DEVELOPMENT OF A TELEMEDICINE SYSTEM FOR THE PATIENT WITH RESPIRATORY DISEASES

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Abstract: We developed a telemedicine system for the patient with respiratory diseases. This system is made up of three biosignal instrumentations of a spirometer, a pulse oxymeter and an electronic stethoscope. The patient uses this system in daily life and the measured data is firstly recorded on a local PC at patient's home and then transferred to a medical service center by the Ethernet protocol. The functional objective of this system is to provide information about the patient's clinical state to experts at a distance. Thereby, the system provides the patient with appropriate directions by medical experts, and eventually enables the patient and the supervisor to manage the changes in patient's health condition. It is self-evident that an integrated telemedicine system can be beneficial to the elderly and patients of respiratory disease by providing a periodic health condition monitoring and a medical response in abnormal situations, based on information exchange between the patient and doctor. It will benefit not only individual users, but eventually the whole community in terms of reduced total healthcare cost.

Introduction

In patients with chronic obstructive pulmonary diseases and sleep apnea, it is important to evaluate the extent of obstruction of the respiratory system, and regular examination is very useful in this regard [1]. In addition, a long-term ambulatory recording of the patient's respiration-related biosignals will provide more extensive and specific information about the occurrence of abnormalities.

In this paper, we report progress in the development of a telemedicine system for the patient with respiratory diseases. Figure 1 shows a usage scenario of the proposed system. In daily life, the patient or caregiver uses the developed system to monitor patient's health state periodically so that the changes in health condition can be managed by a supervisor or a doctor.

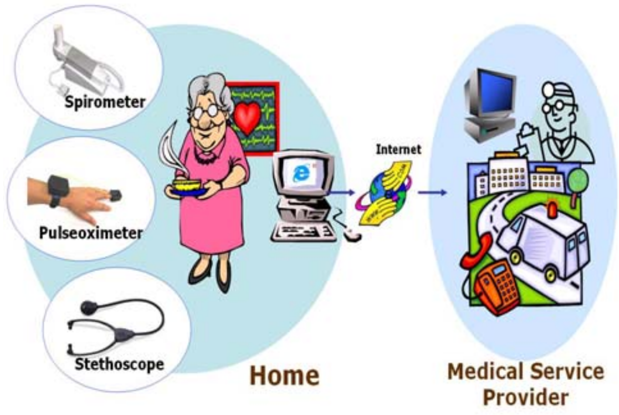

Figure 1: Usage Scenario of the respiratory telemedicine system.

Materials and Methods

As shown in Figure 2, the developed system consists of three measurement modules which include a spirometer, a pulse oxymeter and an electronic stethoscope.

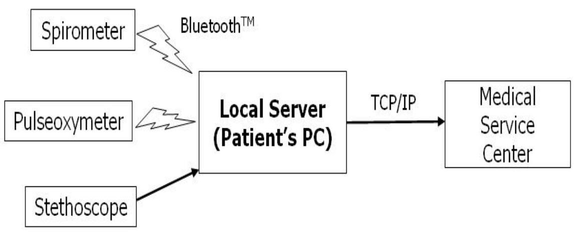

Figure 2: Functional block diagram of the developed system.

Each module communicates with local server, a PC at patient's home, through the Bluetooth™ RF linkage and direct connection using a sound card line-in port. The measured data is then transferred to the medical service center (Boondang Seoul National University Hospital, Seoul, Korea) by the Ethernet protocol. The transferred data is analyzed by doctors. The detailed specifications of each measurement module are as follows.

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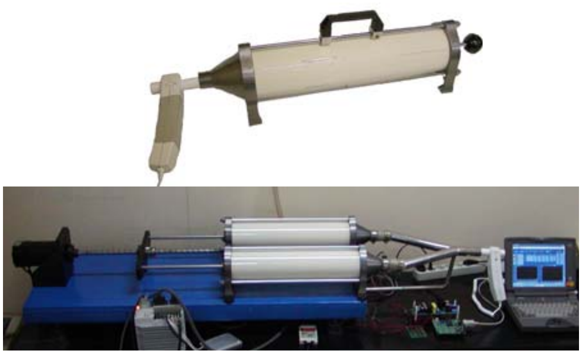
Spirometry has been widely used to evaluate human ventilatory function by sensing and analyzing the respiratory air flow rate, and is a clinically important diagnostic test for a wide range of pulmonary diseases.

For example, chronic obstructive pulmonary disease (COPD) can be detected only by spirometry at more than ten years before definite symptoms occur. Periodic testing could provide valuable information regarding disease progression, the nature of the physiologic abnormality, and the effectiveness of a therapeutic protocol [2].

In this paper, we developed a spirometer system that consists of (1) a disposable flow tube (paper mouthpiece) and (2) a hand-held main processing unit [3]. The flow tube provides the air flow passage within which the flow rate sensor (the sensing rod) is installed. Tiny holes on both edges of the sensing rod sample the air velocity and convert the air's kinetic energy into a differential pressure based on Bernoulli's principle. The expected maximum differential pressure is approximately 12cmH_2O for 12LPS of air flow.

(a)



(b)

Figure 3: Pictures of (a) the developed spirometer and (b) the 3L syringe with a motor driven flow generator.

Figure 3 shows the developed spirometer system and a performance test set-up. Performance evaluation was accomplished using the 3L calibration syringe with a motor driven flow generator. The flow generator is made up of a brushless DC motor and a 6L syringe. The total 24 standard waveforms recommended by American Thoracic Society were used for performance evaluation [4][5].

