MEDINFO 98
B. Cesnik et al. (Eds)
Amsterdam: IOS Press

Telematic System for Monitoring of Asthma Severity in Patients' Homes

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Abstract

Despite advances in the treatment of asthma the morbidity and mortality of this disease has increased significantly in the past several years. Recent studies have shown that monitoring of asthma severity in the patient home especially combined with patient education can reduce incidence of asthma exacerbation and subsequent hospitalization. The existing methods for home asthma monitoring are limited by four factors; they completely rely on a patient's ability to document and to evaluate test results; there is no easy way for a physician to review data in a timely manner; they use imprecise tools for evaluation of asthma severity and they don't provide clinical decision support tools.

The goal of this study is to develop and to evaluate a telematic system for asthma severity monitoring which will minimize patients' efforts in performing self-testing at their homes and allow prompt reciprocal exchange of all relevant information between patients and health care providers.

In our setting, patients use portable spirometer and pocket-sized palmtop computer for data exchange. Our system allows daily serial monitoring of asthma severity at patients' homes using Forced Vital Capacity test and symptom diary. The results of the tests become available for physicians review immediately after completion of self-testing procedures via Web browser. The results can be transmitted from patients' homes (or any other remote location) to the medical records database via landline or wireless networks in several minutes. Each time the remote server receives patient's results, it invokes the application which tests the validity of data, analyzes parameters trends and dispatches corresponding messages for the patient and, if necessary, for physicians. Such an approach provides constant feedback loop between asthma patient and physician.

The system has been tested in 10 healthy volunteers and asthma patients. Patients participated in the study from two to 21 days. The test results showed that the system provides reliable reciprocal exchange of all relevant information between a physician and asthma patient in home settings.

Average transmission time from the patient's palmtop to the remote central data repository was about 1 minute for 14.4 Kbps landline modem, 6 minutes for cellular network and 8 minutes for RAM Mobile network. After transmission, the test results were immediately available for review at our web site.

Keywords

Telemetry; Asthma; Spirometry

Introduction

The scientific basis for the medical treatment of asthma has improved greatly in recent years. However, asthma continues to present significant management problems for patients trying to handle the disease on a day-to-day basis and for the physicians guiding and advising them. There are an estimated 15 million Americans who suffer from asthma. Despite advances in the understanding and treatment of asthma, the morbidity and mortality has increased significantly in the past several years. Of 6.2 billion dollars spent on asthma in the US in 1990, about 2 billion dollars was spent on inpatient hospital services and emergency room use and approximately 2.6 billion dollars was attributed to indirect costs of loss of work, child care and premature death [1]. Recent studies have shown that monitoring of asthma severity in the patient home especially combined with patient education can reduce those expenditures by preventing asthma exacerbation and subsequent hospitalization [2]. People with asthma frequently underestimate the severity of their bronchoconstriction [3]. Several studies described significant discrepancy between the level of airway obstruction and its perception by asthma patients [3,4]. Home monitoring of asthma severity may show a decrease in lung function before respiratory symptoms become evident [5]. This is very important, because by identifying a decline in lung function pre-dating clinical symptoms, a patient or physician may intervene early to prevent an exacerbation which otherwise may result in hospitalization or even death. The Expert Panel of National Asthma Education and Prevention Program considers ongoing monitoring of pulmonary function as an essential part of asthma management.

Existing systems for home asthma monitoring are limited by several factors. Even the most advanced systems allow patients to download peak flow measurements to a central station via telephone only on monthly or weekly basis. Physician's receive reports with peak flow trends every month via fax. There is no way for a physician to review data in a timely manner. The systems do not notify the physician or patient of any changes in peak flow trends that occur between scheduled reports. If an ominous trend or asthma exacerbation occurs between downloads, there is no recognition or intervention until after a monthly report is produced. The systems completely rely on a patient's ability to perform and document the test and do not provide automatic tools for assessment patient's compliance. Because of their simplicity, existing methods use only peak expiratory flow (PEF) measurements. PEF is recognized to be less precise than Forced Vital Capacity test (FVC), which requires computerized analysis. PEF depends on patient effort and the strength of expiratory muscles, which result in significant intra-patient variability. It has been shown that PEF reflects primarily large airway caliber whereas FVC allows assessment of small airways resistance [6]. Several studies have documented persistent airway obstruction in asymptotic children and adults with asthma with normal PEF's [7, 8]. The same studies concluded that FVC provides the most reliable assessment of airway dysfunction in asthmatics. Another limitation of existing systems is that they do not provide computerized decision support tools, leaving physician alone with large amounts of data which are very hard to analyze in timely and effective manner.

