedicine-guided naïve to CPAP patients recently diagnosed with OSA along with greater satisfaction, concluding that telehealth might be cost-effective for CPAP adherence management [66]; while no differences were found in hours of CPAP use, functional status or client satisfaction in another study [67]. It is worth to mention that these two studies followed the

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patients for a 12-week and 30 days period, respectively. More recent clinical trials have added some light to the subject. A 12-month telemedicine intervention resulted in a median CPAP usage that was 0.9 h/night higher than that of an attention control group after 6 months, and 2.0 h/night higher after 12 months in a clinical trial including 250 patients, although the median adherence of all patients was low, with 19% of patients refusing the use of CPAP at all [68]. Another clinical trial of 75 patients, showed higher rates of adherence to CPAP after 3 months of telemedicine intervention, which was determined as a significant predictor of adherence, apart from age and sleepiness symptoms measured by the Epworth Sleepiness Scale [69]. Finally, although no difference in hours of CPAP use was found in a study including 139 OSA patients, telemedicine showed to be more cost-effective than the usual face-to-face management, with travel costs and lost work time being the most important sources of savings [70].

Improvement in case detection and the resulting higher healthcare demand has not been accompanied by any real improvement in OSA management. In addition, health resources assigned to OSA and its treatment have been found to be inadequate [71]. Telemedicine is an appealing approach that needs to be explored and taken into consideration in order to obtain a diagnosis and follow-up of sleep-related breathing disorders in a more timely fashion, which would help to achieve the desirable management of these diseases.

5. Lung transplantation

[Lung transplantation is offered for a great variety on respiratory diseases that have reached their end-stage, where no other treatment would obtain a reasonable survival. They are complex patients who are in need of aggressive immunosuppressive treatment for a lifetime that exposes them to opportunistic infections; so numerous complications are often taking place. By far, the major problem for every lung transplant patient is the allograft dysfunction, either acute or chronic (basically in its form of bronchiolitis obstructive syndrome). Allograft dysfunction is characterized for a functional decline of the implant, which is usually measured by FEV_1 [72], and daily home spirometry has been shown to lead to earlier detection and staging of bronchiolitis obstructive syndrome when compared with standard pulmonary function testing [73]. Concerning the need of retrieving daily spirometric data, telemedicine has been studied as a feasible instrument, making some interesting progress conducive to a more efficient follow-up of patients and the prompt recognition of a possible complication.

Earlier works determined the telemonitored spirometry as feasible, valid, reliable, and repeatable, when compared to the regular in-clinic functional testing [74–76]. Although these studies were clearly underpowered due to the small samples included. While on earlier works the objective is to determine the technical aspects of collecting acceptable spirometries, recent works have carried out clinical trials to demonstrate that a computerized rule-based decision support algorithm for nursing triage of potential acute bronchopulmonary events is effective [72, 77], or the identification of these events taking decision rules developed using wavelet analysis of declines in spirometry and increases in respiratory symptoms [78]. In conclusion, the evidence of the increase of quality of life and reduction of hospital admissions seems fairly positive, though we are still in need of more studies [79] and the training process for both medical staff and patients needs to be thorough [80] A different approach was revised by another study where telemedicine was employed in a clinical trial for lung transplant candidates, and clinical outcome measures were monitoring adherence and level of communication (for monitor acceptability and utilization), hospital length of stay after transplantation and survival at 4 months. However, no significant differences in clinical outcomes between groups were determined [81].

Similar to the previous three respiratory conditions, telemedicine for lung transplant patients is feasible. Still and all, no cost-effectiveness has been demonstrated, thus, larger clinical trials are required to establish the position of these new techniques in lung transplantation.

6. Conclusions

Telemedicine is a helpful tool to improve chronic respiratory patient management. Almost all results shows reduction in Emergency visits and the number of hospitalizations but despite of these results its implementation is troublesome and with different kind of factors relationship with this slowly development. Most users report that the difficult to use the devices or technology platform is the most important factor related to refuse telemedicine by users. We need to work to improve its implementation through educational programs to healthcare professionals and patients.

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References

[1] Jaana M, Paré G, Sicotte C. Home telemonitoring for respiratory conditions: a systematic review. Am J Manag Care. 2009;15:313–20.

