Clinical Effectiveness of the "Healthwear" Wearable System in the Reduction of COPD Patients' Hospitalization

Alexis Milsis, Theodoros Katsaras, Nicolaos Saoulis, Evita Varoutaki, and Aggelos Vontetsianos

e-Health Unit, 'Sotiria' Hospital,
Athens, Greece
{amilsis,tkatsa,agelvonte}@gmail.com,
{nsaoulis,evitavaroutaki}@hotmail.com

Abstract. Patients with Chronic Obstructive Pulmonary Disease (COPD) experience frequent exacerbations and hospital readmissions. Early hospital discharge schemes have been proved effective and safe approaches for suitable patients. Forty-eight (n=48) COPD patients were included in a randomized control trial (ratio 1:1), after their hospital admission due to an acute exacerbation. The aim of the study was to evaluate whether they could be early discharged and successfully continue their treatment at home, assisted by the use of wearable systems. Study group patients were discharged early (3^{rd}-5^{th} day) and monitored at home through the wearable "Healthwear" system while control group patients underwent conventional care. Intervention patients intensive home monitoring included ECG, heart and respiratory rate, oxygen saturation, activity and body position, combined with 3G mobile video sessions. The results indicated a significant reduction of in-hospital days, outpatient clinic and emergency room visits, as well as in readmission rates. Wearable systems that allow continuous wireless monitoring of bio-signals, can play a significant role in early hospital discharge.

Keywords: e-Health, Remote monitoring, Smart clothes, Smart textiles, wearable, COPD, RCT, Early hospital discharge.

1 Introduction

Chronic obstructive pulmonary disease is a leading cause of chronic morbidity and mortality. Hospital admissions due to exacerbations, especially in the winter period, constitute a major problem in the management of the disease, due to their negative impact on health-related quality of life, prognosis and costs [1,2].

Early hospital discharge (ED) schemes is one of the most promising approaches for efficient healthcare system intervention, in order to control cost and provide high quality services at patients' premises [3,4,5,6].

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New technologies can play a major role towards this transition. Moreover innovative, non-invasive wearable systems that allow continuous wireless monitoring of patients' status, can play a significant role to ED schemes.

The aim of the present study was to evaluate the clinical effectiveness of the "Healthwear" wearable system in the reduction of in-hospital length of stay (LoS), for COPD patients who were admitted to clinical wards of "Sotiria" Hospital, after an acute exacerbation.

2 Materials and Methods

The wearable solution used is based on the "Wealthy" prototype [7,8]. The "Healthwear" system consisted of a wearable garment (easy to wear, washable, available in variable sizes, yet suitable only for male patients at the time of the study) with biosensors embedded into the textiles, coupled with a small, lightweight (145gr) electronic device, called Portable Patient Unit (PPU) (Fig. 1). The PPU is easy to use, with two LEDs and a buzzer for user-warning purposes and a button to let a manual trigger of an alarm. Data transmission is done over a General Packet Radio Service (GPRS) link. The device is powered by a Li-Ion battery, autonomous up to 4 hours with real time streaming of all signals. The PPU collects and transmits the signals from the knitted sensors, as well as from other external medical devices connected via an available RS-232 port (in our case an oximeter was used). The bio-signals (6 lead ECG, pulse rate, respiratory rate, oxygen saturation, skin temperature, and body position), were transmitted via a GPRS mobile connection to a central server.

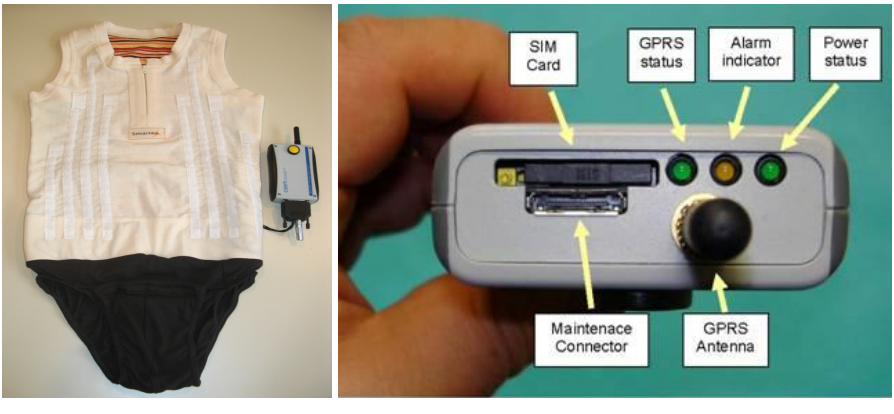

Fig. 1. Healthwear garment and PPU

Complementary, regular 3G cell phones could be used to perform videoconferencing sessions with the patients (Fig. 2).

