An Asthma Management Framework for the RespDoc Clinical Decision Support System Based on the Combination of the Official Clinical Guidelines

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***Abstract*— In this paper we propose a new framework for the in- and out-hospital homogeneous management of childhood asthma through a combination of official clinical guidelines for asthma management. The main indicator used for the assessment of the child's asthma is the measurement and interpretation of Fraction of exhaled Nitric Oxide (FeNO). As a whole, the decision making algorithms that we created are organized as a Clinical Decision Support System (CDSS), termed RespDoc. The performance of the RespDoc has been evaluated by means of data acquired from real world medical cases.**

I. Introduction

Asthma is one of the most common childhood diseases. It is a chronic inflammatory disorder of the airways resulting in obstructive lung disease and deterioration of lung function. Asthma causes bothersome symptoms, such as cough, wheezing, chest tightness and shortness of breath; it may manifest as acute exacerbation. These exacerbations can become very serious, even life threatening. In such cases the patient needs transfer to the emergency department or even requires hospitalization [1].

Due to the high prevalence of asthma, there has been a multitude of initiatives with the aim of developing clinical practice guidelines and standardizing patient management. The US National Heart Lung and Blood Institute (NHLBI) coordinates the National asthma Education and Prevention Program (NAEPP); this has resulted in the creation of the current Expert Panel Report-3 (EPR-3) guidelines for the diagnosis and management of asthma [2]. The American Academy of Allergy, Asthma and Immunology (AAAAI) has also published an asthma management guide for pediatricians, taking into account the results of the NAEPP initiative [1]. In addition, the Global Initiative for Asthma (GINA) was created to provide a common framework to control asthma for health professionals, health organizations and patients [3], while the British Thoracic Society (BTS) together with the Scotish Intercollegiate Guidelines Network (SIGN) produced an asthma clinical guideline as well.

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In addition to the aforementioned guidelines, Clinical Decision Support Systems (CDSSs), namely expert systems used to facilitate clinical practice, are being developed for asthma management. These CDSSs incorporate clinical guidelines into their knowledge base, and, thus, provide a decision making tool which serves to promote guideline adherence by patients and health care professionals. The design of such tools is focused on one or more of the following goals: diagnosis, treatment, exacerbation management and patient education. To achieve these goals, the majority of the CDSSs incorporate either the EPR-3 or the GINA guidelines into their knowledge base [4], [5].

We describe a CDSS for asthma management, termed RespDoc, aimed to be used either at a clinical care setting by a doctor or a school nurse, or at home by the patient's parents. Our system is implemented as a web service and it comprises a Doctor and a Parent Interface [6]. The novelty of the RespDoc is its unique design that incorporates the official guidelines of the American Thoracic Society (ATS) for measurement and interpretation of Fraction of exhaled Nitric Oxide (FeNO) [7], [8], which is an objective marker of the level of asthmatic inflammation [9].

In this paper, we expanded the capabilities of the RespDoc with more algorithms based on the results of clinical examination, oxymetry measurement and spirometry. In order to create an asthma management framework for our CDSS, which will be efficient at the clinical care setting and at home, we used a combination of the ATS guidelines with the EPR-3, GINA and AAAAI guidelines.

This paper is organized as follows: Following the introduction, in Section II a general description of the RespDoc CDSS and the use of FeNO is given. In Section III the Diagnostic process incorporated into the system is presented. In Sections IV and V the Treatment Planning and the Exacerbation Management processes are analyzed, respectively. In Section VI the Appointment Scheduling process is described. Finally, Section VII includes the Discussion and the Conclusion.

II. The RespDoc CDSS and The Use of FeNO

The RespDoc is developed in order to assist the pediatrician who does not specialize in pulmonology with patient examination and management. The doctor is guided through the necessary steps of pertinent patient information acquisition and asked to insert into the system the results of these processes (clinical examination results, medical

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history, laboratory results, lung function measurements, asthmatic inflammation measurements, context information etc.) through the Doctor Interface. In addition, the RespDoc is designed to provide telemonitoring of the patients by giving the parents access to the web service, through the Parent Interface [6].

The core of the RespDoc comprises four processes designed to model the main aspects of patient management: Diagnosis, Treatment Planning, Exacerbation Management, and Appointment Scheduling. These processes will be initiated when the patient examination is completed and the necessary data has been entered into the system. In order to incorporate these processes in the form of IF-THEN rules into our knowledge base, we have used algorithms that combine the EPR-3, the GINA, the AAAAI and the ATS official guidelines for asthma, as mentioned above.

