Home Automated Telemanagement (HAT) System to Facilitate Self-Care of Patients with Chronic Diseases

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Abstract

Successful patient self-management requires a multidisciplinary approach that includes regular patient assessment, disease-specific education, control of medication adherence, implementation of health behavior change models and social support. Existing systems for computer-assisted disease management do not provide this multidisciplinary patient support and do not address treatment compliance issues. We developed the Home Automated Telemanagement (HAT) system for patients with different chronic health conditions to facilitate their self-care. The HAT system consists of a home unit, HAT server, and clinician units. Patients at home use a palmtop or a laptop connected with a disease monitor on a regular basis. Each HAT session consists of self-testing, feedback, and educational components. The self-reported symptom data and objective results obtained from disease-specific sensors are automatically sent from patient homes to the HAT server in the hospital. Any web-enabled device can serve as a clinician unit to review patient results. The HAT system monitors self-testing results and patient compliance. The HAT system has been implemented and tested in patients receiving anticoagulation therapy, patients with asthma, COPD and other health conditions. Evaluation results indicated high level of acceptance of the HAT system by the patients and that the system has a positive impact on main clinical outcomes and patient satisfaction with medical care.

Introduction

A number of studies of patient self-testing (PST) or patient self-management (PSM) with point-of-care (POC) devices have recently indicated the potential for improved outcomes [1,2]. Successful patient self-management, however, requires a multidisciplinary approach that includes not only regular patient assessment, but also disease-specific education, control of medication adherence, implementation of health behavior change models and social support both for patients and caregivers [3,4]. Existing systems for computer-assisted disease management do not provide this multidisciplinary patient support and do not address treatment compliance issues. The aim of this project was: (1) to develop the Home Automated Telemanagement (HAT) system to fully implement multidisciplinary model of chronic disease management, (2) to evaluate acceptance of the HAT system and impact of the system on clinical outcomes.

Methods

General Considerations for HAT Design

The HAT system is designed to conform with principles of patient-centered model of health care [10]. The design of HAT implements multidisciplinary approach to the chronic disease management by using current state-of-the-art knowledge about the educational, behavioral, cognitive and organizational components of self-care process. The main objective of the HAT system is to minimize the burden of chronic disease management both for patients and physicians and to simplify clinical guidelines implementation in present-day ambulatory care delivery. To achieve this goal the HAT system is required (1) to support a constant information feedback loop between the patient and health care providers; (2) to take over all routine repetitive tasks; and (3) to provide real-time clinical decision support both for the patient and clinician.

Technical Design of the HAT System

The technical design of the HAT system is presented in the Fig. 1. The HAT system includes patient units, HAT server and clinical units. Each *patient unit* includes four modules: data collection, presentation, computing and communication. The patient unit may be built as a single stand-alone device or may be constructed as a combination of interconnected devices. The data collection module collects objective information about disease severity from disease-specific sensors and obtains patient self-report about clinical symptoms and medication usage. The presentation module implements user-friendly multimedia patient interface for data presentation and exchange. It can be implemented in a wide variety of ways: from LCD screen on a stand-alone device to a color desktop display or TV set. The computing module is responsible for initial evaluation of the patient self-testing results and basic decision support functionality which is not dependant on remote connectivity. This functionality may be built-in in a stand-alone device or may be implemented as a software component running on a patient computer. An important feature of the computing module should be an ability to update itself (including decision support logic and functional

