Clinical decision support system for managing asthma in school-age children

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***Abstract* — Asthma, a chronic inflammatory disease of the airways, is the most common chronic disorder of children, affecting as many as 10-12 % of children in USA. The purpose of this paper is to propose an integrated computerized decision support system for managing asthma in school-age children. The system is intended to cover various aspects of the patient's life, including the home environment, the school and the doctor's office, thus improving the treatment of asthma overall.**

***Key words* — Asthma, clinical decision support system, evaluation, hand-held device, peak flow, school-age children**

I. Introduction

ASTHMA is a chronic, inflammatory and life-threatening disease of the airways that affects people of all ages, races, and ethnic groups [1]. It is considered to be a modern disease, which is steadily increasing despite a better understanding of the disease and improved medical treatments. Of additional concern is the fact that the prevalence of asthma among children is increasing at a considerably faster rate than the prevalence of asthma in the entire population. From 1980 to 1995, the prevalence of asthma in children in United States doubled from 3.6% to 7.5% [2]. Since 1995, the numbers continued to increase, but at a slower rate; in 2005, the estimated prevalence of asthma in children was 8.9% [2]. It is one of the leading causes of school absences and missed sport activities among the students as well as missed work days of their parents.

Managing asthma in school age children is challenging and responsible process involving the parents, the school health practitioners and the doctors. The goal of asthma management is to control the disease well enough that the child can lead a near-normal life [3]. The Expert Panel Report 3 (EPR-3) guidelines suggest that the four aspects of care that are essential to achieving and maintaining control of asthma are: providing education for a partnership in care, controlling environmental factors and comorbid conditions that affect asthma, prescribing medications that are appropriate and assessing and monitoring asthma severity and asthma control [3].

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While being a parent of school age child carries a burden of responsibilities, taking care of a child with a chronic illness, such as asthma, brings additional problems. The major activities that are being performed on a daily base are: giving the prescribed medicine to the child, performing the regular measurements of the peak flow, taking notes of the child's daily activities, monitoring the symptoms and in emergency situations deciding whether to call the doctor or go strait to the emergency room. Normal activities, such as playing soccer or running on the playground can sometimes be challenging for the children suffering from asthma. Even the school days of the children with asthma can be different than the school days of the healthy children. Instead of enjoying the recess, the child with asthma could be running to the nurse office to get the prescribed inhaler dose.

Considering all of this, it is extremely important to establish an efficient process of managing the child's asthma to allow the child live as close to normal as possible. The main purpose of this paper is to propose a model of clinical decision support system (CDSS), which can assist and improve the management of asthma in school-age children.

The rest of the paper is organized as follows. The section 2 outlines typical definition of CDSS together with a general CDSS model and a brief background. The section 3 describes and outlines the high-level architecture of PedAst, the system for managing asthma in school-age children. The section 4 describes how the validation of the system will be performed. The last section provides summary and directions of future improvements of the system.

II. Clinical Decision Support Systems

In the literature there are many definitions of Clinical Decision Support Systems (CDSSs). Sim et al. defined CDSSs as "software designed to be a direct aid to clinical decision-making, in which the characteristics of an individual patient are matched to a computerized clinical knowledge base and patient specific assessments or recommendations are then presented to the clinician or the patient for a decision" [4].

The Figure 1 shows a general model of CDSSs as presented in [4]. The clinical decision support system receives patient related data (clinical signs, symptoms, laboratory results) as input and generates diagnostic and therapeutic recommendations as output. The system is composed of two main architectural components:

knowledge base and inference (reasoning) mechanism. The knowledge base represents a structured collection of expert medical knowledge used by CDSS. The inference mechanism consists of computer algorithms used to process the patient data in relation to the medical knowledge base and generate conclusions and recommendations.

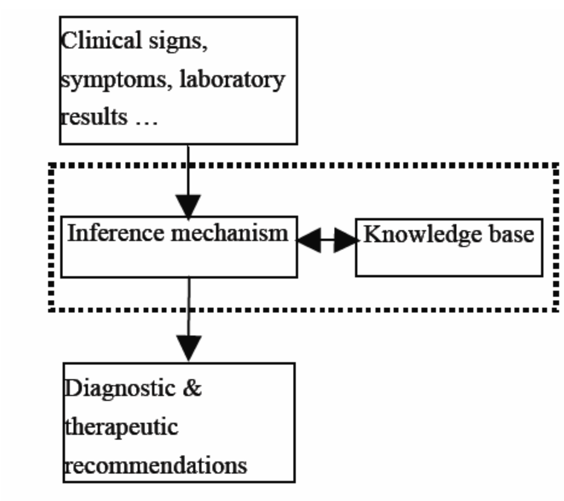

Figure 1. The General Model of CDSSs

Computerized decision support systems within health care have been considered since the mid 1950's [5], resulting in many experimental systems, while some of the later developed systems were commercialized. Examples of systems designed to provide clinical decision support in the area of pulmonology are: PUFF - designed to interpret measurements from respiratory tests [6] and Asthma Critic – designed for detecting asthma patients based on the analysis of patient's data captured during the routine visits of the primary care physicians [7]. However, the acceptance and the use of the CDSSs within the clinical environment has been limited by number of factors, such as the lack of models to capture the medical knowledge in a structured way which will efficiently support the decision-making process and the inexistence of integrated and real-time patient care information system [8].

