Expert system for diagnosing and prescribing the treatment for three of the heart diseases (myocardial infarction, angina and rheumatic fever)

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Abstract

This paper studies an essential topic in artificial intelligence that deals with the process of diagnosing and prescribing the medication for three heart diseases, namely myocardial infarction, angina and rheumatic fever, using expert system technique. The proposed expert system will assist beginner physicians in detecting and describing treatment for the disease, beside, reducing the time for a correct diagnosis and diagnostic errors. This technique has been designed using visual basic programming language and SQL for the database, and has tested in the Sudan's Center for the Heart Diseases and its experimental results showed that this system did quite better than non-expert physicians and about 57% as a well as the expert did.

Keywords: Heart diseases, diagnosis, expert system.

Introduction

Heart diseases are one of the major causes of death, and are common not only in old and middle aged people but also in young people and it is caused due to improper diet habits [1]. The diagnosis process of these diseases is very tedious and hard, because they have the same symptoms and need all most the same investigations and laboratory tests [2]; the diagnostic process requires sufficient knowledge about the specific domain [3]. In some developing countries with large number of population; the ratio of physicians to population is equal to or less than 1 to 10000 (One physician for every ten thousands persons) and physicians includes both generalists and specialists [2]. In such countries there is a shortage of experts in all medical specialties.

Expert system is a computer program capable of performing at a human-expert level in a narrow problem domain area [4]. This technology has been used in the field of medical diagnosis to obtain medical knowledge in a computer and diagnose the diseases that usually require human expertise.

Many researchers treated with this problem and suggested different types of expert systems for the diagnosis of many diseases. But despite all those efforts still there is a considerable need for more expert systems to meet the shortage of specialist physicians. Various expert systems have been developed to work in the field of medical diagnosis to aid the medical experts in diagnosing certain diseases or helping the layman to diagnose the disease themselves [5]. The intelligent systems which used the pure expert system technology [6-9], depends on the rule based system (production rules) and inference technique (forward or backward). These systems represent their knowledge in a form of if-then rules and surely can explain how they arrive to a particular solution. However they have not the ability to learn independently from human intervention and they cannot deal with incomplete and noisy data, moreover they cannot deal with fuzzy information (continuous data).

According to the previous studies there are four groups of intelligent systems have been applied in medical diagnosis: The first expert system for medical diagnosis and the most well known is (MYCIN) [6]. This expert system was developed by Shortliffe at Stanford University in 1976 to help physicians in diagnosing and treating patients with infectious blood diseases caused by bacteria in the blood and meningitis. That expert system used rule based system for the knowledge representation and it used the backward chaining as the inference technique. It has been designed by using lisp programming language. It contained explanation system to explain results. Researchers at Stanford found that MYCIN has an approximate correctness rate of 65%, which is better than the majority of physicians who are not specialists in diagnosing infections, and only slightly worse than physicians who were experts in that field (who had an average correctness of approximately 80%). However the big problem of MYCIN is that under specific conditions it may produce wrong decisions and makes mistakes in diagnosis process. If a patient has more than one disease, we cannot rely on MYCIN. In fact, therapy prescribed for the blood disease, might even be harmful because the other disease. Beside that MYCIN expert system cannot learn by itself and produce new knowledge separately from the human expert, only human expert can add to or modify the knowledge base of MYCIN expert system.

Diagnosis of eye diseases [7], is an expert system designed for diagnosis eye disease using CLIPS (C Language Integrated Production System). A set of rules is created where each rule contains an IF part that has the symptoms and in THEN part has the disease that should be realized. The inference engine (forward reasoning) is a mechanism through which rules are selected to be fired. This expert system has an explanation facility to explain results. The scope of this technique is the following eye diseases: discharge from the eye, bulging eye, double vision and dropping eyelid. However the system has a correctness rate of 42%, when compared to manual diagnosis; this system cannot learn by itself.

The intelligent systems which used the fuzzy system technology [10-13], with inference technique such as Mamdani or

Sugino, can deal with continuous data and they can also explain their results. However they cannot learn by themselves, deal with incomplete and noisy data.

A Fuzzy expert system for heart disease diagnosis [10], has 13 input fields for symptoms and risk factors and one output field refers to the presence of heart disease in the patient. This system uses Mamdani inference method. The results obtained from designed system are compared with the data in upon database and observed results of designed system are correct in 94%. The system designed in Matlab software. However the system in its output does not determine the heart disease namely, it just indicates there is a problem in the heart to some extent. Moreover, it has not any mechanism for machine learning or capable of justifying and explaining its conclusion.

