A pilot study of nurse-led, home monitoring for patients with chronic respiratory failure and with mechanical ventilation assistance

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Summary

We assessed the feasibility of telemedicine for home monitoring of 45 patients with chronic respiratory failure (CRF) discharged from hospital. The patients transmitted pulsed arterial saturation (pSat) data via a telephone modem to a receiving station where a nurse was available for a teleconsultation. A respiratory physician was also available. Scheduled and *ad hoc* appointments were conducted. Thirty-five patients were on home mechanical ventilation, 13 with invasive and 22 with non-invasive devices. The main diagnosis was chronic obstructive pulmonary disease (COPD). The follow-up period was 176 days (SD 69). In all, 376 calls for scheduled consultations were received and 83 *ad hoc* consultations were requested by the patients. The actions taken were: 55 therapy modifications, 19 hospitalizations in a respiratory department for decompensated CRF, three hospitalizations in an intensive care unit (ICU), 22 requests for further investigations, 25 contacts with the general practitioner (GP), 66 demands for respiratory consultations and 10 calls for the emergency department. The mean time recorded for the 459 calls was 16 min/patient/week. In 82% of calls, a pSat recording was received successfully. The nurse time required to train the users in the operation of the pSat instrument was high (mean time 30 min). However, the results showed that home monitoring was feasible, and useful for titration of oxygen, mechanical ventilation setting and stabilization of relapses.

Introduction

The number of patients with chronic respiratory failure (CRF) needing mechanical ventilation at home is increasing. This is mainly because of the growing number of elderly respiratory patients and patients recovering from stays in hospital intensive care units (ICUs).[1,2] These patients have poor outcomes[3] and are often at risk of being readmitted to hospital with high burden of care costs. To the best of our knowledge, there is no published information about the use of telemedicine for these very severely ill patients.

We have conducted a pilot study to test:

(1) the feasibility of telemedicine for out of hospital use
(2) the number of pulsed arterial saturation (pSat) recordings needed to titrate oxygen supply, mechanical ventilation setting and drugs during relapses
(3) data transmission by modem.

Methods

Forty-five patients consecutively discharged from our Institute from 30 April 2004 to 31 January 2005 with

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a confirmed diagnosis of CRF were considered for inclusion in the study. All subjects were recipients of a domiciliary programme for persons who were partly self-sufficient. The main diagnoses were chronic obstructive pulmonary disease, neuromuscular diseases including amyotrophic lateral sclerosis (ALS) and diffuse interstitial lung diseases. Patients with impaired cognitive status and who lacked a care-giver, patients with severe psychiatric illness or cancer, or patients who refused to be enrolled in the protocol were excluded from the study.

After providing informed consent, the patients were provided with a portable pulse oximetry machine (model 2500, Nonin Medical, MN, USA), which was able to transmit a pulse arterial saturation trace via a home telephone line (see Figure 1). The trace was sent to a central workstation, where a nurse was available for consultation. A nurse was available for urgent requests from 09:00 until 16:00 during weekdays. Out of hours, the calls were transferred to the respiratory physician on duty.

Two kinds of teleconsultation were conducted:

1. *Scheduled appointments* (telemonitoring) were conducted every week for patients with CRF and invasive mechanical ventilation and/or with unstable conditions, or every 15–20 days for patients with CRF with oxygen therapy or non-invasive mechanical ventilation. During these appointments, the patients transmitted the pSat trace by telephone if necessary. A standardized interview was then carried out by the nurse. Questions were asked about bodyweight, clinical stability, night-time problems, hospitalizations and access to emergency examinations performed by the general practitioner (GP). For patients re-hospitalized during follow-up, the information on the cause of re-admission was obtained from the GP. Respiratory deaths were ascertained through families, GP or hospital records.

   Patients were also asked about the names, dosages and the timetable of the medicines prescribed. The nurse recorded any episodes of desaturation (defined as pSat $<90\%$). A severe nocturnal desaturation was defined as pSat $<90\%$ for more than 15% of the total trace recording time, or the presence of more than three severe desaturations of pSat $<80\%$.
2. *Ad hoc appointments* (teleassistance) were those in which the patient called the nurse, because of symptoms or any doubt about therapy. The operative flow chart was the same for telemonitoring with particular attention to the symptoms and signs referred by the patients.

Contact with the patients was by telephone or email, with pSat measurement sent by modem. In selected cases, the patient transmitted an ECG trace using an ECG monitor (Card-Guard 2206, Card-Guard, Israel). At the end of the telephone consultation, the nurse took one of the following actions:

- made a new scheduled appointment if the patient's condition was stable
- implemented therapy (e.g. diuretics, oxygen, inhaled bronchodilators and steroids) pre-planned with the respiratory physician or with the GP. Every new drug prescription was decided by a respiratory physician or GP
- asked for further investigations or scheduled a respiratory consultation
- contacted the GP or the respiratory physician if there were pSat trace desaturations or signs of clinical instability.