Photoplethysmography(PPG) is a common non-invasive method mainly used to measure blood oxygenation level, heart beat and changes in blood flow [6]. The PPG signal also contains information about the circulatory dynamics [7] and respiratory rate and volume [8]. Pulse oxymetry using PPG is a non-invasive method of monitoring the arterial oxygen saturation level based on the Beer's law for the absorption of light by hemoglobin and oxyhemoglobin. The pulse oxymeter makes use of the pulsatile components of arterial blood's absorbance values at two different wavelengths. We used Red(660nm) and infra-Red(940nm) LED(light emitting diode) as a incident light source. The reflected light is recorded by a photo-detector and variations in light intensity are caused by changes in flow and pressure pulsations in blood. And then SpO2 value is calculated from the level of variations in light intensity in each channel (Red, IR).

For this system, Pulse oxymetry module was developed using a commercial finger clip sensor (8000H, NONIN, USA) and an ear clip sensor (8000Q, NONIN, USA) connected to a main unit which includes the required electronic circuitry and program. This module is used for continuous monitoring of the patient's SpO_2 level changes. Figure 4 shows the developed two pulse oxymeters with the wrist–worn type for a finger clip sensor and the waist-worn type for an ear clip sensor.

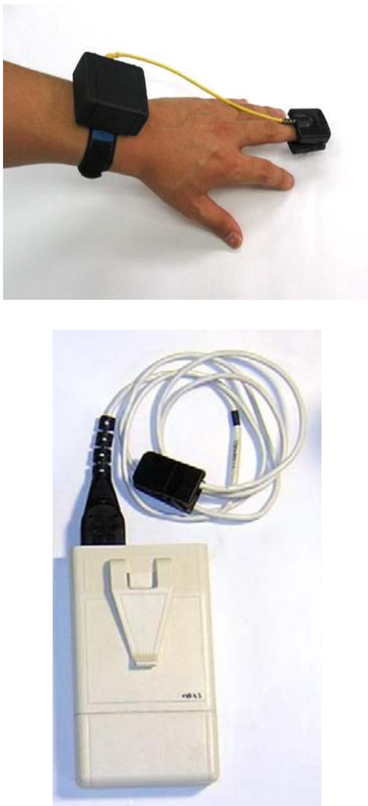


Figure 4: Developed two pulse oxymeters of the wrist-worn type and the waist-worn type.

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Performance of the developed SpO_2 module was verified using a commercial SpO_2 simulator (Oxitest plus7, DNI Nevada Inc, USA).

Respiratory sound auscultation is a basic procedure of clinical diagnostics. The traditional stethoscope and human ear system has, however, drawbacks of poor frequency response, lack of objectivity in diagnosis, and inability of the human ear to distinguish events occurring close to each other in the time or frequency domain. To overcome these limitations, the sounds need to be recorded with sensitive microphones, stored in digital form, visualized, and analyzed quantitatively.

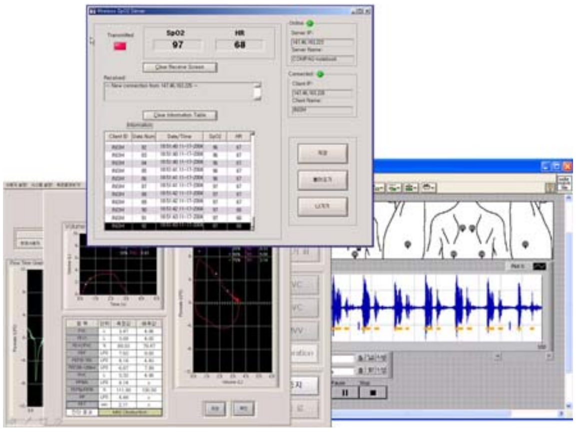
In our system, we used a commercialized electronic stethoscope (i-stethos, Andromed, Canada) and developed programs for the lung sound analysis algorithm and the required services. Lung sound analysis is composed of amplitude and breath period on time domain and FFT or PSD analysis on freqeucny domain.

Tele-reporting is an essential part of telemedicine or telehealthcare systems. , Out of any different kinds of telecommunication method available now, e.g. LAN, radio frequency (RF) transceiver, and a cellular phone, we chose the Bluetooth^{TM} and the Ethernet protocol for short and long range communications, respectively [9]. Each module except the electronic stethoscope transfers the measured data to a local server using the Bluetooth^{TM} RF modules. The local server records the transferred data with time information and the recorded data is consecutively transmitted to a medical service center by the TCP/IP Ethernet protocol. In the medical service center, a central server gathers all the patients' data and reports the results to a doctor or a supervisor on request.

Results

Figure 5 shows a photograph of the total developed system and a screen display of the analysis program.

(a)



(b)

Figure 5: Photograph of (a) the developed system and (b) screen display of the analysis program.

Results of performance evaluation tests are summarized in TABLE I. The developed spirometer showed an accuracy within an error range of ±3%. Over various range of SpO_2 levels, the pulse oxymeter performance test showed an accuracy within an error range of ±2%. In this table, we skip the stethoscope evaluation because the device is a commercial product.

Table 1: Summary of the performance evaluation tests.

	Spirometer	**Pulse Oxymeter**	**Stethoscope**
Evaluation Method	Calibrator and Flow generator	simulator	Commercial product
	3L syringe and Motor controlled 6L syringe	Oxitest plus7, DNI Nevada Inc, USA	N/A
Number of tests	24 test waveforms by ATS standard	100	N/A
Performan-ce parameter	Error range	Error range	N/A
	Within ±3%	Within ±2 %	N/A

Conclusions

We have developed a telemedicine system for the patient with respiratory diseases. The developed system was designed to provide the doctor with the information about the patient and the patient with appropriate medical services by the doctor at a distance. This system is now on the clinical applications at the pulmonology unit of the Bundang Seoul National University Hospital.

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