The intelligent systems which used combination of neural networks technology and rough set technology have the ability to learn without human intervention and also they can deal with incomplete and noisy data [14-16]. However they cannot justify or explain their results, deal with fuzzy and continuous data.

A rough neural expert system for hepatitis diseases is a hybrid architecture of expert systems which is based on the connectionist neural networks and the reduction of rough set analysis [14]. Knowledge acquisition process happened by using two techniques, the first one by using rough sets as a mathematical representation, and the other technique by using the network. The two techniques are formed the hybrid expert system. This system has the ability to learn without human intervention and also can deal with incomplete or noisy data (generalization). However, it has not the ability to justify or explain their conclusions, deal with fuzzy or continuous input values.

A rough neural expert system for coronary artery disease is combination of rough set theory and neural networks [15]. The system has the ability to learn without human intervention and also can deal with incomplete or noisy data. However, it has not the ability to justify or explain their conclusions, deal with fuzzy or continuous input values.

The intelligent systems which used the neural networks technology, with different structures, topology, and learning methods (supervised, unsupervised, etc) have the ability to learn without human intervention and they can treat with incomplete and noisy data [14, 17, 18]. However they cannot deal with fuzzy or continuous data, justify or explain their results.

Karabatak and Ince proposed an automatic diagnosis system for detecting breast cancer [17]. This system based on association rules and neural network. The association rules are used for reducing the dimension of breast cancer database, and neural network is used for intelligent classification. The system has the ability to learn without human intervention and also can deal with incomplete or noisy data. However, it has not the ability to justify or explain their conclusions, deal with fuzzy or continuous input values.

A computerized system to aid in the detection and classification of coronary artery diseases is using forward neural network as the structure of the network and back propagation algorithm as learning algorithm [14]. The final results show that the performance of neural network is better than junior doctors but worse than experienced radiologists. This system has the ability to learn without human intervention and also can deal with incomplete or noisy data. However, it has not the ability to justify or explain their conclusions, deal with fuzzy or continuous input values.

In this study, an expert system has proposed to diagnose and prescribe the medication for three heart diseases, namely Myocardial infarction, Angina and Rheumatic fever.

Materials and methods

An expert system [3] includes the following was used in this study.

Knowledge acquisition

Knowledge acquisition on the specific domain (heart diseases), interview with experts (physicians) and reading some specific references on heart disease diagnosis has been done [2], Table 1 displays the acquired knowledge about the diseases.

Table 1. Symptoms, risk factors, investigations and medications for three heart diseases.

Disease	Symptoms and risk factors	Investigations	Medications
Rheumatic fever	vomiting, joint swelling, fever, joint pain, epistaxis, abdominal pain, skin rash, skin nodules, the season	ESR, C-reactive protein, Blood Pressure, ASO-Titer	bed rest, Penicillin, Erythromycin, Aspirin, Anti-inflammatory medications
Angina	crashing, tightness, wheezing, chest pain	CPK, Blood pressure, Echocardiography	stop smoking, lose weight, control blood pressure, control diabetes, control cholesterol, Aspirin, Antianginal medication, Nitrates-Beta blockers, Calciumchannal blocker
Myocardial infraction	Tightness, Diaphoresis, Anxiety, Cough, Vomiting, Wheezing, Chest pain, The age	CPK, SGOT, LDH, ESR, ASO-Titer, ECG	exercise program, lose weight, control blood pressure, control diabetes, control cholesterol, modify diet, stop smoking

Knowledge representation

Rule-Based deduction [3] has been used in knowledge representation, which means a set of rules told what should be done or what can be concluded in different situations. This system consists of a set of IF-THEN rules, a set of facts normally representing things that are currently held to be true. in this study the facts are the patient's symptoms and the other necessary information (the risk factors) which required for the diagnosis process, and as the result of these two factors the necessary investigations will be determined. According to the results of the laboratory tests, the disease has been determined and the treatment has been prescribed. Therefore, the rule-base system will be looked like that:

IF the symptoms are chest pain AND tightness AND diaphoresis AND anxiety AND cough AND wheezing AND the age > 45 THEN the investigations are CPK AND SGOT AND LDH AND ESR AND ASO-Titer AND ECG.