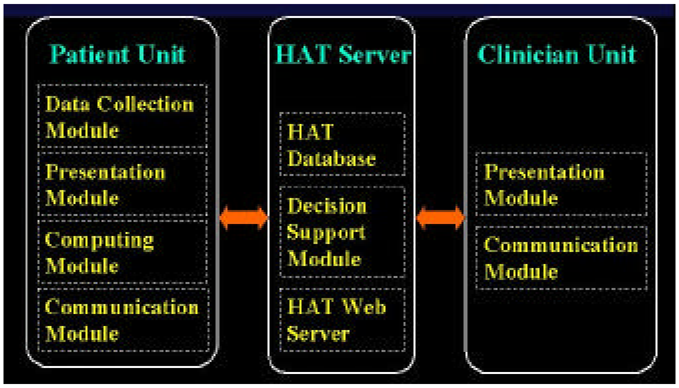

Figure 1. Technical design of the HAT

parameters) during communication with the HAT server. The communication module is responsible for communication with HAT server and may be implemented using different interfaces such as direct dial-up, DSL, ISDN, CDPD and many other data exchange protocols depending on local availability. The *HAT server* includes HAT database, decision support module and a web server. The HAT database stores all information pertinent to patient telemonitoring including data received from patient units, alerts generated by the system, nurse/physician notes, electronic patient-provider correspondence. Decision support module, which functionality is described below, is a core of the HAT system and implements constant analysis of all data traffic between HAT participants. The HAT web server implements a secure access to the data via Internet. It also provides patient- and physician-tailored features for disease management. The components of the HAT server may be distributed between several computers or may run on a single computer. The HAT server can function in a conjunction with hospital information system and Electronic Medical Record (EMR) or may function as a stand-alone product. The *clinician units* are used by medical personal to access data, to adjust certain parameters related to decision support or individual treatment plans, to review alerts, and to exchange messages between HAT participants. Each clinician unit includes a presentation module to display or enter information and communication module to connect to the Internet. The clinician units may be implemented using a variety of solutions: from cellular phone to an office computer.

Decision Support in the HAT System

The HAT system provides automatic decision support for monitoring and analyzing all information traffic between the patient and the system in real-time mode. The decision support is directed at ensuring patient compliance with the self-testing protocol, the validity of self-testing and for interpreting changes in patient data, and is performed by a combination of the patient unit and the remote HAT server. Allocation of the basic decision support functionality in the patient unit and more complex algorithms in the HAT server ensures availability of the basic decision support for the patients even in the absence of remote connectivity. The patient unit performs an initial validity check of the results obtained from sensors and the consistency of the self-reported data, and generates an immediate feedback to the patient based on these data. Further analysis is performed by the HAT server. Each time the HAT server receives new data, it retrieves previous results and analyzes all data to check whether predefined conditions are met (which are specific for each patient and are consistent with that patient's treatment plan). The system also periodically checks patient's compliance with self-testing. If predefined conditions are met, the system automatically sends an alert to medical personnel and/or the patient. The computerized alerts are generated if: (1) patients do not perform self-testing on schedule; (2) patients do not adhere to their medication regimen (according to their self-report); (3) patients do not follow their treatment plan (according to their self-report of what they did in response to current symptoms and sensor data). All alerts are checked by the patient's nurse on a daily basis. Patients who are non-compliant with any aspect of their self-care plan, are contacted by the nurse who evaluates the reasons for non-compliance and provides remedial assistance or patient support. If alerts occur in the evening or weekends the system will call the patient automatically. Patients' physicians receive periodic reports and are notified immediately in the case of an emergency.

Structure of a HAT Session for a Patient at Home

Each HAT-patient session is divided into monitoring, analysis and educational components (Table 1). The monitoring component interacts with the patient to collect self-reported data (symptom and medication use questionnaire) and from the disease-specific sensors. The analysis component interprets the received data according to the patient’s treatment plan and detects clinically significant events and patient non-compliance. The analysis component identifies which part of a patient's treatment plan that patient should follow and which alerts, if any, should be generated. The educational component includes two parts. The first part is based on the results of the analysis component and provides the patient with immediate interpretation of the self-testing. The patient is educated on how to follow the treatment plan according to the interpretation results and receives disease-specific information tailored to the current disease status. The second part of the educational component does not depend on the self-testing results and is aimed at providing basic disease-specific education. This part is organized in the form of multiple choice questions and “Tips of the day.” The design of HAT utilizes concepts of behavioral change (behavioral capability, self-efficacy, outcome expectation, reinforcement), which were successfully used previously in automated systems for management of chronic health conditions [4].