III. PEDAST – CDSS FOR MANAGING PEDIATRIC ASTHMA IN SCHOOL AGE CHILDREN

This paper proposes a computerized system called PedAst (named after Pediatric Asthma), which will provide means for capturing and storing the patient's medical information, open communication channel between the patient's home, school and doctor offices and will assist the decision making process by assessing the patient's state based on the entered data and generating reminders and recommendations.

PedAst will be web-based modular system composed of the following major modules, shown on Figure 2:

Doctor's module – which will be used in the doctor's offices by the medical practitioners for following and assessing the patient's state and will provide support when making diagnoses and prescribing medications.

School module – which will be used by the nurses in the schools for following the patient's state in the school and generating messages and recommendations when needed. For example, when the doctor determines that the patient's state deteriorates, a message can be sent to the nurse in the child's school to check the child through the day and act as needed.

Patient's personal module – which will be used by the child's guardians for capturing and storing data from the regular peak flow measurements, medications received during the day, daily activities, symptoms, unexpected reactions etc. This data would be integrated in a central electronic medical record, which will be accessible by the medical practitioners in the school and the doctor's offices for following the patient's state. This module will also be able to generate advices and recommendations for the patient, based on the entered data. For example, when the peak flow is bellow the recommended value, the system would advice the patient to call the doctor or to go to the emergency center.

Core module – will be composed of inference machine and repositories for the knowledge base and the patient's electronic records. The knowledge base will contain the medical knowledge, which must be represented in a human-understandable but computer-interpretable manner [9]. The method of logical rules (IF – THEN), which may be assigned factor of probability and can be linked in a chain of rules, seems appropriate for this system. An example of a simple rule would be: If the peak flow reading is less than 50 percent of the normal value, generate an alert message for the patient to go strait to the emergency room. The knowledge base can be edited through a knowledge base editor, accessible by the medical experts who can add new rules or edit the existing ones. The electronic medical record of the patient will be updated by the patient's guardians and the medical practitioners in the schools and the doctor offices. It will contain information such as demographic data of the patient, general medical history, including other major diseases, surgeries, allergy information and a log of the asthma treatment, including the regular measurements of the peak flow, received medications, symptoms and daily activities, laboratory results, diagnosis etc. The inference engine will be processing the patient medical information in a relation to the medical knowledge and will generate appropriate answer (i.e alert message, diagnostic or therapeutic recommendation). The activity of the inference machine may be triggered by a specific request, issued by user of the system (i.e. doctor in process of determining a therapy is looking for the system's recommendations, which will consider previously used medications and patient's allergy information), it can be triggered by an event (every time the patient's medical record is updated, the inference machine starts a background processing which may result in alert messages, reminders or recommendations) or some tasks may be scheduled to run