[2] Sabati N, Snyder M, Edin-Stibbe C, Lindgren B, Finkelstein S. Facilitators and barriers to adherence with home monitoring using electronic spirometry. AACN Clin Issues. 2001;12:178–85.

[3] World Health Organization. http://www.who.it. Last up to date 21st December 2015.

[4] American Telemedicine Association (ATA). http://atmedad.org. Last up to date 21st December 2015.

[5] Bashur RL. On the definition and evaluation of telemedicine. J Telemed Telecare. 1995;1:19–30.

[6] Norris TG. Telemedicine and teleradiology. Radiol Technol. 1997;71:139–64.

[7] Bashur R, Lovett J. Assessment of telemedicine: results of initial experience. Aviat Space Environ Med. 1997;48:65–70.

[8] House AM, Roberts JM. Telemedicine in Canada. Can Med Assoc J. 1997;117:386–8.

[9] Kopec A, Salazar AJ. Generalities about telemedicine. In: Bustamante MA, Rodríguez G, editors. Uses of telecommunication in Health in Andean region. Telemedicina. Perú: ORAS-CONHU; 2006.

[10] Segrelles-Calvo G, Chiner E, Fernández-Fabrellas E. Acceptance of telemedicine among healthcare professionals. Arch Bronconeumol. 2015;51:611–2.

[11] Mira-Solves JJ, Orozco-Beltrán D, Sánchez-Molla M, Sánchez-García J. Chronic patients satisfaction about telemedicine devices and the care received. ValCrònic Program. Aten Primaria. 2014;46:16-23.

[12] Jódar-Sánchez F, Ortega F, Parra C, Gómez-Suárez C, Jordán A, Pérez P, et al. Implementation of a telehealth programme for patients with severe chronic obstructive pulmonary disease treated with long-term oxygen therapy. J Telemed Telecare. 2013;19:11–7.

[13] Vitacca M, Bianchi L, Guerra A, Fracchia C, Spanavello A, Balbi B, et al. Tele-assistance in chronic respiratory failure patients: a randomised clinical trial. Eur Respir J. 2009;33:411–8.

[14] Motulsky A, Sicotte C, Lamothe L, Winslade N, Tamblyn R. Electronic prescriptions and disruptions to the jurisdiction of community pharmacists. Soc Sci Med. 2011;73:121–8.

[15] Cresswell K, Coleman J, Slee A, Williams R, Sheikh A; ePrescribing Programme Team. Investigating and learning lessons from early experiences of implementing ePrescribing systems into NHS hospitals: a questionnaire study. PLoS One. 2013;8:e71238–49.

[16] Mahmud K, LeSage K. Telemedicine—a new idea for home care. Caring. 1995;14:48–50.

[17] Johnston B, Wheeler L, Deuser J, Sousa KH. Outcomes of the Kaiser Permanente Tele-Home Health Research Project. Arch Fam Med. 2000;9:40–5.

[18] Nakamura K, Takano T, Akao C. The effectiveness of videophones in home healthcare for the elderly. Med Care. 1999;37:117–25.

[19] Hoaas H, Andreassen HK, Lien LA, Hjalmarsen A, Zanaboni P. Adherence and factors affecting satisfaction in long-term telerehabilitation for patients with chronic obstructive pulmonary disease: a mixed methods study. BMC Med Inform Decis Mak. 2016;16:26.

[20] Bauer MS, Krawczyk L, Miller CJ, Abel E, Osser DN, Franz A, et al. Team-based telecare for bipolar disorder. Telemed J E Health. 2016 (in press).

[21] Story A, Garfein RS, Hayward A, Rusovich V, Dadu A, Soltan V, et al. Monitoring therapy compliance of tuberculosis patients by using video-enabled electronic devices. Emerg Infect Dis. 2016;22:538-40

[22] Balas EA, Jaffrey F, Kuperman GJ, Boren SA, Brown GD, Pinciroli F, et al. Electronic communication with patients. Evaluation of distance medicine technology. JAMA. 1997;278:152–9.