IF the symptoms are chest pain AND tightness AND wheezing AND crashing THEN the investigations are CPK AND Blood Pressure AND ECG AND Echocardiography.

IF the symptoms are vomiting AND fever AND joint pain AND joint swelling AND epistaxis AND abdominal pain AND skin rash AND skin nodules AND the season is autumn OR winter THEN the required investigations are ESR AND C-reactive protein AND Blood Pressure AND ASO-Titer.

IF the result of the investigations are CPK$>$4 AND SGOT$>$40 AND LDH$>$300 AND ESR is high AND ASO-Titer is positive AND ECG is Q-wave THEN the disease is Myocardial infarction.

IF the result of the investigations are CPK$>$8 AND Blood Pressure > 120/80 AND ECG is Q-wave AND Echocardiography is abnormal THEN the disease is Angina.

IF the result of the investigations are ESR is high AND C-reactive protein is positive AND Blood Pressure >120/80 AND ASO-Titer is positive THEN the disease is Rheumatic Fever.

IF the result of the investigations are CPK=4 AND SGOT=40 AND LDH=300 AND ESR is high AND ASO-Titer is positive AND ECG is Q-wave THEN meet the specialist doctor.

IF the result of the investigations are CPK=8 AND Blood Pressure = 120/80 AND ECG is Q-wave AND Echocardiography is abnormal THEN meet the specialist doctor.

IF the result of the investigations are ESR is high AND C-reactive protein is positive AND Blood Pressure =120/80 AND ASO-Titer is positive THEN meet the specialist doctor.

IF the disease is Myocardial infarction THEN Control cardiac risk factors whenever possible. Control blood pressure and total cholesterol level, reduce or avoid smoking, modify diet (increase high density lipoproteins, decrease low density lipoproteins) if necessary, control diabetes, lose weight if overweight. Follow an exercise program to improve cardiovascular fitness. (Consult the health care provider first).

IF the disease is Angina THEN preventions are stop smoking, lose weight if overweight, Control blood pressure, diabetes, cholesterol AND treatment aspirin, antianginal, medication, such as nitrates (nitroglycerin), beta-blocker, calciumchannal-blocker, or others may be prescribed to prevent the occurrence of angina and lessen its severity.

IF the disease is Rheumatic Fever THEN Treatment: Antibiotics, preferably penicillin or erythromycin, are used to fight the infection. Antibiotics may be given long-term for chronic or resistant cases. Medication to reduce pain and swelling include aspirin, anti-inflammatory medications (NSAIDS and corticosteroid-oral), and analgesics. (Consult with your health care provider before giving aspirin or NSAIDS to children) Reduce your physical activity. Bed rest may be recommended for a time to allow the body to heal. Fluids are encouraged, often at least 6 to 8 glasses of water per day.

Inference technique

The forward chaining has been used as the inference technique, in this technique, the system starts with some initial facts, and keeps using the rules to draw new conclusions (or take certain actions) in order to create new data. The forward chaining for this expert system like the following:

The symptoms of the diseases and the other necessary information for the diagnostic process (risk factors) such as sex and age, those initial facts will determine the necessary laboratory tests and other investigations as conclusion.

The previous conclusion (the result of the laboratory tests and the investigations) will become the new facts which used to deduce the diagnosis of the disease as the new conclusion.

The diagnosis result (the disease) will become the new fact which used to deduce the treatment as the final conclusion.

If an Angina disease has taken as an example for explaining the forward chaining inference technique, the logic of the operation would become like this:

Consider the rule and facts in the following:

R1: IF the symptoms are chest pain AND tightness AND wheezing AND short duration AND crashing THEN the investigations are CPK AND Blood Pressure AND ECG AND Echocardiography.

R2: IF the result of the investigations are CPK>8 AND Blood Pressure >120/80 AND ECG is Q-wave AND Echocardiography is abnormal THEN the disease is Angina.

R3: IF the disease is Angina THEN preventions are stop smoking, lose weight if overweight, control blood pressure, diabetes, cholesterol AND treatment aspirin, antianginal, medication, such as nitrates (nitroglycerin),betablockers,calciumchannal blocker, or others may be prescribed to prevent the occurrence of angina and lessen its severity.

The patient comes and tells about his own suffering with the disease and his symptoms. If the symptoms of the patient are like the following:

Chest pain, tightness, wheezing, short duration, crashing.

So the initial fact looks like the following:

F1: chest pain, tightness, wheezing, short duration and crashing.