Objective

The main goal of this study is to develop and to evaluate a telematic system, which will overcome the limitations in asthma monitoring, described above. This system will provide

- constant reciprocal exchange of all relevant information between patient and physician in a timely manner
- daily serial monitoring of asthma severity at a patient's home or work based on FVC tests and a symptom diary
- immediate availability of test results to physicians via a Web browser
- computerized decision support tools for notifying physicians and patients about changes in data trends

assessment of the applicability of computerized home monitoring in asthma management on day-to-day basis and in clinical research.

Methods

To meet the objectives described above we developed a general model of information flow. According to this model, an asthma patient uses a portable spirometer and computing device to perform self-testing at home on a regular basis. The spirometer is used to perform the FVC test and to transmit the results to the computing device. Computing device:

- collects information from the patient for the symptom diary and FVC test results from the spirometer
- performs initial error detection
- connects to the network and transmits results to the remote clinical application server
- provides reciprocal exchange of information between the patient and the health care providers in the form of messages, alerts and reminders
- downloads software upgrades from the network.
- The results of patient's self-testing are transmitted immediately after the testing is completed. Each time the remote application server receives test results it:
- checks the validity of data and sends back either a confirmation message or a request to repeat the test
- evokes algorithms to analyze data trends and to generate and forward corresponding messages to the patient or physician
- stores test results in the central clinical repository.

After the test results are stored in the repository they become available for review by physicians from any Web browser.

Figure 1 illustrates how the described model was implemented at Columbia-Presbyterian Medical Center (CPMC). In our setting, patients are given a portable handheld spirometer (Vitalograph) to perform FVC tests and a pocket-sized palmtop computer for data exchange. HP200LX (Hewlett Packard) and MiniNote PS-3000 (Prolinear) are used as a palmtop computing devices. Both palmtops run MS-DOS compatible software and have PCMCIA slots which are used for network interface. They can work with batteries or with AC adapter. The MiniNote PS-3000 has a bigger screen, better keyboard and built-in modem. The spirometer is connected to palmtop via serial port. Palmtops were chosen because of their small size, relatively low price, mobility and convenience.

Patients usually are asked to perform tests twice a day in the morning and evening before and after bronchodilator. The asthma measurement comprises a FVC test and a symptom diary. The computer allows patients to promptly evaluate the severity of their asthma symptoms using visual scales, and then patients perform the FVC test. After completion of self-testing, the data is immediately transmitted to the CPMC application server (see UNIX host in Figure 1). Several minutes after the completion of the test the patient receives an acknowledge message from CPMC server. If a connection cannot be established the data is stored locally and is transmitted during the next communication session.

The system currently allows data transfer between the patient's computing device and the CPMC application server using three different communication technologies: standard telephone landlines, Cellular Digital Packet Data network (CDPD) and wireless RAM Mobile network. Thecommunication over telephone lines can be implemented using any landline modem. We use a PCMCIA modem which also has flash memory on board with an installation copy of our palmtop software. This simplifies recovery procedures in the case of computer power failure. CDPD and RAM Mobile networks provide wireless data connectivity.