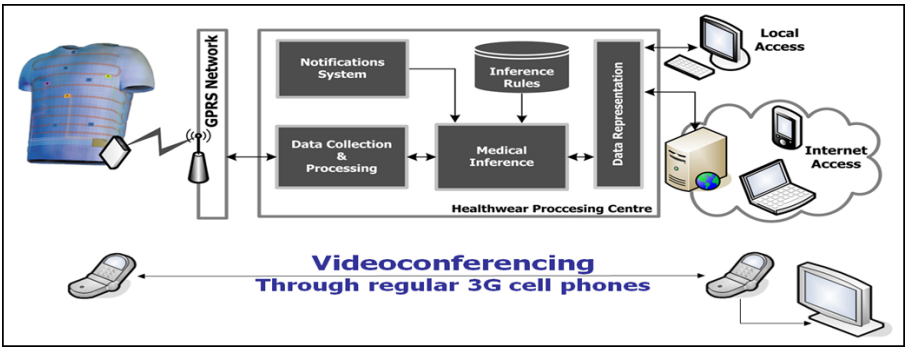

Fig. 2. Architecture of the "Healthwear" System

Medical measurements were stored into patient's electronic health record (EHR) and accessed via a secure TCP/IP connection by the attending physician or other authorized healthcare professionals, in near real-time or off-line mode, using a specifically designed software application with a suitable graphical representation (Fig. 3).

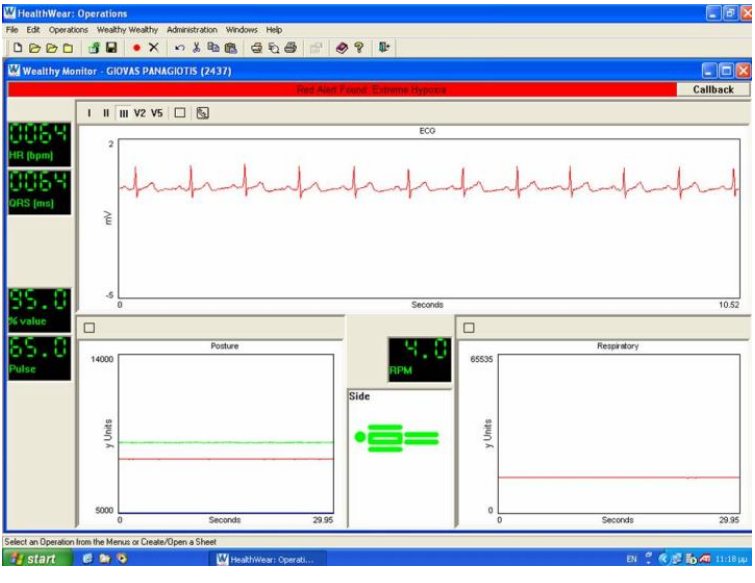

Fig. 3. Biosignals obtained by "Healthwear" system

Eligible patients for the trial were COPD exacerbated patients, admitted as emergency cases to the pulmonary wards of "Sotiria" Chest Diseases Hospital of Athens. Patients requiring inpatient imperative management or investigation for other medical problems and co morbidities were excluded. Additionally, patients who were not residents of Athens, homeless, living under extremely poor social conditions, or unable to give informed consent, were not considered eligible.

A total number of forty eight (n=48) male patients, were included and randomized (1:1 ratio) to intervention (early discharge) and control group (conventional inpatient care) by a third party staff member. The necessary equipment (garment, PPU, external oximeter) was provided to each patient of the intervention group, while they were hospitalized. During their in-hospital stay, the system functionality was validated and the patients were trained on its usage (Fig. 4). The patient learned how to wear the garment and set-up the system in order to facilitate the bio-signal collection and transmission whenever he was instructed to.

Fig. 4. Patient being monitored during his in-hospital training and while performing outdoor activities, using the "Healthwear" system

A multidisciplinary team (specialists, nurses, social workers and physiotherapists), in close cooperation with the physician in charge of the patient, designed a personalized care plan [9] to be followed at home, after the patient's discharge. Between the 3rd and 5th day of hospitalization, the patient was early discharged by the attending physician and continued his treatment at home. The patient was given unlimited telephone access to a respiratory nurse (case manager) of the hospital's home care team, who was responsible for the implementation of the prescribed care plan. The patient, using the PPU, was also capable to alert the case manager in case of deterioration, or initiate a session of bio-signal transmissions, according to the given instructions.

During the follow up period of the patient, a number of remote sessions (e-visits) were performed, consisting of bio-signal transmissions and simultaneous videoconferencing with the case manager or the attending physician (Fig. 5). The frequency and the duration of the sessions were adjusted as required, according to the patients' health status and findings. Usual sessions were scheduled while the patients were at their home premises or during outdoor activities, while performing prescribed physical exercises. Scheduled or patient initiated sessions of vital sign transmissions (unattended monitoring) could also be performed and be reviewed later on by the healthcare professionals (off-line mode).

During the first week after ED, patients were monitored more intensively with about three scheduled sessions per day, while one scheduled session per day was approximately performed, in the following three weeks.