Initially the system checks to find the rules whose conditions hold, given the fact (F1). The only such rule is rule (R1), so this rule is selected and its action (The investigations are CPK AND Blood Pressure AND ECG AND Echocardiography) is performed.

Suppose that:

The result of the investigations are CPK>8 AND Blood Pressure >120/80 AND ECG is Q-wave AND Echocardiography is abnormal.

When the result of the investigations comes, and has been inputted to the system as a new fact (F2), the cycle starts again. This time the conditions of the second rule (R2) hold. So the action (the disease is Angina) is performed. After determining the disease, the disease itself has been inputted to the system as a new fact (F3), this time the condition of the third rule (R3) hold to produce the treatment and preventions.

User interface

Visual basic programming language has used to design a graphical user interface, because it provides a nice clean interface. SQL was used for the date base to save the data entered into the expert system during the execution.

Results

Medical data set from Sudan's Center of the Heart Diseases has been extracted to use as examples for the expert system. The data set included symptoms, risk factors, laboratory tests and medications about the three diseases.

The results of the experiment for the Angina disease are shown in the following figures; Figure 1 shows the process of entering the symptoms and risk factors to the expert system. Figure 2 shows the laboratory tests which determined by the expert system. Figure 3 shows the laboratory test results which entered into the system. Figure 4 shows the diagnosing process of the disease.

Figure 5 show that the program determined the treatment of Angina disease. Finally, Figure 6 shows a sample of the final report.