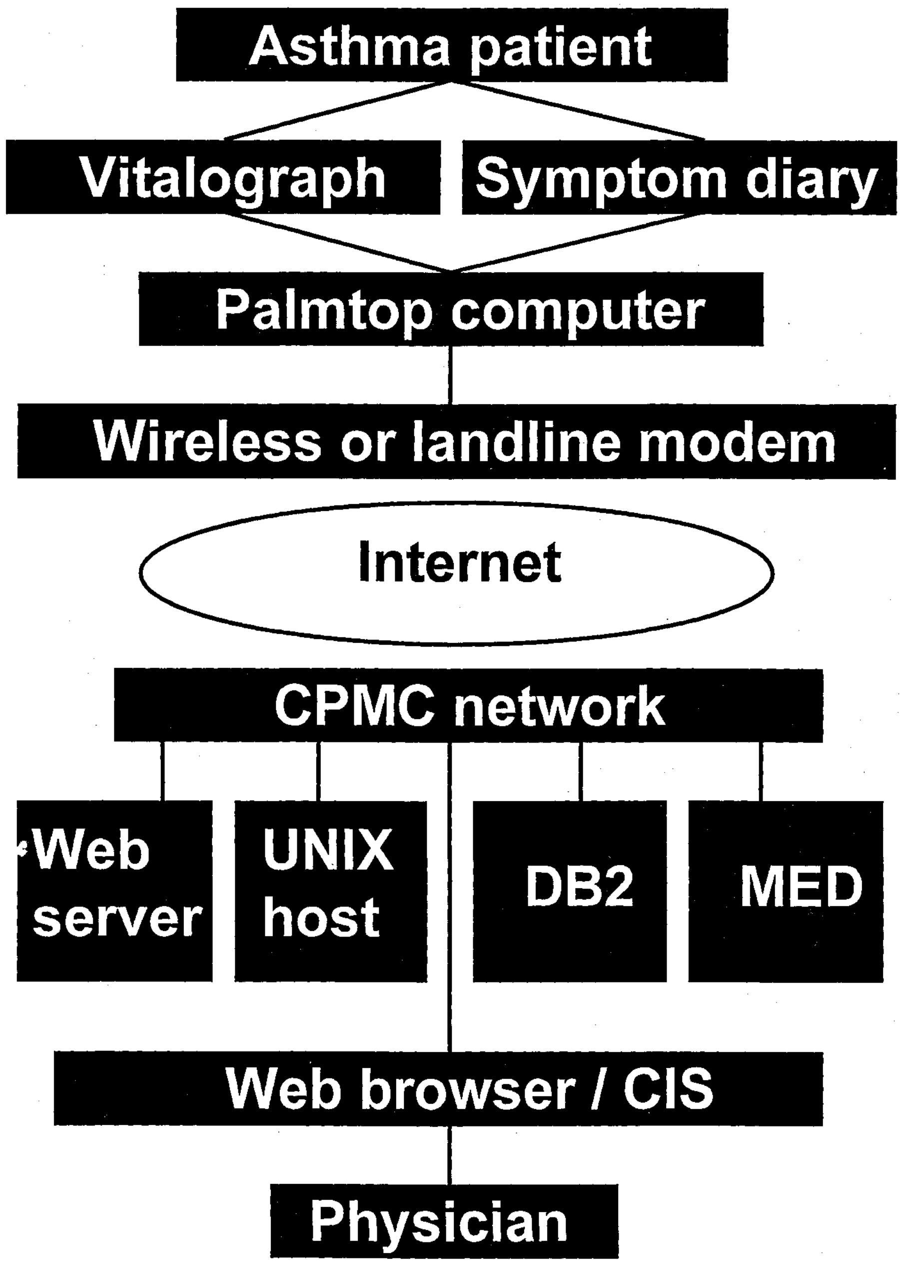

Figure 1 - System diagram (see text)

For the CDPD network a PM100C modem from Motorola is used, and for the RAM Mobile network an AllPoints wireless modem from Megahertz is used. The data transfer over the landline modem is based on direct dial-up connection with the CPMC network; data transfer based on the CDPD modem uses the Telnet protocol, and data transfer over the RAM Mobile network is based on e-mail exchange with the CPMC application server. Our palmtop software recognizes the modem type automatically and allows seamless transfer from landline to wireless technology. We use different communication technologies because together they allow the most flexible and mobile way for asthma monitoring in different settings.

