Multicenter Support Network for CPAP Therapy Follow-up in Sleep Apnea

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Abstract— **Despite its fast penetration into many fields, the application of information and communication technologies in clinical practice is still limited, especially in respiratory medicine. The availability of tools such as the Internet has grown rapidly but it is rarely considered as an option for management of the Obstructive Sleep Apnea Syndrome (OSAS). We developed a novel multicenter support system for the follow-up of continuous positive airway pressure (CPAP) therapy in patients with OSAS. The system essentially consists of a support network that allows several sleep centers to perform online monitoring of their patients, whose data are stored in a secure central server. Patients interact with the system through a web-based interface that can be accessed from their home personal computer or tablets. By visiting the website, patients can answer a weekly questionnaire about their status and therapy, with access to continuously updated temporal trends in a graphic format. The system also provides easy communication with sleep center staff by e-mail and videoconference. After the development phase, the system has started to be put into operation. The positive preliminary results obtained show the potential usefulness of the Internet as a tool for supporting home monitoring of CPAP treatment in OSAS.**

Keywords-eHealth; Obstructive Sleep Apnea; CPAP; telemedicine; home monitoring.

I. INTRODUCTION

Obstructive sleep apnea syndrome (OSAS) is a serious disorder caused by partial or complete obstruction of the upper airway and it is associated with deterioration of quality of life, daytime sleepiness, neurocognitive impairment and cardiovascular disease [1]. OSAS is estimated to affect 2–4% of adult men and 1–2% of adult women in Western countries [2][3]. OSAS is strongly related to obesity even though it is also increasingly identified in non-obese subjects with a particular craniofacial structure. The incidence of OSAS is likely to grow in parallel with the spread of obesity now occurring in many countries. European and Spanish public health resources assigned to this problem have proved to be relatively inadequate and unlikely to handle the increase in OSAS cases [4], so cheaper and alternative management approaches are needed.

The most frequently used treatment for OSAS is continuous positive airway pressure (CPAP) applied through a mask to the nose or the mouth of the patient at home during sleep. This pressure in the mask is transmitted to the pharyngeal area, thereby avoiding upper airway obstruction. One critical factor in CPAP effectiveness is compliance. A minimum of 4 hours per night of CPAP use is recommended to avoid compromising outcomes. However, a number of patients suspend or underuse CPAP treatment, mainly due to the numerous side effects and lack of knowledge about possible solutions [5][6]. Some of these side effects could be easily solved by a close follow-up, especially during the first weeks, but busy sleep centers have difficulties in giving such support [7]. Accordingly, there is a clear need to improve patients' understanding of the expected advantages of CPAP use and to monitor and properly address side effects of CPAP therapy, as well as facilitate the communication of patients with sleep centers.

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It has recently been recognized that telemedicine could have a valuable role in improving CPAP adherence and should be integrated into OSAS patients' care as fast as possible [8]. It has been shown that simple telemedicine interventions, such as weekly phone calls to clarify doubts and encourage CPAP use, can markedly improve compliance [9]. A randomized clinical trial showed that the use of a telephone-linked communication system providing feedback and counseling to OSAS patients at home improved CPAP adherence, patients' functional status and reduced depressive symptoms [6]. Furthermore, another previous study employed an Internet-based informational support service for problems experienced with CPAP use [10]. Despite the organizational limitations and poor differences between intervention and control group follow-up, they obtained good patients' acceptance of this monitoring approach. It is also remarkable that telehealth interventions, such as televisits, have been found to improve CPAP adherence in a small group of nonadherent patients versus a placebo-controlled group [11]. The cost of the interventions, including the telehealth monitor, home installation and telephone charges, was lower than the same number of presential visits. Nevertheless, larger studies are needed to generalize any conclusion.

Under the framework of an Investigation Project promoted by the Spanish Society of Pneumology and Thoracic Surgery (SEPAR) on sleep-related respiratory disorders, we developed a multicenter support system for the follow-up of CPAP therapy in OSAS patients. This system essentially comprises a support network that can be connected with several sleep centers to monitor and communicate online with their patients, whose data are stored in a secure central server. Patients interact with the system through a user-friendly web-based interface that can be accessed from their home personal computer or tablet. Moreover, videoconferencing is available to promote long-distance communication with the sleep center and provide non-presential visits.

This telemedicine application seeks to introduce a new approach to CPAP therapy monitoring, which focuses on enhancing patients' motivation and self-management skills and strengthening the professional-patient relationship, in order to improve CPAP compliance and reduce presential clinical visits.

In this paper, the telemedicine support system is described in detail and preliminary results of the practical application phase on OSAS patients are shown.