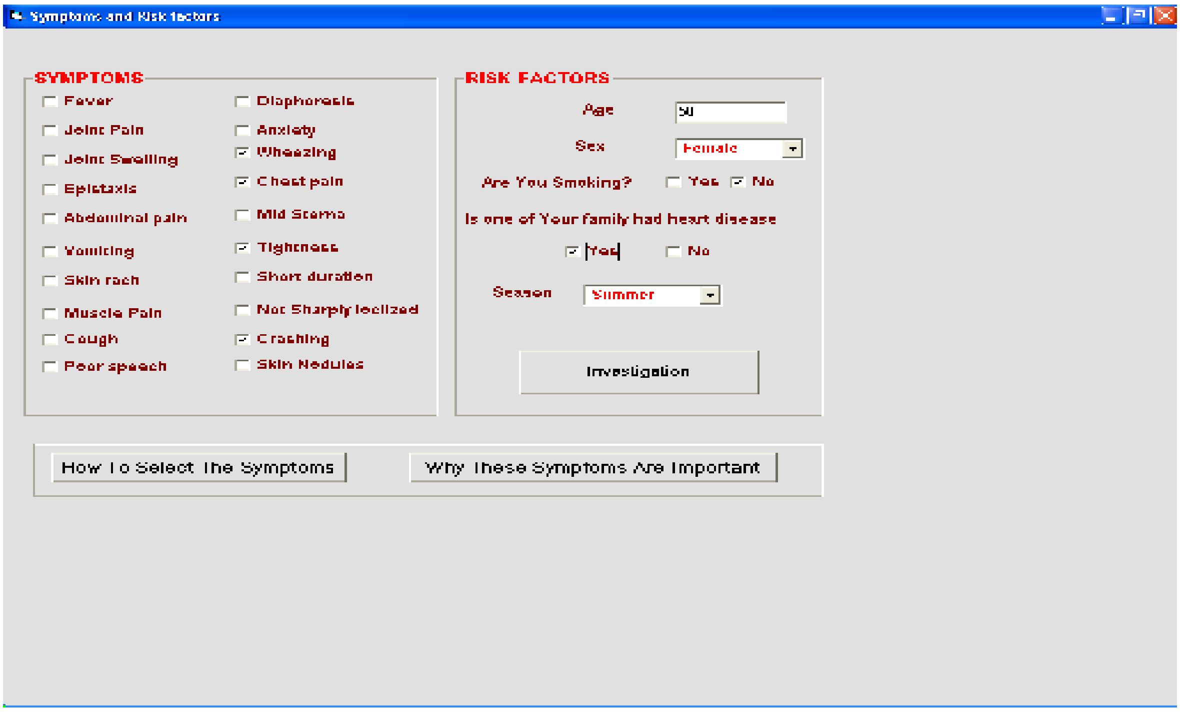

Figure 1. Angina's symptoms

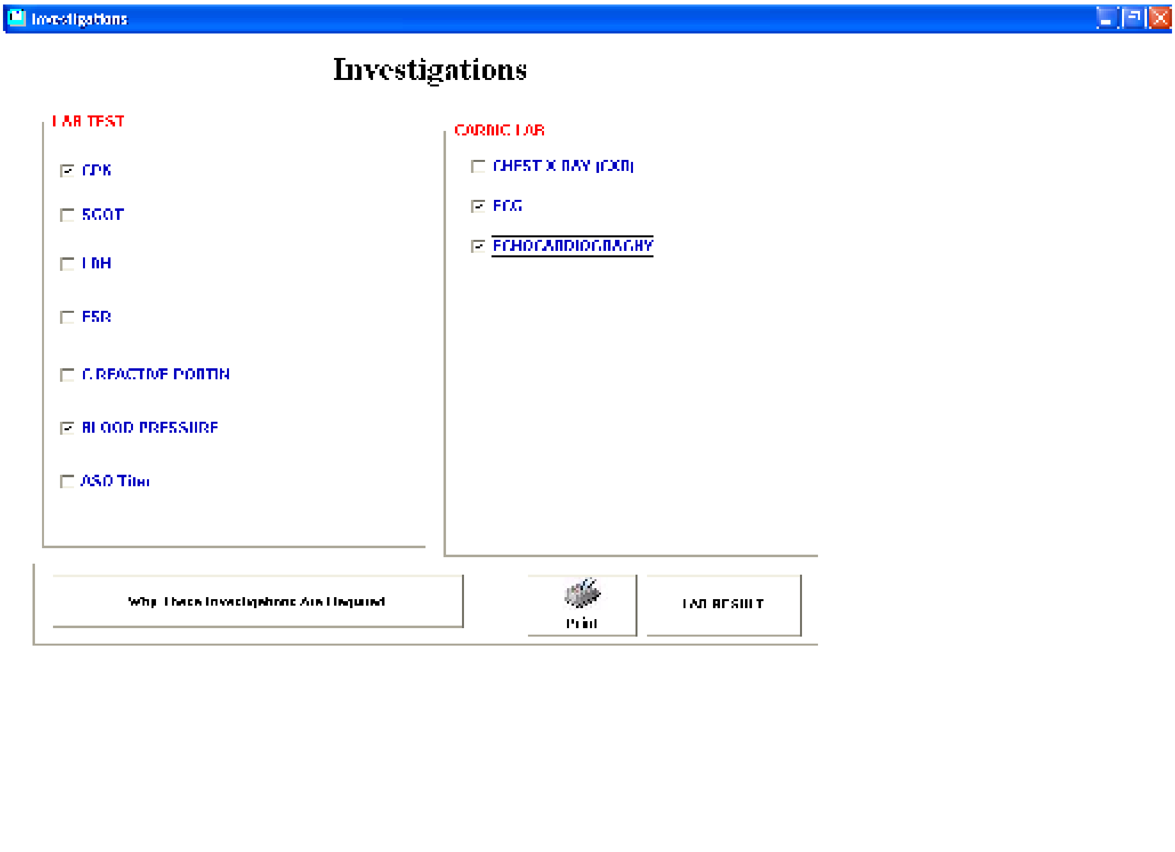

