An Expert System to Suspect Chronic Kidney Disease

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***Abstract*—Chronic Kidney Disease is one of the major health problems throughout the world. Every year large number of people loses their lives because of this disease. According to statistics, many of these patients die of Chronic Kidney Disease because the disease is not suspected in time. Therefore, suspicion of Chronic Kidney Disease plays a vital role to save many lives. But the suspicion of Chronic Kidney Disease is hampered due to some uncertainties. However, this paper represents an expert system that suspects Chronic Kidney Disease from the observation of signs and symptoms of a patient. The histories of the patients are also considered in this purpose. Belief Rule-Based Inference Methodology Using Evidential Reasoning Approach (RIMER) is used to develop the expert system. This system handles uncertainties that come from signs, symptoms and clinical domain knowledge. Real patients' data, collected from Chittagong Medical College & Hospital, are used to construct the knowledge base. The physician's consultation is also considered in this case. The system is tested over 95 patients and it has been observed that the system is more efficient in suspicion of Chronic Kidney Disease than the manual system.**

Keywords—Belief Rule Base (BRB); Belief Rule Base Inference Methodology using Evidential Reasoning (RIMER); Expert System; Chronic Kidney Disease (CKD); Uncertainty

I. INTRODUCTION

The condition of irreversible kidney damage is considered as Chronic Kidney Disease (CKD) which can reach up to end stage renal disease (ESRD) [1]. It is considered as a major public health problem. Some 13% of US population is suffering from CKD [2], [3]. The number of ESRD patients was approximately 14500 in 1978 and it increased to 100359 in 2002 [4] .The patients of CKD related to dialysis and transplantation was about 340000 in 1999 which increased up to 651000 in 2010 [4], [5]. 10% adult people in UK are suffering from CKD [6]. The number of the CKD patients is not small in the developing countries like Bangladesh, India etc. So CKD is a fact of great concern for the people around the world. Though medical science has been developing and treatment of CKD is available, the death rate is not decreasing in that proportion. Because, CKD is not suspected at the early stage of the disease and treatment for CKD is not provided in time. So it becomes clear that, an early suspicion of CKD can save many lives. Hence, there should be a system to suspect Chronic Kidney Disease. The development of such a system named "An Expert System to Suspect Chronic Kidney Disease" is presented in this paper. This system is developed based on Rule based Inference Methodology using Evidential Reasoning (RIMER) [7] approach which suspects CKD from signs, symptoms and histories of the patients. The system is capable of handling uncertainties. Uncertainties can exist both in sign-symptoms and medical domain knowledge [8]. For handling uncertainties rationally, reliably, and correctly researches have been conducted for more than four decades [9]. RIMER approach handles the uncertainties that come from the limitation of human knowledge. The paper is organized as follows:

An overview of Chronic Kidney Disease together with its Sign-symptoms and Patient's History is described in Section II. In Section III the review of the existing work related to the proposed system is represented. Section IV provides an overview on the RIMER methodology. Section V presents the assessment of Chronic Kidney Disease. Result and discussion is presented in Section 6 and Section VII concludes the paper.

II. CHRONIC KIDNEY DISEASE

The major health problem of today's world is Chronic Kidney Disease (CKD).Chronic Kidney Disease is a heterogeneous disease that affects the function and structure of the kidney [10].The decreased kidney function or kidney damage for three or more months is called Chronic Kidney Disease [5]. Chronic Kidney Disease is classified into 5 stages [3], [6]: (1) normal, (2) mild, (3) moderate, (4) severe and (5) end stage renal disease (ESRD).In each of stages patient has some sign and symptoms .The signs and symptoms in stage1 to 4 are almost same[11]. Stage 1 to 4 is referred to the early stage of CKD. End stage renal disease (ESRD) shows some more signs and symptoms than the other stages. In this paper all these signs and symptoms are estimated [11]-[13]. Chronic kidney disease is determined from physical condition and history of a patient. Physical condition covers general condition, skin condition, pulmonary condition, cardiovascular condition, neuromuscular condition, gastrointestinal condition, hematologic condition and endocrine-metabolic condition

of a patient [11]. Each of these conditions exposes some signs and symptoms [11]. The signs and symptoms of early stages take after the signs and symptoms of end stage of kidney disease (ESRD). However, patient's histories [11] are some issues that the patient or any member of the patient's family experienced.