II. SYSTEM OVERVIEW AND FUNCTIONALITIES

The system was implemented using PHP language and all the user interface components were developed as dynamic server-side pages. In order to enforce completion and internal consistency of all the forms and surveys contained in the web application, Javascript components were employed. The system was developed with a focus on usability and structural simplicity. During each development stage, special effort was made to guarantee the maintainability and versatility of the tool. The system architecture was designed to allow frequent updating of the individual modules and easy adaptability to different clinical requirements. The web application functioning was successfully tested with the most important operating systems (Windows XP, Windows Vista, Windows 7, Mac OS X) and web browsers (Internet Explorer 6 and later versions, Mozilla Firefox, Google Chrome, Opera and Safari).

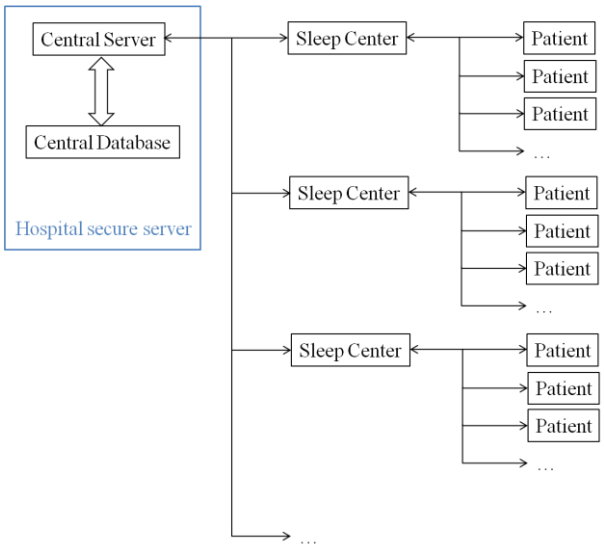

Figure 1. Network overview.

The system overview is shown in Figure 1. The main actors of this structure are: the patient, the Sleep Center and the Central Server.

A. *Patient interface to the system*

Patients included in the project are given access to an Internet-based application implemented as an interactive website. The equipment needed is nothing more than an Internet-connected computer or tablet, a microphone and a webcam. In order to ensure the confidentiality and preserve security, patients can access the website by logging in with their personal username and password, assigned during the enrollment. The system identifies the user by comparing inserted credentials to the ones stored in the Central Server and dynamically generates pages containing only the information available to each user. After logging in, patients are redirected to the website Home Page. The menu bar contains the links to the different sections of the website.

- The "Questionnaire" button in the menu bar of the website redirects patients to a short questionnaire they are asked to answer once a week. The questionnaire is composed of 6 questions about patients' weight, the amount and kind of physical activity they have done over the week, the time they have slept and used the CPAP device, the occurrence of sleepiness in daytime and problems caused by the use of the CPAP device. In order to ensure patients' compliance with the weekly questionnaire, an e-mail reminder is sent automatically to each patient once a week.

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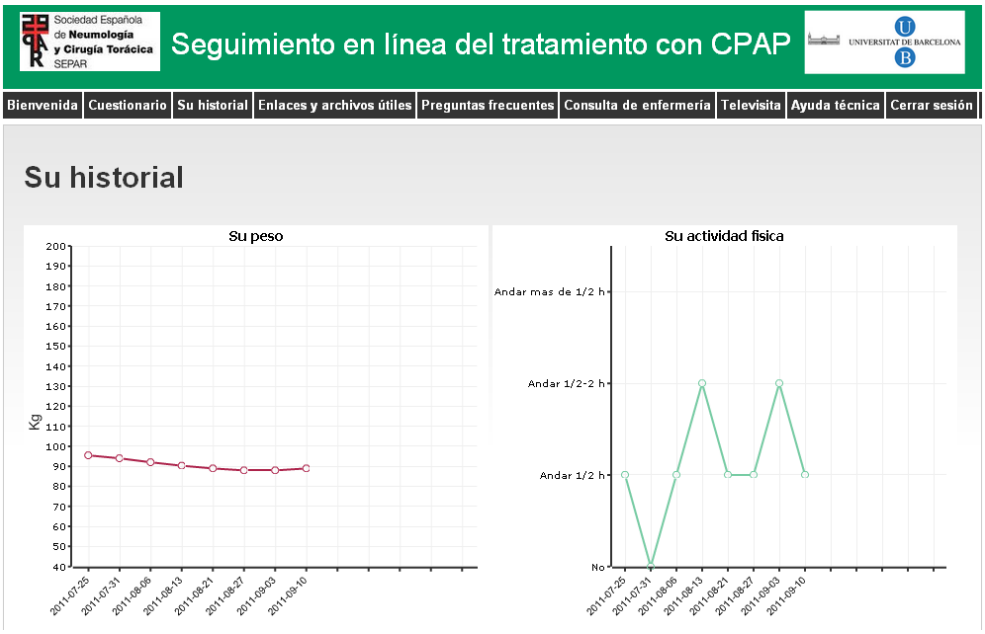

Figure 2. Screenshot of the "You record" page. Two of the six charts are shown here. Translation from original version in Spanish: *Header:* "Online follow-up of CPAP therapy". *Top menu-bar:* "Questionnaire", "You record", "Useful files and links", "Frequently asked questions", "Contact the sleep staff", "Televisit", "Technical support", "Log out". *Content:*"Your weight", "Your physical activity".