Once a week the respiratory physician and the nurse met to review the patients' data. Only the respiratory physician and/or the patient's GP could decide whether to send the patients to the emergency department or to a respiratory department. The personnel involved were a group of three nurses (one dedicated for half of her

Figure 1 Patient at home with the portable pulse oximeter (left) and care-giver sending a recording by modem (right)

duty time) employed in the respiratory department of the Foundation S Maugeri IRCCS Gussago Lumezzane.

At baseline, the patient's anthropometric data were collected, including number of hours prescribed for mechanical ventilation, oxygen therapy, number of hospitalizations/month in the year preceding enrolment, number of GP calls/month, number of admissions to the ICU, a pre-morbidity lifestyle score (PMLS) (ranging from 0 = employed with maximum level of autonomy to 4 = bed-ridden), level of nursing dependency,[4] respiratory function (forced expiratory volume in the first second and vital capacity), respiratory muscular pressures (inspiratory and expiratory maximum pressure), arterial blood gases on air and on oxygen, nocturnal percentage of saturation recording, dyspnoea evaluation (BORG scale: 0 = no dyspnoea to 10 = maximum dyspnoea), number of comorbilities and pharmacological therapy.

During follow up, the following data were recorded: number of exacerbations of respiratory failure necessitating the use of antibiotics or steroids, number of hospitalizations/month, number of ICU admissions, number of emergency admissions, causes for exacerbations of CRF, number of GP calls requested by the patient, scheduled nurse calls, nurse calls requested from patient, number of calls to the respiratory consultant, requests for new diagnostic examinations, problem-solving calls, problems with the ventilator, changes in ventilator setting, changes in therapy (oxygen prescription and drugs), number of home nurse visits, number of saturimetric recordings and survival.

The local ethics committee approved the study and all patients gave their informed consent to participate.

Table 1 Characteristics of the patients at enrollment

	Mean	SD
No of patients	45	
Age (years)	59	19
Males	30	
Primary diagnosis, number of patients		
COPD	17	
RD	6	
NM	13	
ALS	5	
Others	4	
Groups: number of patients		
NMV	22	
IMV	13	
LTOT	10	
Number of hospitalizations in the previous year (/patient/month)	0.15	0.08
History of ICU admission (% of patients)	51	
FEV1 (% prd)	33	16
VC (% prd)	38	19
pH	7.38	0.04
$PaCO_2$ (mmHg)	47	10
PaO_2 (mmHg)	61	13
MIP (cmH_2O)	36	15
MEP (cmH_2O)	38	19
PMSL	2.5	0.8
DNS	13	7
Dyspnoea (BORG scale)	2.8	1.4
Percentage of patients with nocturnal desaturation (<90%) on room air	100	
Mean nocturnal pSat on room air (%)	85	4
Mean time spent under 80% pSat	20	12
Mean pSat nadir (%)	62	8
Discharge medications		
Beta 2 stimulants (% of patients)	49	
Inhaled steroids (% of patients)	38	
Oxygen (% of patients)	78	
Mechanical ventilation (% of patients)	77	
Oxygen at discharge (L/min)	1.3	1
Diuretics (% of patients)	60	
Inspiratory pressure on mechanical ventilation (cmH_2O)	15	3
Expiratory pressure on mechanical ventilation (cmH_2O)	4	2

COPD=chronic obstructive pulmonary disease; RD=restrictive disease; NM=neuromuscular disease; ALS=amyotrophic lateral sclerosis; NMV=non-invasive mechanical ventilation; IMV=invasive mechanical ventilation; LTOT=long-term oxygen therapy; ICU, intensive care unit; FEV_1=forced expiratory volume in 1 s; VC=vital capacity; $PaCO_2$=partial pressure of carbon dioxide; PaO_2=arterial pressure of oxygen; MIP=maximal inspiratory pressure; MEP=maximal expiratory pressure; PMSL=premorbility style of life; DNS=Dependency Nursing Scale [4]; BORG=dyspnoea subjective scale

Results

A total of 59 patients with confirmed CRF were consecutively discharged during the nine-month study period. Among them 14 patients were not eligible due to at least one exclusion criterion: five patients with reduced cognitive status, two with reduced family cultural ability, one with dementia, one with cancer and five because they refused to participate. The baseline characteristics of the 45 patients studied are shown in Table 1.