III. BACKGROUND STUDY

Many expert systems have been developed for kidney disease [14]-[16].For example , S. Soman, G. Zasuwa and J. Yee built an expert system for chronic kidney disease which is a clinical support system[17] ,E Crowe , D Halpin,P Stevens developed an expert system on the identification and management of chronic kidney disease [18]. But the expert system represented in this paper is based on only the signs and symptoms of Chronic Kidney Disease which is not implemented before. Besides RIMER methodology is used for the first time to suspect CKD.

IV. OVERVIEW OF RIMER METHODOLOGY

An expert system has two components: a knowledge base and an inference engine. To construct the knowledge base rules are established by the experts. User's observation facts are also considered in this case. A rule based system supports human for decision making and handling uncertainties. An uncertainty comes from vagueness and incompleteness that come from human knowledge limitations. The proposed system is developed based on Rule base Inference Methodology using Evidential Reasoning (RIMER) Approach. The knowledge of the expert system is constructed by the collection of some If-Then rules from the experts. The basic rule base representation is done as

If {(Anemia is High) ^ (Bleeding diathesis is Medium)} then {Hematologic condition is (High, 0.6), (Medium, 0.3), (Low, 0.1)}

In this system, inputs are provided based on the signs, symptoms and histories of the patients. The inputs may be High, Medium or Low for each sign, symptom or the history. For example, if a patient says that he/she does not sleep at all then, the input for the 'sleep disorder' will be 'High'.

In RIMER approach, inputs for each attribute are transformed into referential values [7]. For that, some matching degrees are used. For example, 1 is transformed into (High, 1.0) or 0.5 is transformed into (Medium, 1.0). When the patient provides the input 'High' the system takes the input '1' and transform that into referential values like, (H, 0.4), (M, 0.5), (L,0.1). After that, the system calculate the activation weights and update the degree of belief if the degrees provided by the experts are not complete. For example, if the consequence of a rule is {(H, 0.4), (M, 0.4), (L, 0.1).} then, the degree of belief is not complete because 0.4+0.4+0.1<1.0. At that case, the degree of belief is needed to update.

The inference in RIMER approach is done by combining the all the belief rules. The rules are aggregated by using Evidential Reasoning (ER) Approach [7], [19]. ER approach calculates the probability masses [20] and unassigned probability masses [20]. Then it aggregates all the rules and provides the final results.

V. ASSESSMENT OF CHRONIC KIDNEY DISEASE

In this section, the design and implementation of Belief Rule Base Expert System (BRBES) to determine Chronic Kidney Disease is discussed. An architectural design of a computer based system is represented in the following figure.

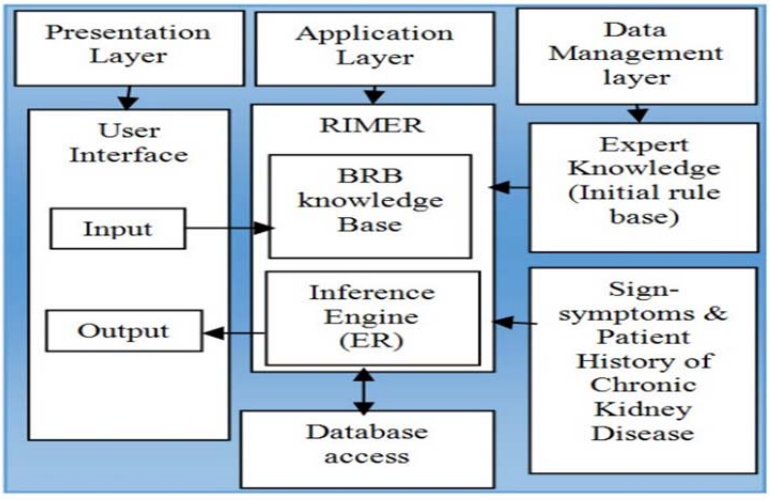
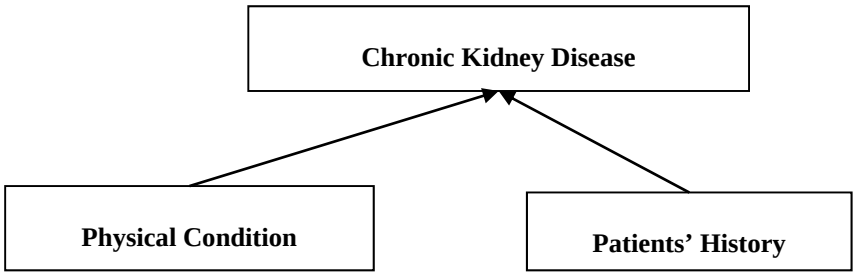