- In the "Your record" section, the patient's parameters, which correspond to the weekly questionnaire answers, are plotted in dynamic Flash charts and continuously updated. This section was created in order to give patients a visual feedback of their answers to the weekly questionnaire (Figure 2).
- In the "Useful files and links" section, high-quality informative documents about OSAS management and CPAP therapy are available for free download. Moreover, a list of links to the official websites of the most relevant OSAS patients associations is also provided. Educational videos that train patients in the correct use of the CPAP device and mask are accessible in this section.
- A validated list of answers to "Frequently asked questions" elaborated by sleep specialists is available.
- By clicking on the "Contact the center staff" button, the patients can easily communicate online with the sleep center staff by exchanging messages via e-mail to discuss doubts and ask questions regarding OSAS and CPAP therapy.
- In addition, the "Televisit" button gives patients access to an interesting function of the system which allows them to talk to the sleep center staff by videoconferencing. For this purpose, the LinkCare Videoconference Module was integrated into the system [12]. Videoconferences are scheduled by the sleep center staff and patients automatically receive a confirmation e-mail containing the day and time of the appointment. When a videoconference is undertaken, a new browser window opens, containing the videoconference client. The user enters the videoconference client application according to his/her user role in the system (professional or patient). Patients enter the videoconference application as simple participants and they are unable to activate or deactivate their webcam and microphone. This tool allows patients to see the healthcare professionals and receive teaching and support regarding their therapy.
- The application also provides continuous technical support. By visiting the section "Technical support", patients can directly contact the Webmaster, who is available to solve potential technical problems about the website functioning.

B. *Sleep center*

Several sleep centers can connect simultaneously to the support system. The healthcare professionals from each center can undertake the following management activities:

- Patients' status monitoring. Each center can access only the list of its own patients. The sleep center staff can observe patients' data, corresponding to their answers to the weekly questionnaire. Data are retrieved from a MySQL database connected to the Central Server and shown in dynamic Flash charts. After evaluating the patients' data, if necessary, professionals can write them a message with advice and comments about their status.
- New patient registration. The sleep center staff has to fill in a simple registration form inserting the identification data of each patient, such as the electronic health record (EHR) number, name initials and a contact e-mail address. To protect patients' personal information, their

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name and surname are not included in the registration form. In addition, some initial medical data are requested, such as weight, height, apnea-hypopnea index (AHI), cumulative time with oxygen saturation less than 90% (CT90), etc. Once the registration is completed, a "welcome" e-mail is sent to the patients' contact e-mail address with the credentials needed for authentication by the website. The username is the contact e-mail address and the password is automatically assigned, with the possibility of changing it at any time. If necessary, professionals can also deregister a patient and prevent his/her access to the website.

- E-mailing and videoconferencing. Besides e-mail communication, sleep center staff can easily arrange a videoconference meeting with patients via a simple management interface that communicates with the LinkCare Videoconference Module. By filling in a short form, professionals schedule the videoconference for a time suited to both them and their patients. Professionals enter the videoconference application as coordinators, allowing them to activate or deactivate the webcam and the microphone of the different participants of the meeting.

C. Central Server

All network data, such as the patients' answers and authentication data, are stored in the system Central Server. Data storing is supported by a relational database developed with the MySQL management system, which is incorporated into the secure environment of the "Hospital Clinic" of Barcelona server. The central server administrator is responsible for all data management and system functioning supervision. Moreover, the administrator is in charge of the registration in the network of the sleep centers included in the project.

III. PRELIMINARY RESULTS

Once the development phase was finished, the system's practical application phase began. The support system is already operating in the main center for the project, the "Hospital Clinic" of Barcelona.