[23] Vos T, Flaxman AD, Naghavi M, Lozano R, Michaud C, Ezzati M, Shibuya K, Salomon JA, Abdalla S, Aboyans V, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease study 2010. Lancet. 2012;380:2163–96.

[24] Mannino DM, Buist AS. Global burden of COPD: risk factors, prevalence, and future trends. Lancet. 2007;370:765–73.

[25] López-Campos JL, Tan W, Soriano JB. Global burden of COPD. Respirology. 2016;21:14–23. doi: 10.1111/resp.12660.

[26] Mannino DM, Higuchi K, Yu TC, Zhou H, Li Y, Tian H, Suh K. Economic burden of chronic obstructive pulmonary disease by presence of comorbidities. Chest. 2015;148:138–50.

[27] Polisena J, Tran K, Cimon K, Hutton B, McGill S, Palmer K, Scott RE. Home telehealth for chronic obstructive pulmonary disease: a systematic review and meta-analysis. J Telemed Telecare. 2010;16:120–7. doi: 10.1258/jtt.2009.090812.

[28] McLean S, Nurmatov U, Liu JL, Pagliari C, Car J, Sheikh A. Telehealthcare for chronic obstructive pulmonary disease: Cochrane Review and meta-analysis. Br J Gen Pract. 2012;62:e739–49. doi: 10.3399/bjgp12X658269.

[29] Bolton CE, Waters CS, Peirce S, Elwyn G; EPSRC and MRC Grand Challenge Team. Insufficient evidence of benefit: a systematic review of home telemonitoring for COPD. J Eval Clin Pract. 2011;17:1216–22. doi: 10.1111/j.1365-2753.2010.01536.x.

[30] Segrelles Calvo G, Gómez-Suárez C, Soriano JB, Zamora E, Gónzalez-Gamarra A, González-Béjar M, Jordán A, Tadeo E, Sebastián A, Fernández G, Ancochea. A home telehealth program for patients with severe COPD: the PROMETE study. Respir Med. 2014;108:453–62. doi: 10.1016/j.rmed.2013.12.003.

[31] Gottlieb M, Marsaa K, Andreassen H, Strømstad G, Godtfredsen N. Feasibility of a telecare solution for patients admitted with COPD exacerbation: screening data from a pulmonary ward in a university hospital. Eur Clin Respir J. 2014;1:24193

[32] Cruz J, Brooks D, Marques A. Home telemonitoring effectiveness in COPD: a systematic review. Int J Clin Pract. 2014;68:369–78. doi: 10.1111/ijcp.12345.

[33] Ringbæk T, Green A, Laursen LC, Frausing E, Brøndum E, Ulrik CS. Effect of tele health care on exacerbations and hospital admissions in patients with chronic obstructive pulmonary disease: a randomized clinical trial. Int J Chron Obstruct Pulmon Dis. 2015;10:1801–8. doi: 10.2147/COPD.S85596.

[34] Lundell S, Holmner Å, Rehn B, Nyberg A, Wadell K. Telehealthcare in COPD: a systematic review and meta-analysis on physical outcomes and dyspnea. Respir Med. 2015;109:11–26. doi: 10.1016/j.rmed.2014.10.008.

[35] Paneroni M, Colombo F, Papalia A, Colitta A, Borghi G, Saleri M, Cabiaglia A, Azzalini E, Vitacca M. Is telerehabilitation a safe and viable option for patients with COPD? A feasibility study. COPD. 2015;12:217–25. doi: 10.3109/15412555.2014.933794.

[36] Henderson C, Knapp M, Fernández JL, Beecham J, Hirani SP, Cartwright M, Rixon L, Beynon M, Rogers A, Bower P, Doll H, Fitzpatrick R, Steventon A, Bardsley M, Hendy J, Newman SP; Whole System Demonstrator evaluation team. Cost effectiveness of telehealth for patients with long term conditions (Whole Systems Demonstrator telehealth questionnaire study): nested economic evaluation in a pragmatic, cluster randomised controlled trial. BMJ. 2013;346:f1035. doi: 10.1136/bmj.f1035.