Figure 2. Angina's tests

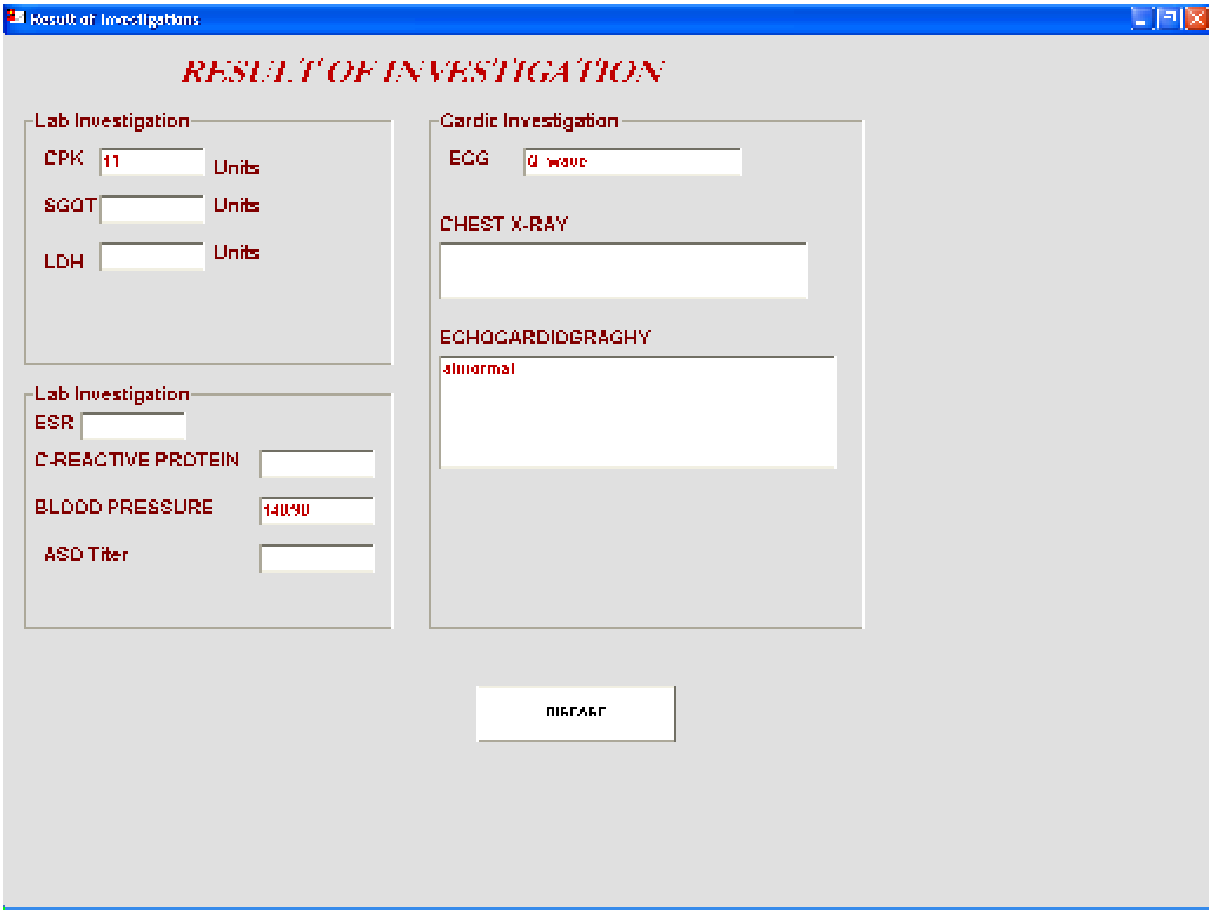

Figure 3. Angina laboratory test results

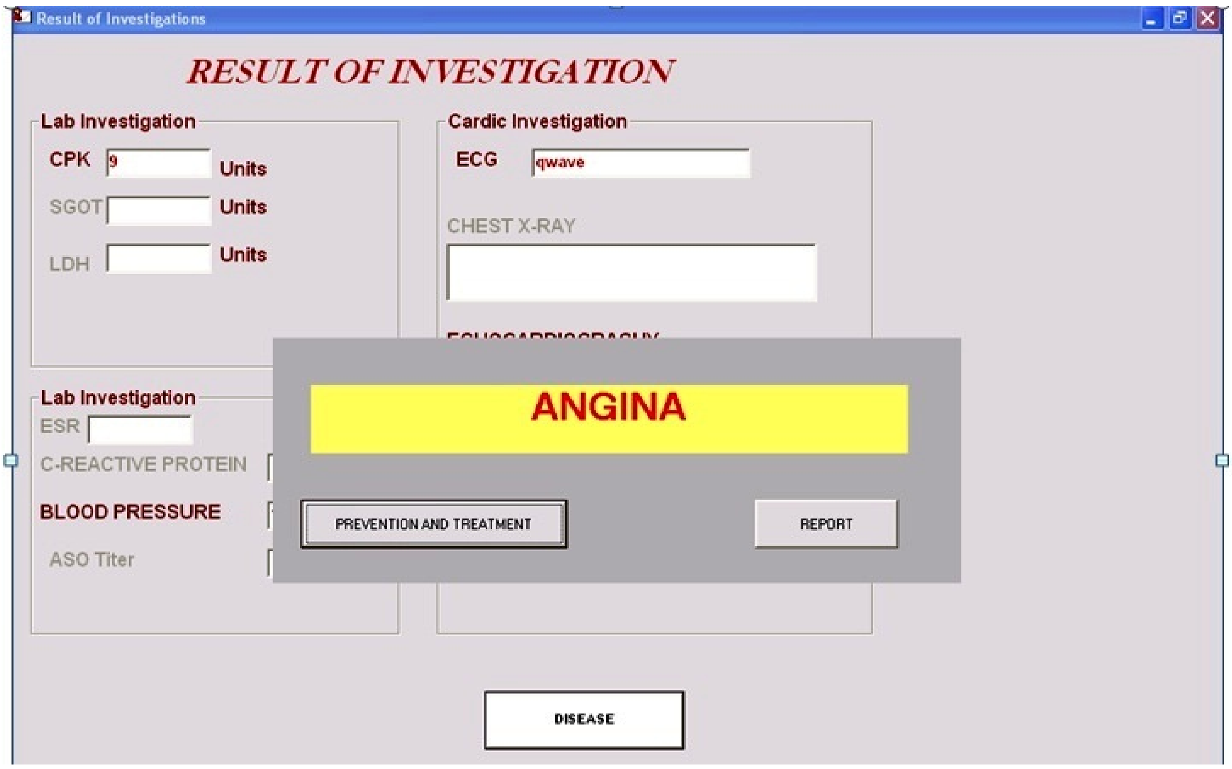