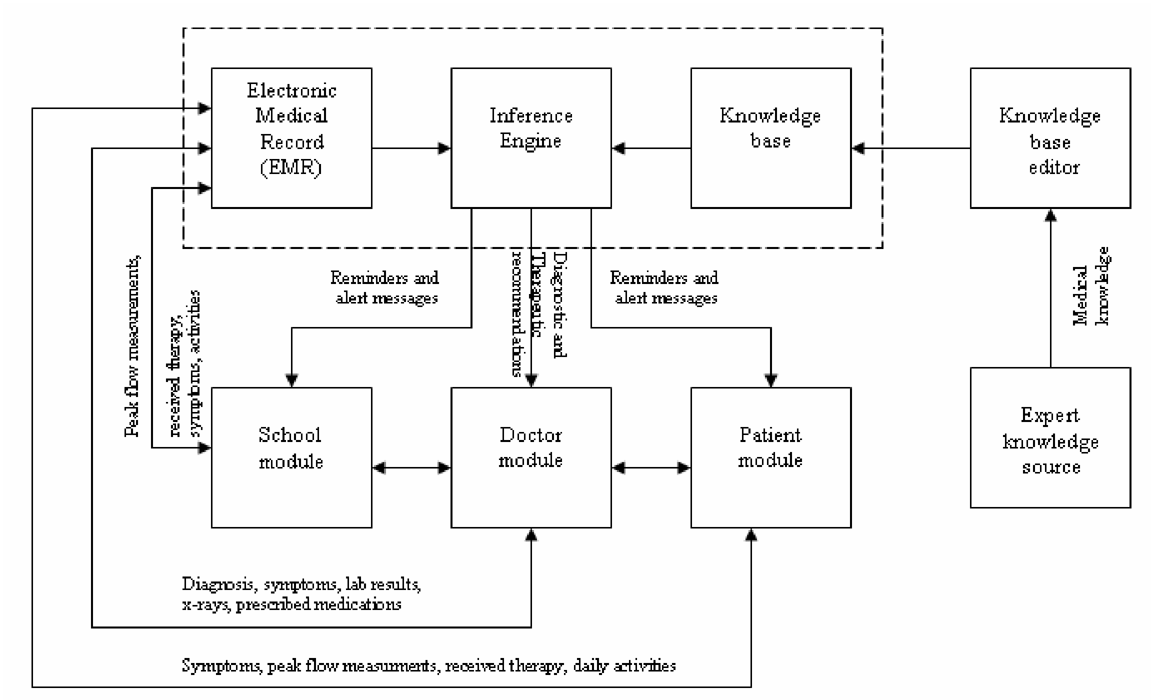

Figure 2. System architecture, representing the modules of the system and the interaction between them

on a regular base (i.e. the system analyses the patient's data on a weekly base and generates a report for the doctor, based on which the doctor may call the patient for a follow appointment).

The challenges in designing this kind of system are numerous: construction of the knowledge base, selecting the appropriate inference algorithms for achieving optimal results, maintaining an accurate patient's electronic medical record, privacy of the patient's data etc.

IV. System Evaluation

A crucial part of designing any system is evaluation of the system [10], which represents quantification of its value. So, even if the advantages of using the system may be obvious, it must be tested empirically.

When evaluating PedAst, most importantly is to determine if the effectiveness of managing asthma in school age children has been improved, which is the main goal of the system. This can be achieved by deploying the system in a pilot school, including all of its asthma patients and their doctor's offices. By using the system over certain period of time, the following specific factors should be measured and compared to the same period of the previous year when the system was not used:

- Number of missed school days because of asthma – related problems;
- Number of emergency room visits because of asthma – related problems;
- Number of adverse drug reactions because of inappropriate asthma – related therapy.

An important part of the system's evaluation is assessing the usability, in which the feedback form the end-users is crucial. The most important factors to consider here are: time and effort to train the users, willingness to use the system, user satisfaction etc. Particularly important is to determine the extent to which the physicians are satisfied with the assistance from the system in the decision-making activities. This can be evaluated by measuring the time needed for the physician to determine the diagnosis and therapy in two similar patients when using the system and without the system and verifying the accuracy of the diagnosis and the appropriateness of the therapy.

Another aspect of the system to be evaluated is the effectiveness in communication between the patient, the school and the doctor. While the communication itself is probably not an issue, the obvious advantage of the system is that it provides a real-time access to the medical electronic record of the patient. Without using the system, when the patient calls the doctor for an adjustment of the therapy, the doctor does not have access to the patient's log with the latest measurements of the peak flow, daily activities and symptoms, unless the patient sends that information by fax or e-mail. When using the system, the doctor has an immediate access to the patient real-time medical record and the system itself has the capability to process that information and makes recommendations. In addition to this, the automated messaging and alert feature is definitely a bonus. Before using the system, when the patient is recording the daily measurements of the peak flow on paper forms, there will not be any feedback until the doctor sees these results. When using the system, it should be able to recognize that the results are not satisfactory and generate a message to take an appropriate action: schedule a follow-up appointment with the doctor for an adjustment of the therapy or if the peak flow results are critically low direct the patient to the emergency room.

Another measurable benefit of the system is update of the medical documentation. In the paper forms, all the data has to be entered manually. In the on-line forms values and pre-defined comments can be selected from a list, data can be copied from previous entry, etc. More importantly, data validation can occur at the same time when entered, so the probability of typing mistakes is much smaller. In addition, the documentation is integrated and centralized with a real-time access by all the interested parties.

Similar to all clinical decision support systems, it is necessary to perform extensive risk analysis to quantitatively evaluate the relationship between the system and patient safety [11].

V. SUMMARY

The system proposed in this paper is expected to improve significantly the treatment and the management of asthma in the school age patients, by allowing continuous monitoring of the medical conditions of the patients and quick intervention if the results are not satisfactory. However, there are some limitations of this system and areas for future improvements.

The use of the proposed system is limited by the hardware and the Internet connection. That means, the patient will not have access to the system if there is no access to a computer and Internet, which may be the case when traveling or camping. A possible solution to consider in the future would be developing a wireless hand-held portable device, which would be carried by the patient constantly and would provide instant real-time decision support [5]. Also, if the patient is not in the home area and needs to see a doctor who does not have access to the system, the doctor would not be able to access the patient's history and may miss important facts.

Another direction for future improvement would be integration of the system with a pharmacy, which would provide an immediate feedback of the medication availability or suggestions for generic substitutions with the same effect but lower price.

Among the challenges which remain subject of additional research are: finding an effective way of continuous update of the medical knowledge base with the new discoveries as guarantee that the system responses are relevant and improving the current mechanisms of protecting the patient's data and privacy.

Ongoing research should be performed for continuous quality improvement, by selecting the most appropriate improvements to the system [11].

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