[37] Steventon A, Bardsley M, Billings J, Dixon J, Doll H, Hirani S, Cartwright M, Rixon L, Knapp M, Henderson C, Rogers A, Fitzpatrick R, Hendy J, Newman S; Whole System Demonstrator Evaluation Team. Effect of telehealth on use of secondary care and mortality: findings from the Whole System Demonstrator cluster randomised trial. BMJ. 2012;344:e3874. doi: 10.1136/bmj.e3874.

[38] Udsen FW, Lilholt PH, Hejlesen O, Ehlers LH. Effectiveness and cost-effectiveness of telehealthcare for chronic obstructive pulmonary disease: study protocol for a cluster randomized controlled trial. Trials. 2014;15:178. doi: 10.1186/1745-6215-15-178.

[39] Gibson PG, Powell H, Coughlan J, Wilson AJ, Abramson M, Haywood P, et al. Self management education and regular practitioner review for adults with asthma (Cochrane review). In: The Cochrane Library, Issue 4. Chichester, UK: John Wiley and Sons, Ltd; 2003.

[40] Van Gaalen JL, Hashimoto S, Sont JK. Telemanagement in asthma: an innovative and effective approach. Curr Opin Allergy Clin Immunol. 2012;12:235–40. doi: 10.1097/ACI.0b013e3283533700.

[41] McLean S, Chandler D, Nurmatov U, Liu J, Pagliari C, Car J, Sheikh A. Telehealthcare for asthma: a Cochrane review. CMAJ. 2011;183:E733–42. doi: 10.1503/cmaj.101146.

[42] Wootton R. Twenty years of telemedicine in chronic disease management—an evidence synthesis. J Telemed Telecare. 2012;18:211–20. doi: 10.1258/jtt.2012.12021.

[43] van der Meer V, van den Hout WB, Bakker MJ, Rabe KF, Sterk PJ, Assendelft WJ, Kievit J, Sont JK; SMASHING (Self-Management in Asthma Supported by Hospitals, ICT, Nurses and General Practitioners) Study Group. Cost-effectiveness of Internet-based self-management compared with usual care in asthma. PLoS One. 2011;6:e27108. doi: 10.1371/journal.pone.0027108.

[44] Pinnock H, McKenzie L, Price D, Sheikh A. Cost-effectiveness of telephone or surgery asthma reviews: economic analysis of a randomised controlled trial. Br J Gen Pract. 2005;55:119–24.

[45] Pinnock H, Adlem L, Gaskin S, Harris J, Snellgrove C, Sheikh A. Accessibility, clinical effectiveness, and practice costs of providing a telephone option for routine asthma reviews: phase IV controlled implementation study. Br J Gen Pract. 2007;57:714–22.

[46] Raben KF, Vermeire PA, Soriano JB, Maier WC. Clinical management of asthma in 1999: the Asthma Insights and Reality in Europe (AIRE) study. Eur Respir J. 2000;16:802–7.

[47] Rasmussen LM, Phanareth K, Nolte H, Backer V. Internet-based monitoring of asthma: a long-term, randomized clinical study of 300 asthmatic subjects. J Allergy Clin Immunol. 2005;115:1137–42.

[48] Liu WT, Huang CD, Wang CH, Lee KY, Lin SM, Kuo HP. A mobile telephone-based interactive self-care system improves asthma control. Eur Respir J. 2011;37:310–7. doi: 10.1183/09031936.00000810.

[49] Araújo L, Jacinto T, Moreira A, Castel-Branco MG, Delgado L, Costa-Pereira A, Fonseca J. Clinical efficacy of web-based versus standard asthma self-management. J Investig Allergol Clin Immunol. 2012;22:28–34.

[50] Deschildre A, Béghin L, Salleron J, Iliescu C, Thumerelle C, Santos C, Hoorelbeke A, Scalbert M, Pouessel G, Gnansounou M, Edmé JL, Matran R. Home telemonitoring (forced expiratory volume in 1 s) in children with severe asthma does not reduce exacerbations. Eur Respir J. 2012;39:290–6. doi: 10.1183/09031936.00185310.

[51] Brouwer AF, Brand PL, Roorda RJ, Duiverman EJ. Airway obstruction at time of symptoms prompting use of reliever therapy in children with asthma. Acta Paediatr. 2010;99:871–6. doi: 10.1111/j.1651-2227.2010.01715.x.

