Developing a Clinical Decision Support Model to Evaluate the Quality of Asthma Control Level

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Abstract: Background and Objectives: Clinical Decision Support Systems (CDSS) are used to improve clinical decision making on various practices including prevention, diagnosis, treatment as well as specific test ordering based on patient-specific advice. One of the modeling techniques used in the CDSS is the use of qualitative multi-attribute models. Therefore, the present study aims to design a qualitative multi-attribute model to assess the level of asthma control in asthmatic patients. Methods: The type of study described in this paper was an applied study. First, factors influencing the assessment of asthma level were classified through the study of clinical guidelines. Then, qualitative multi-attribute decision model was implemented and the data of 50 asthmatic patients referred to Baghiatollah Hospital (Tehran, Iran) for post-treatment evaluations since January 2012 to December 2012 were extracted and transferred to the system. This system was modeled by Qualitative Multi Attributes method and designed in DEXi shell that based on DEX methodology. Finally, system outputs were evaluated and Selective Explanation analysis was performed on each patient. Results: Comparisons of the CDSS Outputs with physician’s advices showed the accuracy of 80%. In addition, asthma instability and lack of proper medical follow-up along with five cases are the most important weaknesses in controlling patients’ asthma level. Conclusions: Findings of the present study and Integrating Qualitative Multi Attributes Method and Medical Domain indicated that the used CDSS is an appropriate tool for data analysis and modeling in medical decision making and has a high potential for consultation in management areas to remove weak points and to improve strong points.

Key words: Level of asthma control %Clinical Decision Support (CDS) %Qualitative multi-attribute model % Selective Explanation

INTRODUCTION

Asthma is a common chronic inflammatory disease of the airways, which is characterized by aggravated symptoms, recurring obstruction of airways and bronchial spasm [1]. Asthma prevalence has been dramatically increased since 1970s so that it caused the death of two hundred and fifty thousand people in 2009. In 2010, three hundred million people worldwide were stricken with asthma [2]. Asthma has an increasing rate in developing countries and the lack of proper control of this disease significantly affects the quality of life, psychological and occupational aspects and people’s learning. Prescribing and management of this disease are then planned accordingly [3].

There are many possible reasons for poor asthma control. However, regardless of the underlying causes, the level of control achieved reflects the poor performance of both healthcare specialists and patients. Healthcare specialists need to properly manage asthma and take appropriate actions if control is poor. Patients need to engage in self-management behaviors to be appropriately treated [4].
Although asthma control is important to guide the course of disease treatment, it is not often predictable because of confusing patterns and exasperation risk [5]. In asthma clinical guidelines, six criteria are suggested for proper control of the disease. Many of these cases are neglected due to the lack of medical attention or inadequate training of patients [6]. Decision Support Systems being one of the most widely used and effective means to implement the techniques are used to improve the acceptance and to precisely use medical strategies [7].

Clinical Decision Support Systems are computer programs that, in case reasoning trend, help clinical specialists with clinical diagnosis and evaluating the patient’s status as well as choosing treatment methods [8]. These systems have a high potential to reduce medical errors and to improve the quality and efficiency of treatment [9] and have demonstrated that can improve health care costs and outcomes [10]. A systematic study on the effect of Decision Support Systems on physicians’ performance and patients-related outcomes showed that physicians’ performance has been improved in 64% of studies [11].

One of the methods of modeling clinical Decision Support Systems is the use of decision analysis approach, which is a common principle under the subject of applied decisions theory and presents a framework for analyzing decision making-related issues through the following methods:

C Structuring and dividing problems into more suitable and manageable parts
C Direct approach to possible options [alternatives], available data, uncertainties and priorities associated with decision-making process
C Combination of the above-mentioned components to achieve a more efficient and effective decision [12].
C Multi-attribute [multi-criteria] models are a class of models used in the analysis tree to evaluate options based on possible purposes and contradictions. This approach causes the division of decision-related problem [root attribute] into smaller subdivisions with less complexity [13]. This process results in a hierarchical model including utility attributes and functions [14].
C However, the qualitative multi-attribute model, influenced by fuzzy set theory, uses qualitative [symbolic] attributes with discrete scale consisting of words rather than numbers for decision models [12].

DEXii is an educational computer program that supports the Multi-Criteria Decision Analysis [MCDA] and aims to create a qualitative and hierarchical multi-criteria decision model as well as to evaluate options [15]. This program effectively meets the goals of the decision maker in cases we need to choose a specific option among a set of possible options [16]. Actually, this software is the shell of an expert system for modeling and supporting these decisions [17]. DEXii program supports two basic functions:

C Creation and development of qualitative multi-attribute models
C Use of these models to assess and analyze alternatives [18].