The measurement of FeNO is used in three of our system's processes, namely in the Diagnostic, the Treatment Planning and the Appointment Scheduling process. FeNO in exhaled air has been used as a biomarker of asthma inflammation during the last fifteen years. It has been shown to objectively reflect the activity of asthmatic inflammation, mainly at the first stages of the disease, and is considered to be a sensitive indicator of childhood asthma [9].

The level of nitric oxide (NO) in exhaled air is measured with a portable device, the NO analyzer [7]. According to the design of the RespDoc, FeNO measurement will be conducted at the clinical care setting in those patients whose asthma is not life threatening. On the other hand, in cases of severe asthma, the NO analyzer will also be used at home [6]. In these cases, frequent monitoring of asthmatic inflammation on a daily basis is mandatory for a period of time of two months approximately, in order to avoid exacerbations and optimize medication, as suggested by our team's pulmonologists. The patient's parents will be provided with the NO analyzer in order to feed into the system, through the Parent Interface, the results of the FeNO measurement, as well as the necessary information on the patient's symptoms, context and quality of life. Thus, ubiquitous and personalized monitoring of the patient's condition will be accomplished.

III. Diagnostic Process

The Diagnostic Process of the RespDoc CDSS, as depicted in Figure 1, starts with the assessment of the recorded symptoms and medical history of the patient, as recommended by the GINA, the EPR-3 and the AAAAI guidelines. At this stage, the system can reach a diagnosis with an estimated level of certainty, based on the signs of the disease. The higher the number of the indicators of the disease detected by the RespDoc, the greater the certainty of the diagnosis.

Subsequently, the suitability of the FeNO measurement for the patient is checked. According to the ATS guidelines, patients should refrain from eating, drinking and exercise for at least one hour before exhaled NO measurement [7]. In addition, upper and lower respiratory tract viral infections, as well as certain medications, can affect FeNO measurements. If the patient meets the criteria for FeNO measurement, then the level of asthmatic inflammation is defined [6]. Otherwise, the system proceeds directly to the next stage of the Diagnostic Process, which will confirm the diagnosis of asthma based on the result of spirometry, as suggested by the GINA, EPR-3 and AAAAI guidelines.

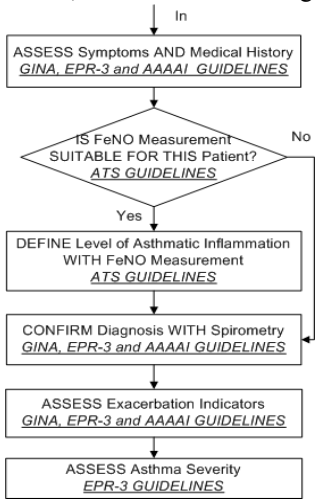

Fig.1.The Diagnostic Process

Then, an assessment of signs of exacerbation is conducted. If the system detects signs that the child is in a state of exacerbation, it directly activates the Exacerbation Management Process.

In the last stage of the Diagnostic Process, an asthma severity assessment is conducted and the child's asthma is categorized as intermittent, mild persistent, moderate persistent or severe persistent. This categorization refers to the intensity of symptoms for the patients who are not yet receiving therapy for asthma. For those children already under treatment, the amount of medication needed to achieve adequate control of the disease is also taken into account [2], [3]. The rules for the severity assessment of the child's condition were created based on the EPR-3 guidelines.

IV. Treatment Planning Process

Medications for asthma are divided in two categories: long term medications and rescue medications [1], [2], [3]. Long term medications are prescribed in order to be taken in a daily basis, as a profylaxis, for long periods of time. Their purpose is to limit asthmatic inflammation with the aim of achieving control of the disease. The Treatment Planning Process of our CDSS is responsible for the definition of the proper long term medication for each patient. On the other hand, rescue medications are used as needed in cases of asthma exacerbations and will be discussed later in this paper.

The Treatment Planning Process, illustrated in Figure 2, is initiated with the evaluation of the level of asthma control for those patients who have been diagnosed with asthma in the past. Asthma can either be controlled, partly controlled

or uncontrolled. The level of asthma control indicates treatment efficacy and the degree to which the manifestations of asthma are minimized [3]. This evaluation, prior to treatment definition, is suggested by both the GINA and the EPR-3 guidelines.