So far, the group of patients included has been selected from consecutive patients coming to the "Hospital Clinic" sleep center for a routine CPAP therapy monitoring visit. At the end of the visit, the nurse in charge of the patients proposed the enrolment in the study. The patients who declared they had good computer-Internet skills and were available to participate in the study were included. The sleep center staff took note of the patients' personal data and e-mail addresses. After being recruited, patients received a first e-mail containing information about the study and the personal credentials required to access the web interface. In order to ensure patients' compliance with the weekly questionnaire, an e-mail reminder was sent automatically to each patient once a week. Moreover, after the third completion of the weekly questionnaire a more personalized e-mail was sent in order to thank them for their collaboration and to encourage them to keep answering the questionnaire. At the end of the monitoring period, participants were invited to express their satisfaction about the website by answering an online questionnaire (Table 1). This questionnaire was developed from the Telemedicine Satisfaction and Usefulness Questionnaire (TSUQ), a 5-point Likert questionnaire designed as part of the telemedicine project IDEATel and validated in English and Spanish [13].

Of a total of 163 consecutive patients from the Sleep Clinic, 66 reported basic knowledge of the Internet and agreed to participate. After 12 weeks of monitoring, the participation rate was high (82%). Thirty-five patients responded to the online satisfaction survey and the results are presented in Figure 3. Patients showed a level of agreement to the statement "Overall, I am satisfied with the web service" of 4.3 ± 0.58 points (mean ± SD, 1 = I strongly disagree, 5 = I strongly agree) and expressed their potential interest in participating in a long-term web-based monitoring.

IV. CONCLUSION

The multicenter support system we have developed represents a novel telemedicine approach to CPAP therapy follow-up in OSAS, where the main objective is patients' confidence and improved therapy adherence. The availability of easy communication tools with the sleep center staff can help patients to rapidly solve problems related to CPAP use

TABLE I. PATIENTS' SATISFACTION SURVEY

	Survey statement
1.	In general, I am satisfied with the CPAP follow-up web service.
2.	The CPAP follow-up web service has helped me to better manage my health and medical needs.
3.	I follow my doctor's advice better since working with the CPAP follow-up web service.
4.	The CPAP follow-up web service has been easy to use.
5.	The weekly questionnaire of the CPAP follow-up web service has been easy to fill.
6.	In the future I would like to use the CPAP follow-up web service as part of my treatment control.
7.	In the future I would like to receive comments from my doctor about my weekly questionnaire answers.
8.	In the future I would like my doctor use information from the CPAP follow-up web service for my medical visits.
9.	Files and information links about sleep apnea and CPAP therapy available on the website have been useful.
10.	The ability to review the progress of my parameters on the "Your record" page has been useful.

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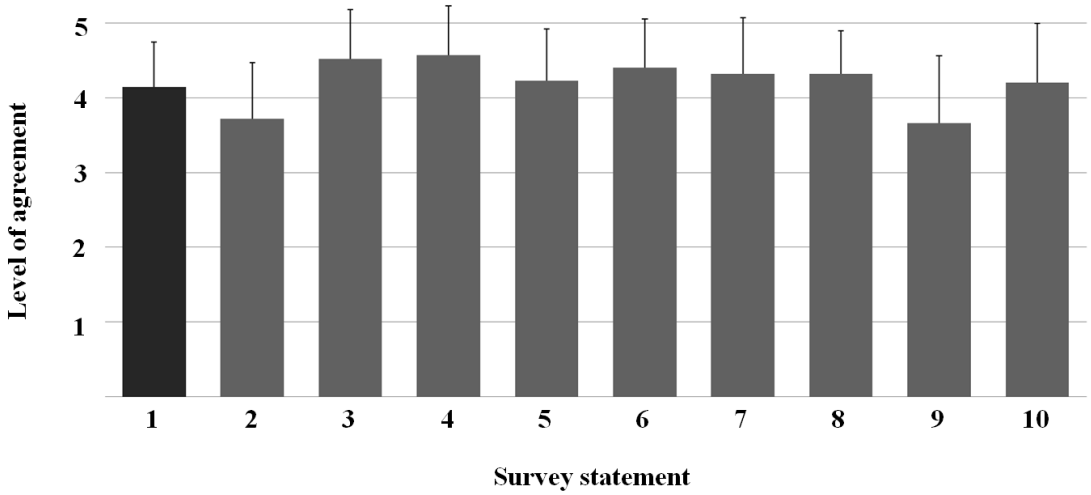

Figure 3. Results of patients' satisfaction survey (mean ± SD) where 1 means "I strongly disagree" and 5 means "I strongly agree". Survey statements are in Table I.

and consequently increase their satisfaction with community service. This system application can be particularly interesting for the management of difficult-to-treat patients, because they do not adapt easily to CPAP, and of special populations. Moreover, the possibility of carrying out non-presential visits via videoconference represents a valuable opportunity to release sleep clinics from a considerable amount of support interventions and extra visits, thereby enhancing the cost-effectiveness of CPAP therapy.

It is remarkable that this system can be readily applicable thanks to the widespread availability of Internet-connected home computers or tablets in the population [14].

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