Fig. 1. BRBES Architecture

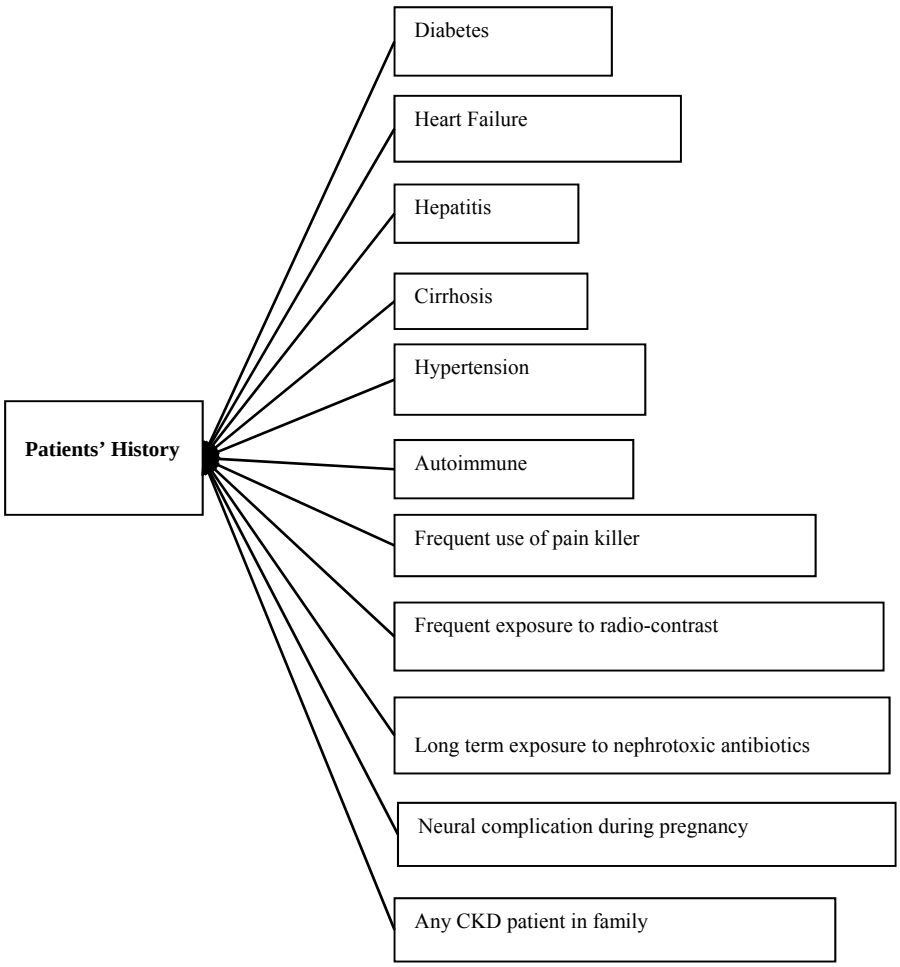
The BRBES architecture is a three layers architecture. The layers of BRBES are presentation layer, application layer and data management layer.