These models are created in DEXii with the following definitions:

C Attributes: Qualitative variables that indicate decision sub-problems.
C Scales: A regular and irregular set of symbolic values being assigned to attributes.
C Attribute tree: A hierarchical structure to display the analysis of decision problems.
C Utility functions: Rules that determine the aggregate attributes from down the tree towards the root [19]. DEXii-based evaluation process follows the following trend (Fig. 1):
C A vector of input attributes is defined and displayed through the attributes’ hierarchy.
C Each of the attributes in the tree are numbered through qualitative scales (e.g. low, medium and high)
C Utility functions are implemented based on the decision rule for each aggregation attribute. In DEXii, a table is presented for users to transfer qualitative values of attributes (e.g. X₁, X₂, and…) to aggregate them in another qualitative attribute (such as Y) representing decision rules [20].

eg: IF X₁ = ‘medium’ and X₂ = ‘very low’ and X₃ = ‘low’; THEN Y = ‘low’

In evaluation and analysis stage, DEXii helps us through creating attributes tree, defining decision rules, evaluating and analyzing alternatives and providing graphical output [21].
Methods: The type of study was applied study. In the present study, factors influencing the evaluation and control of asthma level were extracted from the relevant data of asthma in the Research Center of Chemical Injuries (Baghiyatollah University of Medical Sciences, Tehran, Iran), Baghiatollah Hospital (Tehran, Iran) as well as other medical sources of asthma such as clinical guideline of management and asthma treatment [22]. Designing a form containing these variables and their assessment by two specialist physicians, we achieved a set of attributes affecting the level of asthma control (Fig. 2) including the severity of respiratory symptoms (including daily symptoms, night-time symptoms and asthma), obstructive pulmonary (including forced expiratory volume in the first second, forced and high-pressure vital capacity and the fraction of two previous variables), asthma instability (including pulmonary test and symptoms’ exacerbation), quality of life (including the number of miss days of school or work, the number of miss days in which
the patient’s favorite activities are limited and constant look for new treatments) and current treatment (including the use of ß2-agonist drug in short time, the use of Corticosteroid in long-term and the prescription of other controller drugs).

The information of 10 asthmatic patients were organized in the shape of variables available in Fig. 2 to provide system’s inputs for its evaluation.

To implement clinical decision support system based on qualitative multi-attribute model and to evaluate it, we performed five following steps:

C Design the qualitative decision tree based on input variables: this tree was implemented in DEXi software environment as a hierarchical tree and is shown in Fig. 3 by DEXi tree plugin.

C Scaling attributes: In this stage, possible scales for each variable were assigned using reliable medical sources and data available on detection system of mentioned asthma and their accommodation. Scales used in most attributes are regularly ordered and DEXi environment considers them from bad to good or from the lowest to the highest when defining.

C Design utility functions: Utility functions are used to define decision-making rules in DEXi. These functions perform the aggregation of subcategories as the following formula where Xs and Ys are tree’s attributes and aggregation rate, respectively.

F: X1×X2×…×Xn ? Y

Equivalent of this function’s if-then is as follows:

if X1= value 1 AND X2= value 2 AND …. AND Xn= value then Y=value

F(X1, X2, ..., Xn) = W1×X1 + W2×X2 +…+ Wn×Xn

To determine the rules in utility functions, we enjoyed the opinions of medical specialists. We did this task through special methods such as direct valuation of Y. DEXi software uses a weighting mechanism to determine other output values ??of the system. This mechanism is used in the modeling of attributes’ importance to analyze decisions. This mechanism uses a total of 100 maximum. In the designed system, weights are equal in utility functions. In addition, DEXi uses the following formula for unallocated values in utility functions to weight and determine their values. In this formula, Xs and Ws are assigned attributes and weights, respectively.

Apparently, weighting is not possible in normal condition because of symbolic and qualitative utility functions in qualitative multi-attribute model. An estimation of quantitative weights is used for qualitative models to fill out the differences between quantitative and qualitative models.

Using combined rules, DEXi presents utility functions in a more abstract and understandable format through the integration of a number of basic rules having the same function values. In other words, combined rules represent several basic rules through value intervals in a combined rule.

C Transferring optionsto the system: when the implementation of qualitative multi-attribute model of the designed system and weighting of its utility functions were completed, the final step (i.e., transferring data as system’s options) was performed. In this stage, we transfer data of 25 patients to the system and evaluate the output.

C Evaluating system outputs: System’s accuracy analysis: we should examine all expert and decision support systems using accuracy analyses to evaluate their performance.

Selective Explanation Analysis: we use selective explanation analysis to evaluate system outputs. Using this analysis, strong points and weak points in the level of asthma control becomes highlighted for each patient. An example of this analysis is shown in Fig. 4 for the ninth patient (16).
Fig. 4 can be interpreted as follows: For example, if the patient is able to improve his ICS as a unit (from low to Medium), the quality of his current treatment will be improved from low to high.