Behavioral Background for the HAT Design

The design of HAT uses Social Cognitive Theory (SCT) as its major theoretical behavioral foundation. SCT synthesizes concepts and processes from cognitive, behavioral and emotional models of behavioral change [5]. SCT constructs relevant to the HAT design include behavioral capability, self-efficacy, outcome expectation and reinforcement. In addition, the educational content of HAT is broken down into small digestible parts, which is consistent with concepts from Consumer Information Processing [6].

Behavioral capability includes knowledge of “what to do” and “how to do it” as well as the skills needed to perform it. Behavioral capability is considered a necessary prerequisite for performing a behavior, but is insufficient to guarantee performance. Self-efficacy expectations are a person’s beliefs about one’s capability to perform a specific behavior.

Self-efficacy beliefs have been found to be related to whether or not a person will attempt a task and also to how long a person will persevere. Outcome expectations are a person’s beliefs concerning the effects of engaging in certain actions. Realistic outcome expectations can enhance self-efficacy. Reinforcement is defined as response to a person’s behavior that increases or decreases the chances of recurrences. Table 2 highlights how the constructs of SCT apply to the HAT design.

The above mentioned behavioral constructs were successfully used in other computer-based health-related behavior interventions [4,7]. Although the constructs need to be applied in different ways to affect different types of health behavior (alcohol use, smoking, eating, etc), they are applicable to diverse health-related behaviors.

Table 1 - HAT-Patient interactions during a HAT session (in asthma)

1.	Greeting and personal salutation
2	Ask patient to assess current asthma symptoms (wheezing, cough, chest tightness, shortness of breath, etc.)
3.	Ask patient to assess any limitation of physical activity caused by asthma
4.	Ask patient to report exposure to the asthma triggers (pets, pollens, etc) and their intensity
5.	Ask dose and frequency of use of each maintenance asthma medication
6.	Ask frequency of use of beta-agonist (rescue) inhaler
7.	Ask patient to use flowmeter to measure PEF (data from flowmeter are automatically transferred to the palmtop and sent to the central server together with asthma diary data)
8.	Evaluate the data and provide feedback to the patient, including the PEF-based asthma update
9.	Based on current data, advise patient on action(s) to take that follow patient's individual asthma action plan
10.	Ask patient one multi-choice question from asthma knowledge database
11.	Educate in response to the answer (if the answer is correct, provide "Tip of the day" - a short asthma related topic)
12.	Closing: summarize important points; give brief positive reinforcement; remind about next session

HAT Reports

HAT system generates two types of reports: a Provider Report and a Patient Report. The Provider Report looks like a computerized laboratory test report with a "flow sheet" format. Information for a single item (for example, the number of days the asthma patient experienced wheezing during the previous week) appears on a single line, with the values displayed chronologically from left to right. Any entry important enough to bring to the provider's attention is flagged with an asterisk next to the item. The report includes monitoring information on symptoms, adherence to each prescribed medication expressed as a percentage of prescribed doses taken, and compliance with self-testing.

The adequacy of disease-specific patient's knowledge is presented to the provider regarding symptoms, disease triggers, exacerbation management when symptoms worsen, individual treatment plans, medications, and accessing medical care appropriately. At a minimum, the Provider Report is sent monthly. In addition, whenever the patient reports that he is having significantly worse symptoms, a special Provider Report, a so-called Alert Report, is immediately sent. If an Alert Report is sent during normal working hours, the HAT system will fax the report to the office of the patient's responsible physician. The HAT system will also call the office to notify the staff that an Alert Report is being faxed. In addition, the physician is able to review all results, collected by HAT, at the designated Web page at any time.

The patients also receive monthly reports that contain the same information, but presented in a narrative format. The report also links the patient's knowledge or behavior with their level of symptoms and functioning. For example, if the patient is not adherent to his/her prescribed medication and is having symptoms, the report will suggest that the patient's symptoms would improve if he/she adhered to the prescribed medication regimen. In addition, the data trends for the last several months of monitoring are stored locally in the Patient Unit memory and are available for the patient's review.