A. Knowledge Base Construction for the suspicion of CKD

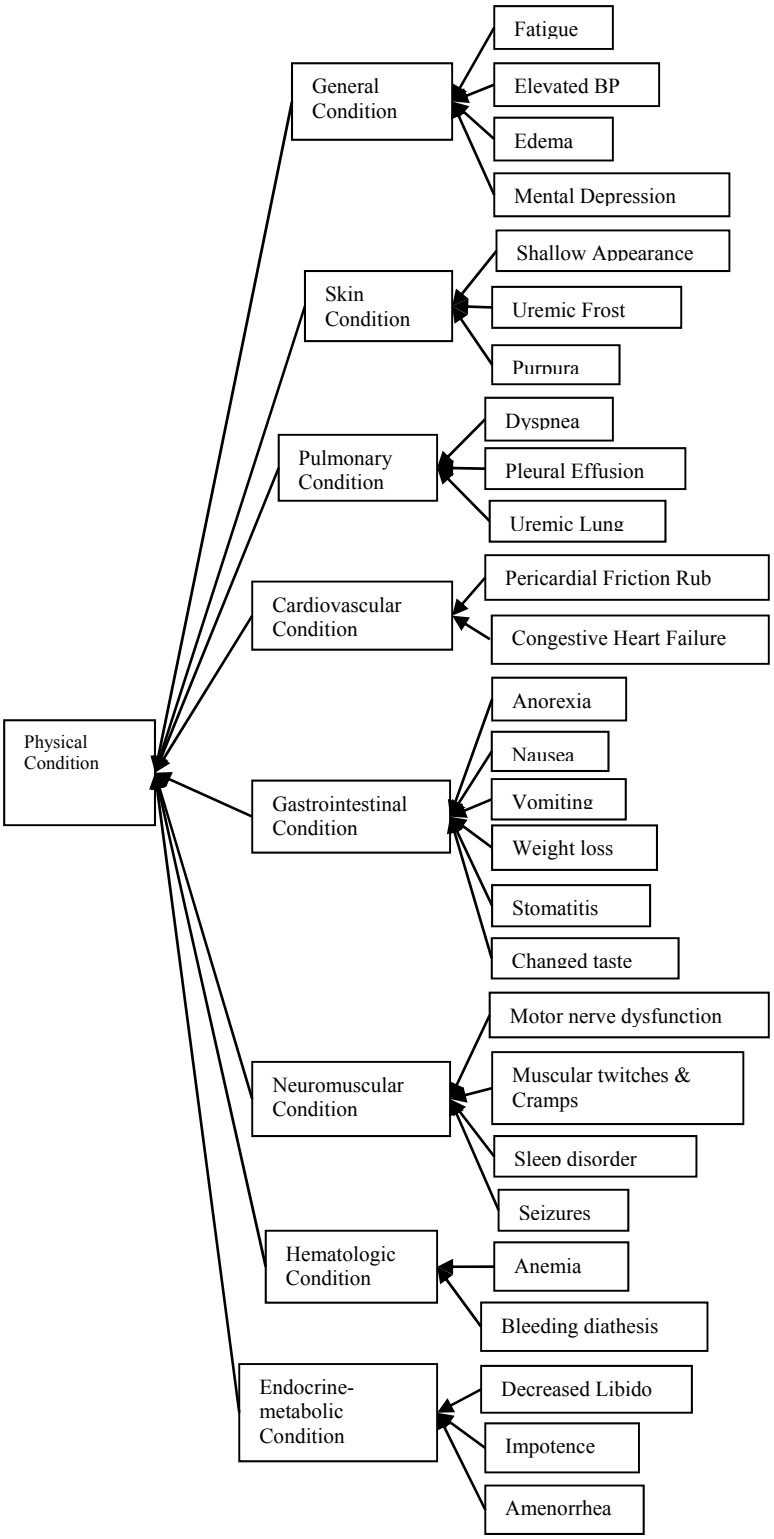
A BRB framework has been developed to construct a BRB knowledge base. For constructing this framework primary data are collected from Chittagong Medical College & Hospital. The domain knowledge is acquired from [1]-[6], [10]-[13]. The BRB framework is shown using an Architectural Theory Diagram (ATD) which is shown in the following figure:



(a)



(b)



(c)

Fig. 2. BRB framework represented through ATD

B. Inference Engine

Finally, an inference engine is developed based on Evidential Reasoning Algorithm to determine CKD [7], [20]. The inference engine acquires the inputs from patient or physician. The expert assign rule weights and attribute weights based on which rules are given relative importance. The final aggregation is done by using the ER Approach. The combined rules provides the final results. The results generated by system are represented through some confidence level. For example, the result for a certain patient may be {(H, 0.6), (M, 0.3), (L,

0.0)}. This results mean, the system is 60% sure that the CKD level of that patient is High, 30% sure that the CKD level is Medium and 0% sure that the level is Low. The remaining 10% is unknown.

VI. RESULTS AND DISCUSSION

Signs, symptoms and histories of the patients are considered as the clinical data which are used to suspect Chronic Kidney Disease. The expert system is used to suspect CKD in some patients and the results are estimated. The results of a patient is shown in the following figure.