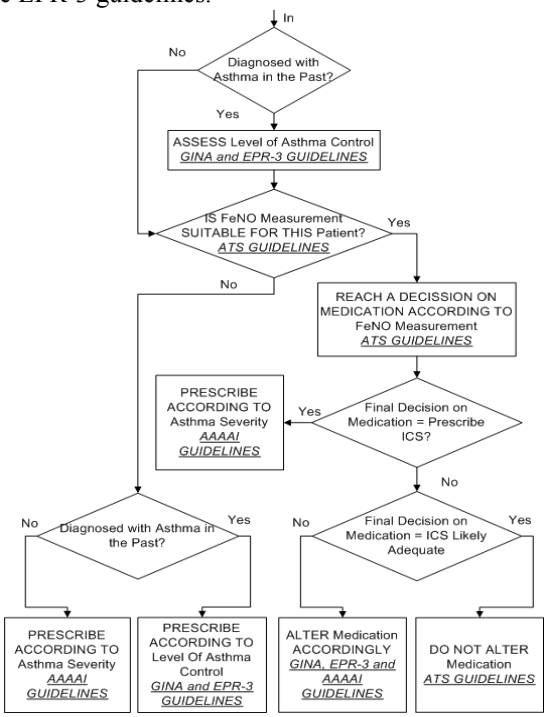

Fig.2. Treatment Planning Process

The next step of the Treatment Planning Process distinguishes between patients who are suited for FeNO measurement and those who are not, according to the same criteria used in the Diagnostic Process, as described above.

For those patients who are suited for FeNO measurement, and whose level of asthmatic inflammation is measured during the clinical examination, the decision on medication is made according to the Asthmatic Inflammation and Medication Definition Process described in [6]. This process, which was designed according to the official ATS guidelines, takes into account the level of asthmatic inflammation in order to reach a decision on medication administration, i.e. prescribe inhaled corticosteroids (ICS), ICS likely adequate, increase or reduce ICS dose. According to this decision the system proceeds as follows:

- If the decision on medication is to prescribe ICS, then the official AAAAI guidelines are applied and treatment is defined according to asthma severity.
- If the decision on medication is that the ICS regimen is likely adequate, then the system informs the doctor that no change in medication should be made, as proposed by the ATS guidelines.
- If the final decision on medication is to increase or decrease the ICS dose, then a step up or a step down in dosage is recommended, respectively. The rules for this decision were designed based on the GINA, EPR-3 and AAAAI guidelines.

On the other hand, for those patients who are not suited for FeNO measurement, the RespDoc proceeds as follows:

- If this is the first time that an asthma diagnosis is confirmed for a particular patient, then the Medication Process applies the AAAAI guidelines and treatment is defined according to asthma severity.
- In the case of a patient with a previous diagnosis of asthma, the level of asthma control defines treatment, according to the GINA and EPR-3 guidelines.

V. Exacerbation Management Process

Asthma exacerbations, often referred to as asthma attacks, are episodes of progressive deterioration of asthma symptoms and lung function. They are independent of the patient's asthma severity and in some cases can even be fatal [2]. Asthma exacerbations can be triggered by viral respiratory infections, environmental factors, stress and other situations depending on each patient's profile [1], [2], [3].

The Exacerbation Management Process of the RespDoc CDSS, depicted in Figure 3, is designed in order to guide either the parent or the doctor of the child, at home or at a clinical care setting, respectively, in case of an asthma attack.

If the parents notice deterioration of the child's asthma symptoms at home, they will be able to access the RespDoc web service through the Parent Interface and be guided by the Exacerbation Management at Home Process, which applies the AAAAI guidelines. This process is responsible for evaluating the condition of the child, through a set of questions to the parent. It also informs the parent on the rescue medication needed. After a certain period of time, it assesses the patient's response to the rescue medication through another set of questions to the parent. Depending on this assessment, the parent is informed whether changes in medication are necessary. The Exacerbation Management at Home Process also decides whether transport to a medical center is mandatory.