Figure 4. Angina diagnosis.

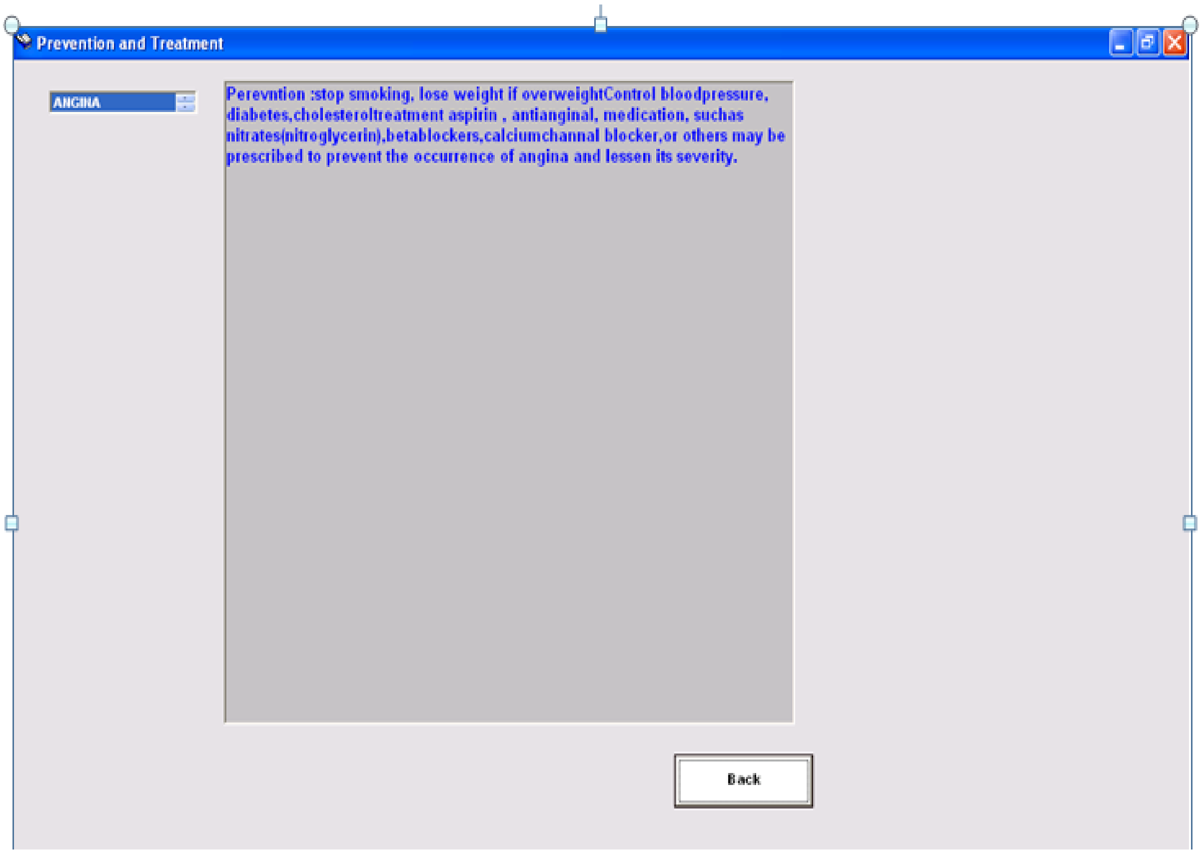

Figure 5. Angina treatments.