RESULTS

System’s diagnostic output was compared for 25 patients with physician’s advice whom visited since January 2012 to December 2012. Results indicate high accuracy of the system in evaluating the level of asthma control, so that among 25 records, 19 responses were perfectly correct and total model’s accuracy was 80%, which is considered as a good estimate regarding the number of records.

The results of accuracy and sensitivity analysis are presented in Table 1. It is noteworthy to mention that if incorrect values are recorded, interval model will consider the medial outputs. In this case, the bottom part of interval will be correct if it is equal to the model’s output.

Table 1: Confusion matrix of system’s diagnostic outputs

<table>
<thead>
<tr>
<th>Actual Class</th>
<th>Very poor</th>
<th>Poor</th>
<th>Fair</th>
<th>Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very poor</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Poor</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Fair</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Excellent</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2: selective explanation analysis of 10 patients selected randomly

<table>
<thead>
<tr>
<th>Patient</th>
<th>Weak points</th>
<th>Strong points</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRS</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DF</td>
<td>?</td>
<td>1</td>
</tr>
<tr>
<td>NS</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DY</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ISOA</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>PEF</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>SE</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>BO</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FEV1</td>
<td>?</td>
<td>0</td>
</tr>
<tr>
<td>FVC</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>?</td>
<td>2</td>
</tr>
<tr>
<td>CT</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>BA</td>
<td>?</td>
<td>1</td>
</tr>
<tr>
<td>ICS</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>CM</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>QF</td>
<td>?</td>
<td>2</td>
</tr>
<tr>
<td>MDS/W</td>
<td>?</td>
<td>1</td>
</tr>
<tr>
<td>MDAct</td>
<td>?</td>
<td>2</td>
</tr>
<tr>
<td>LT</td>
<td>?</td>
<td>5</td>
</tr>
</tbody>
</table>

Notes:
- Weak point ?
- Strong point ?
Table 3: Plus-minus-1 analysis of 10 patients selected randomly

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Patient1</th>
<th>Patient2</th>
<th>Patient3</th>
<th>Patient4</th>
<th>Patient5</th>
<th>Patient6</th>
<th>Patient7</th>
<th>Patient8</th>
<th>Patient9</th>
<th>Patient10</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>BA</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>ICS</td>
<td>M</td>
<td>L</td>
<td>N</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>CM</td>
<td>M</td>
<td>H</td>
<td>N</td>
<td>L</td>
<td>L</td>
<td>N</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>QF</td>
<td>NG</td>
<td>NG</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>NG</td>
<td>NG</td>
<td>NG</td>
<td>NG</td>
<td>NG,G</td>
</tr>
<tr>
<td>MDS/W</td>
<td>Ne</td>
<td>Se</td>
<td>Se</td>
<td>G</td>
<td>So</td>
<td>NG</td>
<td>Fr</td>
<td>Se</td>
<td>So</td>
<td>Ne</td>
</tr>
<tr>
<td>MAct1</td>
<td>Se</td>
<td>G</td>
<td>Se</td>
<td>So</td>
<td>G</td>
<td>Fr</td>
<td>Fr</td>
<td>B</td>
<td>Of</td>
<td>Se</td>
</tr>
<tr>
<td>LT</td>
<td>N</td>
<td>G</td>
<td>N</td>
<td>*</td>
<td>X&lt;2</td>
<td>NG</td>
<td>*</td>
<td>N</td>
<td>N</td>
<td>G</td>
</tr>
</tbody>
</table>

CVL=Very Low, L=Low, M=Medium, H=High, G=Good, NG=Not Good, B=Bad, Se=Seldom, So=Sometimes, Ne=Never, Fr=Frequency, Of=Often

Then, the selective explanation analysis was randomly performed for 10 patients and strong and weak points affecting the quality of the level of asthma control were examined. The results are presented in Table 1.

As Table 2 shows, the results of the selective explanation analysis for the tenth patient indicate that his severe instable asthma resulting from his tense PEF test and severe asthma attacks as well as his negligence in the use of corticosteroid drugs is considered as his weak point and the average quality of his life is considered as the strong point affecting the level of asthma control. It is noteworthy to mention that we can interpret data resulting from the selective explanation analysis of other patients in this way.

In this study, the plus-minus-1 analysis was performed after completing Table 3. In this table, interferable attributes that are improvable are marked with green color and other attributes that are not interferable or improvable are marked in red. The interpretation of the table is to suggest the medical specialist to interfere in green attributes (exclusively, medication management and appropriate follow-up) to improve the patient’s level of asthma control.

**CONCLUSIONS**

The results of this study can be described in two dimensions as follows:

- Combination of qualitative multi-attribute analysis and DEXi presents a systematic and structured approach to solve complex problems of decision-making. Therefore, in more than 50 different areas, decision-making is used in the real world such as industry, agriculture, education and other areas. This approach has been increasingly used in medicine and health care area.

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REFERENCES