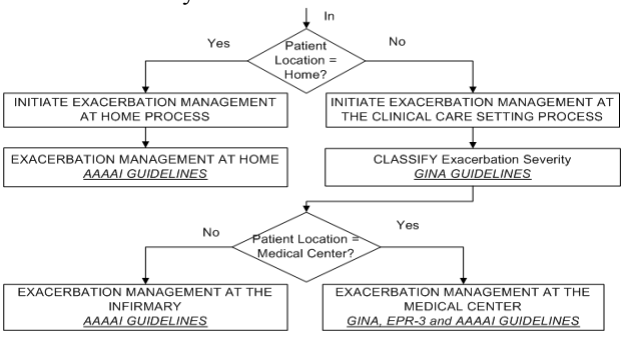

Fig.3. Exacerbation Management Process

In addition, a similar but more specialized guidance for pediatricians is supported by the Doctor Interface of the RespDoc, through the Examination Management at the Clinical Care Setting Process. Access to this process will be provided at the following points:

- At the physician's private office, where the AAAAI

guidelines for exacerbation management will be applied.

- At the Emergency Room setting, where asthma exacerbations management will be conducted according to the GINA and EPR-3 guidelines.

VI. Scheduling the Next Appointment Process

The last process of the RespDoc CDSS was designed in order to organize a schedule for monitoring each patient; it is presented in Figure 4. Careful personalized monitoring of the patient is a key concept in order to ensure responsiveness to medication, reduce exacerbations to a minimum and achieve optimal disease control [1], [3]. The Appointment Scheduling Process can be accessed by both the Doctor and the Parent interface, in order to ensure collaboration and provide all necessary reminders to both parties.

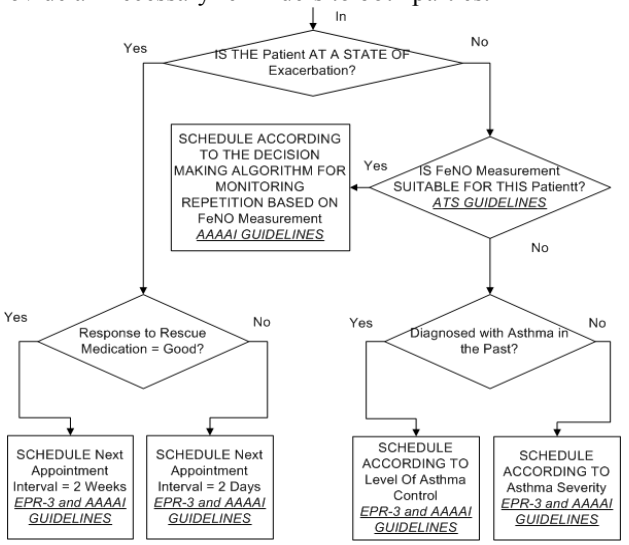

Fig.4. Appointment Scheduling

At the first stage of the process, the patients who are at a state of exacerbation of their asthma are distinguished. If their response to the recommended rescue medication is adequate, a follow-up is scheduled within the next two weeks. Otherwise, the next visit to the doctor should be planned within the next two days, in order to ensure that the exacerbation is under control.

Monitoring of the patients who are suited for FeNO measurement is scheduled according to the level of asthmatic inflammation by the Decision Making Algorithm for Monitoring Repetition, which is based on the AAAAI guidelines and is described in [6].

When FeNO measurement is not suitable and the patient has a previous diagnosis of asthma, the level of asthma control defines the monitoring frequency. For those patients who are diagnosed with asthma for the first time but are not suited for FeNO measurement, it is the severity of the disease that determines when the next examination should be conducted. The rules for these decisions were created based on the EPR-3 and AAAAI guidelines.

VII. Discussion - Conclusion

We used 50 patient's files (archive data), which were included in the research described in [10], in order to evaluate the accuracy of the RespDoc CDSS and the suggested framework for asthma management. The decisions produced by the system were compared to the conclusions of our team's doctors for each patient. According to this evaluation the accuracy of the system is 86%.

However, we also intend to choose an adequate number of patients who will use the portable NO analyzer at home and provide the parents access to the RespDoc web service. This way, we will be able to test the performance and efficiency of the RespDoc as a telemonitoring tool, in terms of its impact on the patients' asthma severity and asthma control.

In this paper we introduced a childhood asthma management framework for the RespDoc CDSS. This framework emerged from the combination of the official EPR-3, GINA, AAAAI and ATS guidelines for asthma management and it includes four processes: Diagnostic, Treatment Planning, Exacerbation Management and Appointment Scheduling. The proposed system is based on the measurement of FeNO, which reliably reflects the state of asthmatic inflammation. The final stage of our work intends to test the RespDoc prospectively in a real world scenario.

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