Table 2 - Application of Concepts from SCT to the HAT Design (in Asthma HAT)

Concept	**Application**
1. Behavioral Capability	Users/patients are given information about specific behavioral actions (asthma trigger avoidance, medication change in response to decreased PEF, etc), and stepwise training and suggestions for how to incorporate desirable behavioral patterns into their daily lives
2. Self-efficacy	The use of praise, feedback, and setting achievable goals are used to increase patients' perceptions of their self-efficacy
3. Outcome Expectations	HAT repeatedly informs the patients that following their asthma self-care plan will reduce respiratory symptoms and increase quality of life
4. Reinforcement	User/patient receives praise and encouragement for following asthma self-care plans. The asthma nurse contacts patients in case of non-compliance to educate and reinforce patient compliance

The Role of the HAT Nurse

The HAT nurse is an integral part of the HAT intervention. The nurse is responsible for checking the alerts generated by the HAT system on a daily basis. She responds to alerts according to established guidelines and contacts the patients to counsel and educate them. The non-compliance alerts are usually resolved by the responsible nurse without physician intervention. The patient's physician will be notified about these events in the monthly reports. However, the physician will be notified about alerts immediately if serious clinical deterioration occurs in patients who do not comply with their self-care plans (e.g., an asthma patient who has a PEF<50% of personal best PEF and who fails to start oral corticosteroid therapy as prescribed by the his/her action plan). The thresholds for each alert and the frequency of the nurse's responses to them are determined according to the current clinical guidelines [1].

Results

Current Implementation of the HAT System

The HAT System has been fully implemented in Boston Medical Center and currently provides an on-going support for patients receiving anticoagulation therapy, patients with asthma, COPD and other health conditions. As it was specified in the *Methods* section the actual HAT system includes a patient unit, a decision support server and a clinical station. For example, for asthma patients the home unit consists of an electronic flowmeter and a palmtop (Fig. 2), for patients on anticoagulation therapy the home unit consists of a coagulation monitor and a laptop. The software for the patient units has been developed in Visual Basic. This allows us to use any computer models running Windows CE/95/98/2000/ME/XP as a part of the patient unit. The disease specific-sensors download the measurements into computer memory automatically via a serial port. The majority of commercially available electronic flowmeters may be used for the asthma patient unit. Patients perform measurements using disease-specific sensors (such as flowmeters, spirometers, pulse oximeters, coagulation monitors) and fill in disease-specific diary on a regular basis. The patient can also transmit a personal message to medical personnel. Immediately after the completion of the self-testing, all data are sent to a remote clinical information server which stores the data in a database. The data can be sent over a standard telephone line or over a wireless network. Patient data for the last four months are also stored locally in the patient unit and are available for the patient's review. During each self-testing session, the patient receives feedback messages generated automatically, or sent by medical personnel, via the same system.

Several minutes after the completion of home self-testing, all results are stored in the HAT database server which implements a secure Web interface. Any computer equipped with a functional Web browser can serve as a HAT clinical station from which the eligible medical personnel can review and analyze patient data almost immediately after the completion of the self-testing.

Evaluation Studies of HAT

The evaluation of the HAT underwent several stages. First, we showed that the HAT system provides reliable reciprocal exchange of all relevant information between a physician and patient in home settings [8]. Further evaluation [9] demonstrated that (1) lung function test results collected during home asthma telemonitoring are comparable to those collected under the supervision of trained professionals, and (2) Internet-based home telemonitoring can be successfully implemented in a group of patients without previous computer experience. Preliminary results of an on-going HAT evaluation showed higher patient compliance to asthma action plans in comparison to the compliance reported for patients in standard care. The clinical impact of HAT on asthma outcomes and patient compliance is being currently evaluated in a randomized clinical trial funded by NIH.

Figure 2. Asthma HAT patient unit.

Conclusion

There is a clear need to provide effective home monitoring and self-care support for patients with chronic diseases. The HAT System is designed to monitor these patients and to help them in day-to-day management of their disease. HAT has a potential for improving clinical outcomes and quality of life in this patient population and may be a model for monitoring and self-management of patients with different chronic health conditions.

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