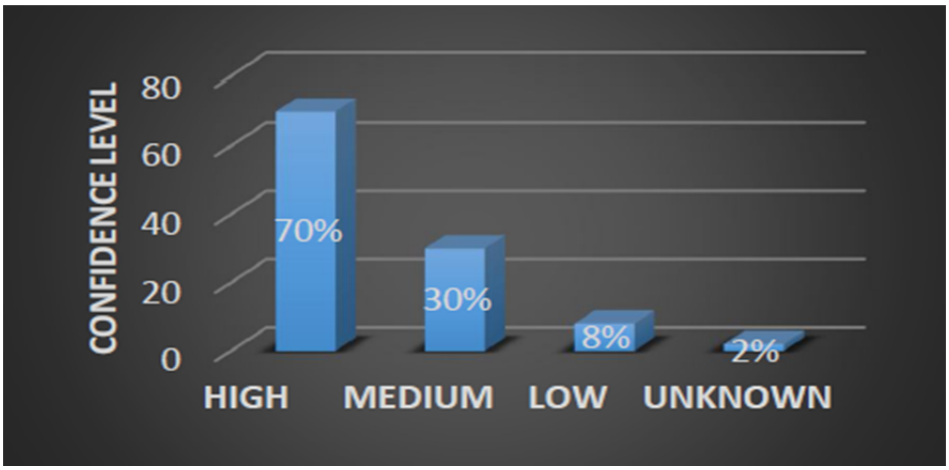


Fig. 3. Results of a CKD patient

The manual suspicion of CKD is done by the help of two physicians. A comparison between the suspicion efficiency of the manual system and the expert system is presented in the following figure to show that the proposed expert system provides a better performance in the suspicion of CKD than the existing manual systems.

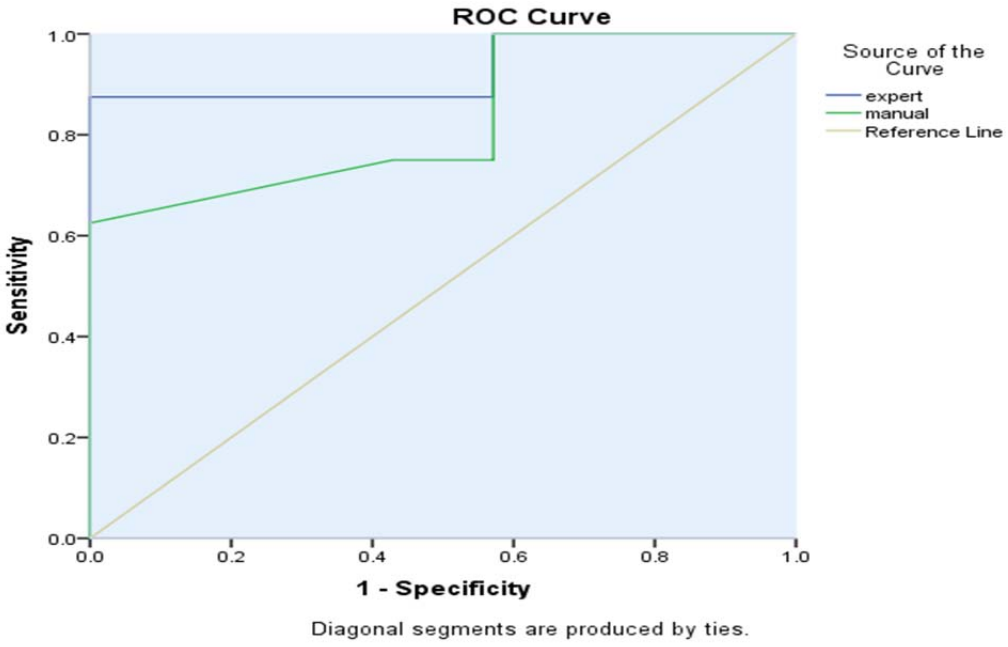


Fig. 4. ROC Curves Illustrate the Performance of BRB Expert System and Manual System

The above figure shows two ROC (Receiver Operating Characteristics Curve) curves. The green curve represents the manual system's performance in the suspicion of Chronic Kidney Disease where the blue curve shows the performance of expert system in the suspicion of Chronic Kidney Disease. The AUC (area under curve) of manual system is 0.830 where AUC of expert system is 0.929. So, it becomes clear that expert system provides the better performance than the manual system in the suspicion of Chronic Kidney Disease.

VII. CONCLUSION

The objective of this research is to suspect Chronic Kidney Disease dealing with uncertainty. It is a matter of great regret that CKD is rarely suspected primarily. So implementing an expert system that suspects CKD in the earliest time is necessary. The system is implemented with a very user friendly interface. The physicians can use the system easily.

In future, a rich knowledge base will be developed with a huge number of rule bases. At that time the system will be more accurate, robust and powerful.

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