The follow-up period was 176 days (SD 69). The mean time recorded for the 459 calls was 16 min/patient/week; the duration of each telephone call ranged from 20 s to 15 min. In total, 376 calls for scheduled consultations were received. Eighty-three *ad hoc* consultations (teleassistance) were requested by the patients. In total, 86% of the patients' problems during telemonitoring and teleassistance were solved by nurses, and in 14% of the cases by the nurse and respiratory physician together.

During the study the following respiratory events were recorded: 30 episodes of clinical instability, 65 episodes of desaturation, four episodes of non-respiratory dyspnoea and 45 symptoms of various types (e.g. increase of sputum production, haemoptysis, palpitation, atypical chest pain). The actions taken were: 55 therapy modifications, 19 hospitalizations in a respiratory department for decompensated CRF, three hospitalizations in the ICU, 22 requests for further

investigations, 25 contacts with GPs, 66 demands for respiratory consultations, and 10 to the emergency department (six for severe relapse with decompensated hypercapnia and acidemia and four for severe broncostenosis).

Figure 2 shows data from two representative patients during follow up. Among 459 nurse contacts, the pSat instrument was used in 153 cases (33%): in most of the contacts (141 cases), the pSat device was used to send a trend of arterial saturation recording while in 12 contacts the care-giver communicated the instantaneous pSat value.

Following teleconsultation, the dosage of oxygen was: equal in 25 patients, increased in 15 and reduced in five. Thirteen patients experienced mechanical ventilator troubles (31%). The setting on the mechanical ventilator was changed in six patients. In the majority of cases, a better rationalization of care resources (for example, fewer nurse or respiratory physician home visits) was obtained. Therapy modifications were made in 55 calls with a mean of 2.0 (SD 1.5) calls per patient.

During a follow-up period of 176 days (SD 69), 19 patients (42%) had at least one re-admission due to acute or chronic respiratory failure with hospitalization. In the observational period, 36% of studied patients suffered a relapse. There was a mean of 0.9 GP calls/month (SD 1.2) and a total of 52% of the patients called their GP. Twenty-eight episodes of clinical instability requiring antibiotics were recorded