Regardless of what communication technology is used, each time the CPMC server receives patient's results, it invokes the application which tests the validity of data, analyzes parameters trends and dispatches corresponding messages for the patient and, if necessary, for physicians. This application also encodes the test results according to the Medical Entities Dictionary (MED) [9] into a HL7 message and forwards it to a central patient data repository (based on IBM's DB2) to store data in the patient's medical record. Immediately after test results are stored, they become available for physicians' review from a Web browser. A *cgi* program on the CPMC Web server allows physicians to review test results, to analyze trends and to compare previous and new results graphically using a superimposition of FVC curves. Absolute values and parameters trends may be analyzed by the system according to the guidelines established by the National Heart, Lung, and Blood Institute.

The system has been tested in 10 healthy volunteers and asthma patients. They were trained to use the system (20-30 minutes), and they were given the equipment for two to 21 days. They were instructed to enter symptom scores and to perform the FVC test twice daily. Reliability of uploading data was assessed, communication time was measured, and subjects were surveyed about ease of use.

Results

All patients successfully uploaded FVC curves and symptoms scores from their homes to the CPMC repository. The results of FVC testing were available for review at CPMC Web site (Figure 2). The system provided reliable reciprocal exchange of all relevant information between a doctor and asthma patient in home settings.

Average transmission time from the patient's palmtop to the CPMC server was about 1 minute for 14.4 Kbps landline modem, 6 minutes for CDPD network and 8 minutes for RAM Mobile network. After transmission, the test results were immediately available for review at CPMC web site.

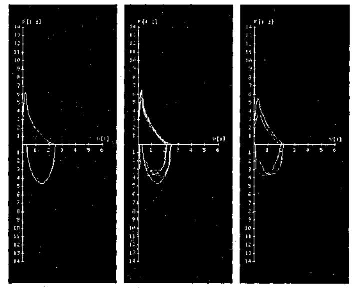

Figure 2 - FVC curves at CPMC Web site. Minutes after a patient uses the system in the home, a physician may review and analyze the FVC curves and additional 29 lung function indices.

Communication over wireless networks was slower because their actual transmission rate did not exceed 9600 bps. The data transmission over wireless networks depends on availability of free radio channels, and, for the RAM Mobile, on the use of e-mail gateway. The time required for connection to the remote server was also longer for the wireless modems. The advantage of the RAM Mobile network is that it is available nationwide. The transmission time for RAM Mobile was the same in New York, Rochester and San Jose. CDPD is currently available only in highly populated areas. The transmission time for CDPD in San Jose (California), Newark (New Jersey) was the same as in New York. The strength of signal for the RAM Mobile network weakens significantly inside buildings, so the palmtop must be placed near a window during transmission. CDPD connectivity was significantly less affected by this factor.

Most of the patients reported that the system was easy to use. One patient needed help in connecting the modem to a telephone jack. In the case of the wireless modem, the main complaint was the necessity to change batteries frequently.

Patients unanimously preferred palmtop with the larger screen size (MiniNote PS-3000 - 175x70mm vs. HP200LX - 120x45mm) even despite the fact that it was bulkier and heavier.

Discussion

The model of information flow implemented in our system supports a constant feedback loop between the asthma patient and health care providers. We hope that by minimizing the burden in asthma monitoring both for patients and physicians, the system can facilitate compliance with asthma management guidelines recommended by National Heart, Lung and Blood Institute. The system provides a backbone for real-time decision support in management asthma on day-to-day basis. Web-based access to the results of asthma severity monitoring combined with automatic alert mechanism may help physician to respond to significant changes in their patients' status in a timely manner, optimize asthma therapy and prevent possible asthma exacerbations.

The current recommendations for monitoring of asthma severity are based only on PEF trends. The trends of other FVC test parameters preceding asthma attack have not been systematically studied yet. Therefore, further studies are required in order to build the most effective decision support tools for prevention of asthma exacerbation which would take advantage of new possibilities in real-time monitoring of pulmonary functions at patients' homes.

Conclusion

A telematic system for asthma severity monitoring in patients' homes has been built. The system provides reliable reciprocal exchange of all relevant information between asthma patients and health care providers.

The influence of the system on asthma management requires further investigation.

Acknowledgments

Funded by New York State Science and Technology Foundation grant "Wireless access to clinical information and physician-driven reminders", US Department of Commerce TIIIAP grant 36-40-94065, and NLM grant #R29-LM05627.

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