[52] Ge X, Han F, Huang Y, Zhang Y, Yang T, Bai C, Guo X. Is obstructive sleep apnea associated with cardiovascular and all-cause mortality? PLoS One. 2013;8:e69432. doi: 10.1371/journal.pone.0069432.

[53] Collop NA. Clinical guidelines for the use of unattended portable monitors in the diagnosis of obstructive sleep apnea in adult patients. J Clin Sleep Med. 2007;3:737e47.

[54] Masa Jimenez JF, Barbé Illa F, Capote Gil F, Chiner Vives E. Resources and delays in the diagnosis of sleep apnea-hypopnea syndrome. Arch Bronconeumol. 2007;43:188e98.

[55] Wang J, Yu W, Gao M, Zhang F, Li Q, Gu C, Yu Y, Wei Y. Continuous positive airway pressure treatment reduces cardiovascular death and non-fatal cardiovascular events in patients with obstructive sleep apnea: a meta-analysis of 11 studies. Int J Cardiol. 2015;191:128–31. doi: 10.1016/j.ijcard.2015.05.003.

[56] Meurice JC. Improving compliance to CPAP in sleep apnea syndrome: from coaching to telemedicine. Rev Mal Respir. 2012;29:7–10. doi: 10.1016/j.rmr.2011.12.007.

[57] Chesson AL Jr, Berry RB, Pack A; American Academy of Sleep Medicine; American Thoracic Society; American College of Chest Physicians. Practice parameters for the use of portable monitoring devices in the investigation of suspected obstructive sleep apnea in adults. Sleep. 2003;26:907–13.

[58] Bruyneel M, Ninane V. Unattended home-based polysomnography for sleep disordered breathing: current concepts and perspectives. Sleep Med Rev. 2014;18:341–7. doi: 10.1016/j.smrv.2013.12.002.

[59] Kayyali HA, Weimer S, Frederick C, Martin C, Basa D, Juguilon JA, Jugilioni F. Remotely attended home monitoring of sleep disorders. Telemed J E Health. 2008;14:371–4. doi: 10.1089/tmj.2007.0058.

[60] Gagnadoux F, Pelletier-Fleury N, Philippe C, Rakotonanahary D, Fleury B. Home unattended vs hospital telemonitored polysomnography in suspected obstructive sleep apnea syndrome: a randomized crossover trial. Chest. 2002;121:753e8.

[61] Bruyneel M, Van den Broecke S, Libert W, Ninane V. Real-time attended home-polysomnography with telematic data transmission. Int J Med Inform. 2013;82:696e701.

[62] Dellaca R, Montserrat JM, Govoni L, Pedotti A, Navajas D, Farré R. Telemetric CPAP titration at home in patients with sleep apnea-hypopnea syndrome. Sleep Med. 2011;12:153e7.

[63] Hirshkowitz M, Sharafkhaneh A. A telemedicine program for diagnosis and management of sleep-disordered breathing: the fast-track for sleep apnea tele-sleep program. Semin Respir Crit Care Med. 2014;35:560–70. doi: 10.1055/s-0034-1390069.

[64] Shapiro GK, Shapiro CM. Factors that influence CPAP adherence: an overview. Sleep Breath. 2010;14:323–35.

[65] Wozniak DR, Lasserson TJ, Smith I. Educational, supportive and behavioural interventions to improve usage of continuous positive airway pressure machines in adults with obstructive sleep apnoea. Cochrane Database Syst Rev. 2014;1:CD007736. doi: 10.1002/14651858.CD007736.pub2.

[66] Smith CE, Dauz ER, Clements F, Puno FN, Cook D, Doolittle G, Leeds W. Telehealth services to improve nonadherence: a placebo-controlled study. Telemed J E Health. 2006;12:289–96.

[67] Taylor Y, Eliasson A, Andrada T, Kristo D, Howard R. The role of telemedicine in CPAP compliance for patients with obstructive sleep apnea syndrome. Sleep Breath. 2006;10:132–8.