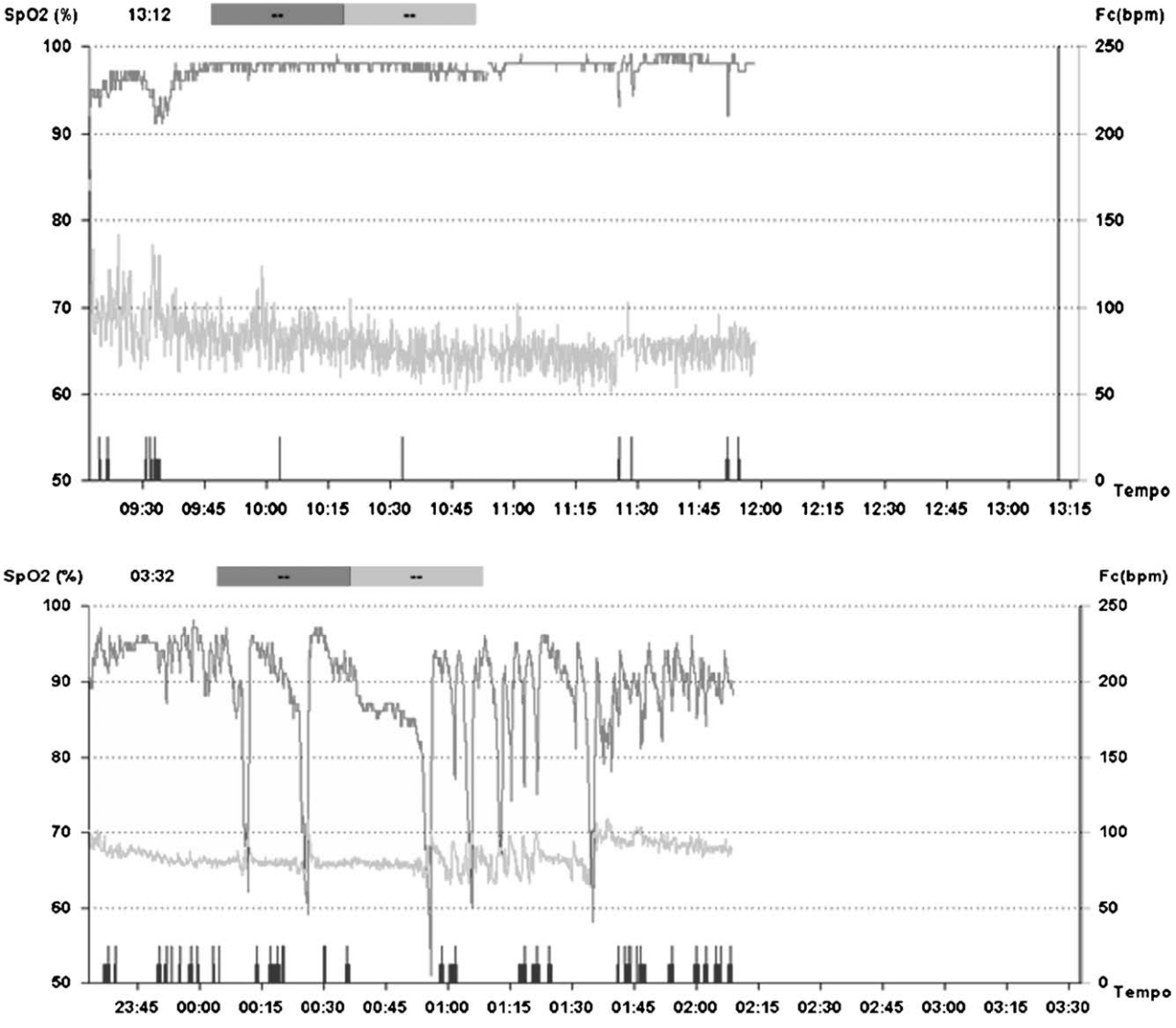

Figure 2 Two representative patients during follow up. Upper panel: pSat (higher line) and heart rate in a patient affected by CRF and COPD under invasive 24-h mechanical ventilation. Lower panel: pSat (higher line) and heart rate in a patient affected by ALS under non-invasive mechanical ventilation (NMV)

in 17 patients (37%), while 12 episodes of clinical instability requiring steroids were recorded in six patients (13%). One patient had a new mechanical ventilator prescription (a negative shell ventilator); three patients were assisted by the telepneumology team in their end life treatment. Mortality was 11% (5 patients), four out five with a diagnosis of ALS.

Limitations

Thirty-five out of 141 (24%) pSat trend transmissions failed for different reasons: initial inexperience of the nurses, poor comprehension of the device instructions by the care-givers, limited time of pSat availability at home with subsequent reduced training for care-givers and sometimes the instrument complexity. Due to the high cost of pSat instruments, the patients were not in possession of the devices for the whole duration of the study. The percentage of pSat transmission failures decreased during the study. The nurse time required for instructing the family in the use of the pSat instrument (10 min) and the operation of modem transmission (20 min) was extremely high. Time to solve the web limitations of system (10 min per each pSat transmission) was often necessary.

Discussion

The present study demonstrated the feasibility of home monitoring for patients with severe CRF necessitating mechanical ventilation. It also showed the usefulness of pSat recordings for titration of oxygen, mechanical ventilator settings and stabilization of relapses. In practice, the method of transmission by modem was often time consuming and complicated. However, the results showed that nurses can manage patients in close collaboration with their GP and the specialists, as a part of an interdisciplinary disease management process. Similar findings have been reported by others.[5,6]

Surprisingly, few papers have been published on the use of telemedicine in respiratory medicine. There has been no clear-cut demonstration of the advantages (if any) of telemedicine as an aid to the management of patients. Previous studies have focused on patients with asthma[7–11] or chronic obstructive pulmonary disease (COPD).[12,13] These studies have addressed the potential of telemedicine to improve the sickness impact profile scores, adherence to treatment regimen, mortality rates and reductions in health-care utilization, home visits by nurses and emergency costs.[12–18] Telemedicine has also been used in obstructive sleep apnoea to deliver home-based education, to offer an alternative to a sleep laboratory and to monitor ventilation.[19,20] Maiolo *et al.* [21] followed 23 patients with CRF with a fixed twice a week transmission of pSat. They demonstrated a reduction in hospital admission and home relapses of 50 and 55%, respectively.

In the present study, we showed the possibility of modulating the follow-up of CRF patients using a nurse-centred home-monitoring programme. The use of the pSat device was important in informing the nurse's decisions about the control of arterial saturation and clinical condition. Telephone interventions are not a new concept, although clinical interventions in most previously reported programmes[5,6] have been based on subjective information solicited from the patient and/or their family. In the present study, 55 therapy modifications were made during the teleconsultation. Physician-supervised, nurse-mediated implementation of pharmacological guidelines was safe and effective.[6,22] Of the telemonitoring equipment described in the literature, we believe that pSat recorders represent a simple device, which is relatively easy to use and inexpensive for patients.

The present study had some limitations. These include the lack of controlled and randomized cases, and the relatively short period of follow up. Nonetheless, the results have demonstrated the feasibility of home monitoring in severely ill patients with CRF necessitating mechanical ventilation, the usefulness of pSat recording system for titration of oxygen, mechanical ventilation setting and stabilization of relapses.

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