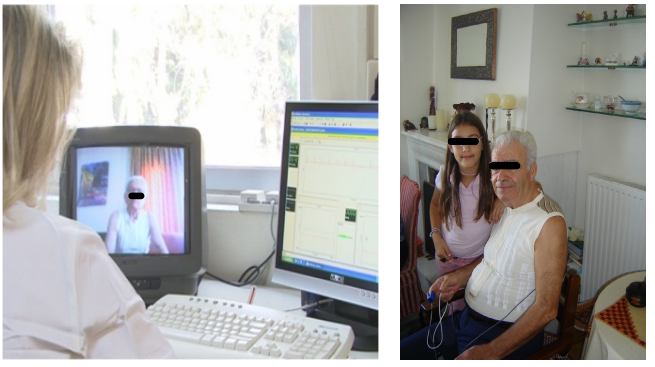

Fig. 5. e-Visit (Biosignal transmission combined with video conference)

At the end of the two months follow-up period, length of stay (LoS), readmission and mortality rate, as well as visits to the emergency room or outpatient clinic, were assessed for both groups [5].

The control group patients were discharged according to the current criteria and practices followed in traditional in-hospital care.

3 Results

The average length of in-hospital stay for the intervention group patients was 3.6 days, versus 6.8 days of the control group. From the control group, three patients were readmitted, compared to one patient of the intervention group. For the study group two emergency room (ER) visits and two outpatient clinic visits were recorded, while for the control group eight and thirty two visits were observed respectively. No mortality incidents were reported for either group, during the studied period (Fig. 6).

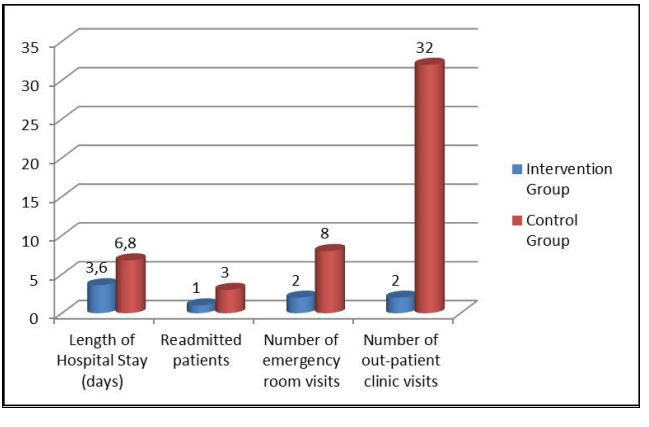

Fig. 6. Length of Stay, Readmission Rate and health services usage

The mean number of biosignal monitoring sessions was 50.3 per patient, while the number of videoconferencing sessions was 7.3 for the follow-up period. From a total of 1388 transmission sessions, 1207 (87%) were successful (175 of them combined with videoconference) (Fig. 7).

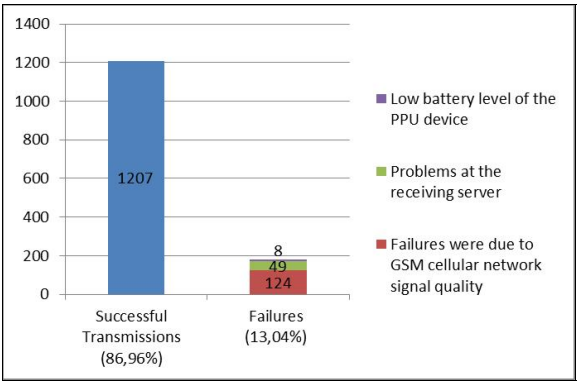

Fig. 7. Biosignal transmission statistics

Twenty out of twenty four intervention group patients considered the garment as acceptable, while remaining four patients reported various reasons for inconvenience.

4 Discussion

Our trial's results presented notable reduction of in-hospital length of stay, which was the main expectation of the trial. Reductions in using hospital emergency services, such as unnecessary ER visits and readmission rate were also observed.

From a technical point of view, the system supported successfully bio-signal transmissions, as most of the failures were not directly related to "Healthwear" (poor GSM/GPRS signal).

In the past, patients with acute exacerbations of COPD were successfully early discharged from the hospital, with the support of visiting respiratory nurses [3,5,9]. According to our findings, the "Healthwear" system supported efficiently the ED intervention, allowing patients' remotely home monitoring, decreasing the need of multiple nurse home visits. The combined use of videoconference sessions contributed substantially to the patients' accessibility, convenience and feeling of safety.

Technical limitations related to the system's capabilities (e.g. garment suitable only for male patients or reduced autonomy of the PPU's battery), are expected to be resolved in upcoming designs. Additionally other services or capabilities, widely available today, are anticipated to be integrated in future implementations (i.e. smart phones / PPU integration, UMTS etc.).

Wearable solutions are new era's tools, facilitating successfully the implementation of early hospital discharge schemes and the reduction of nurse home visits. Extensive

research is expected to prove the value of wearable devices used in the treatment of other chronic diseases such as Chronic Heart Failure or diabetes. It's also expected to demonstrate the utilization of these systems in other services supporting chronic patients' care management and personalized care, such as telemonitoring during exercise and home based rehabilitation.

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