[68] Sparrow D, Aloia M, Demolles DA, Gottlieb DJ. A telemedicine intervention to improve adherence to continuous positive airway pressure: a randomised controlled trial. Thorax. 2010;65:1061–6. doi: 10.1136/thx.2009.133215.

[69] Fox N, Hirsch-Allen AJ, Goodfellow E, Wenner J, Fleetham J, Ryan CF, Kwiatkowska M, Ayas NT. The impact of a telemedicine monitoring system on positive airway pressure adherence in patients with obstructive sleep apnea: a randomized controlled trial. Sleep. 2012;35:477–81. doi: 10.5665/sleep.1728.

[70] Isetta V, Negrín MA, Monasterio C, Masa JF, Feu N, Álvarez A, Campos-Rodriguez F, Ruiz C, Abad J, Vázquez-Polo FJ, Farré R, Galdeano M, Lloberes P, Embid C, de la Peña M, Puertas J, Dalmases M, Salord N, Corral J, Jurado B, León C, Egea C, Muñoz A, Parra O, Cambrodi R, Martel-Escobar M, Arqué M, Montserrat JM; SPANISH SLEEP NETWORK. A Bayesian cost-effectiveness analysis of a telemedicine-based strategy for the management of sleep apnoea: a multicentre randomised controlled trial. Thorax. 2015;70:1054–61. doi: 10.1136/thoraxjnl-2015-207032.

[71] Rotenberg B, George C, Sullivan K, Wong E. Wait times for sleep apnea care in Ontario: a multidisciplinary assessment. Can Respir J. 2010;17:170–4.

[72] Finkelstein SM, Scudiero A, Lindgren B, Snyder M, Hertz MI. Decision support for the triage of lung transplant recipients on the basis of home-monitoring spirometry and symptom reporting. Heart Lung. 2005;34:201–8.

[73] Robson KS, West AJ. Improving survival outcomes in lung transplant recipients through early detection of bronchiolitis obliterans: daily home spirometry versus standard pulmonary function testing. Can J Respir Ther. 2014;50:17–22.

[74] Finkelstein SM, Snyder M, Edin-Stibbe C, Chlan L, Prasad B, Dutta P, Lindgren B, Wielinski C, Hertz MI. Monitoring progress after lung transplantation from home-patient adherence. J Med Eng Technol. 1996;20:203–10.

[75] Lindgren BR, Finkelstein SM, Prasad B, Dutta P, Killoren T, Scherber J, Stibbe CL, Snyder M, Hertz MI. Determination of reliability and validity in home monitoring data of pulmonary function tests following lung transplantation. Res Nurs Health. 1997;20:539–50.

[76] Wagner FM, Weber A, Park JW, Schiemanck S, Tugtekin SM, Gulielmos V, Schüler S. New telemetric system for daily pulmonary function surveillance of lung transplant recipients. Ann Thorac Surg. 1999;68:2033–8.

[77] Finkelstein SM, Lindgren BR, Robiner W, Lindquist R, Hertz M, Carlin BP, VanWormer A. A randomized controlled trial comparing health and quality of life of lung transplant recipients following nurse and computer-based triage utilizing home spirometry monitoring. Telemed J E Health. 2013;19:897–903. doi: 10.1089/tmj.2013.0049.

[78] Wang W, Finkelstein SM, Hertz MI. Automatic event detection in lung transplant recipients based on home monitoring of spirometry and symptoms. Telemed J E Health. 2013;19:658–63. doi: 10.1089/tmj.2012.0290.

[79] Fadaizadeh L, Najafizadeh K, Shafaghi S, Hosseini MS, Ghoroghi A. Using home spirometry for follow up of lung transplant recipients: "A Pilot Study". Tanaffos. 2013;12:64–9.

[80] Fadaizadeh L, Najafizadeh K, Shajareh E, Shafaghi S, Hosseini M, Heydari G. Home spirometry: assessment of patient compliance and satisfaction and its impact on early diagnosis of pulmonary symptoms in post-lung transplantation patients. J Telemed Telecare. 2016;22:127–31

[81] Mullan B, Snyder M, Lindgren B, Finkelstein SM, Hertz MI. Home monitoring for lung transplant candidates. Prog Transplant. 2003;13:176–82.