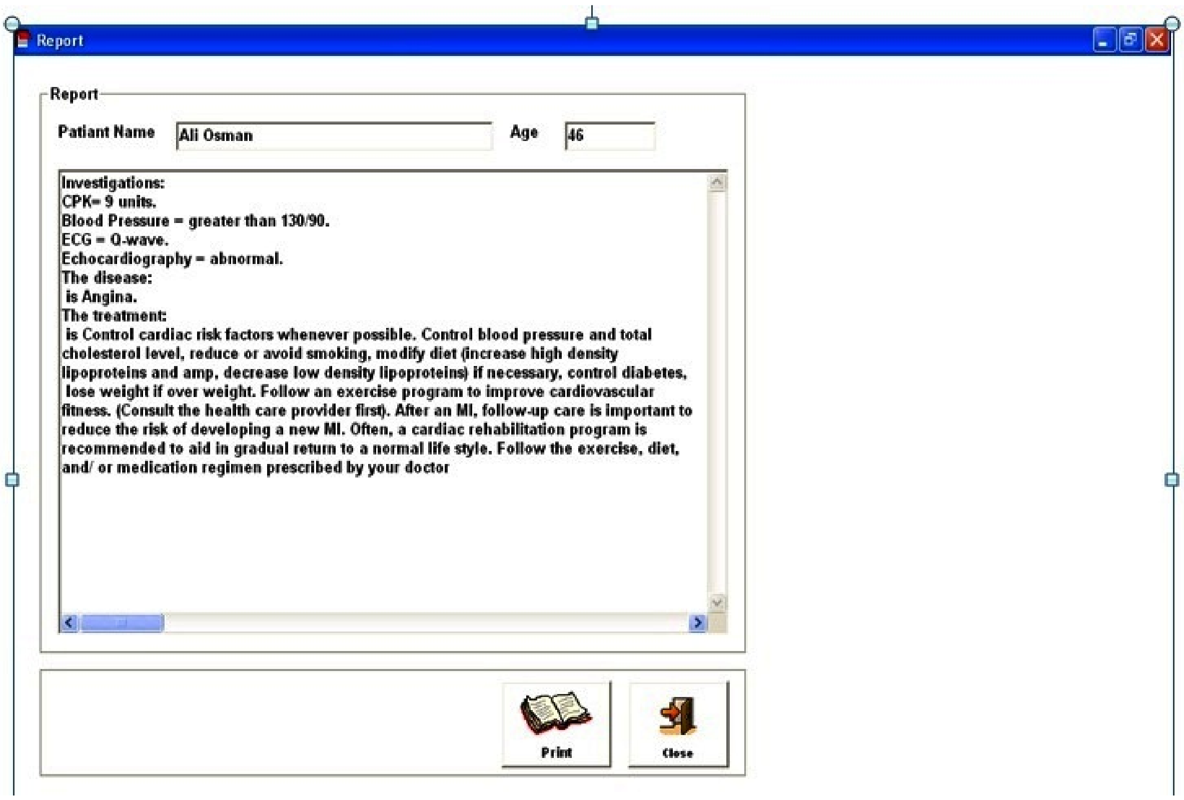

Figure 6. Final report.

Discussion

This system simulates the manner of expert-physicians, and it has been designed in way that used by them. The expected user of the system is someone related with the knowledge specific domain (generalist physician).

The experiment gives more accurate results once the risk factors and symptoms of the disease are clearly known. This expert system has evaluated in Sudan's center for heart diseases and they found it has an approximate correctness rate 57%, it gave better results when comparing to non specialist physicians.

In some situations the expert system does not make the diagnosis because, the result of laboratory tests are not sufficient enough to diagnose the disease and in such case the system recommended the patient to meet the specialist doctor as shown in figure 7.

If we compare the proposed expert system in this study with similar systems in literature such as MYCIN [6] and the expert system which diagnoses eye diseases [7], according to their performance accuracy despite each one prepared to diagnose different type of diseases. As shown in Table 2 the proposed system worse than MYCIN (which had an average correctness of approximately 65%) and better than diagnosis eye diseases system (which had an average correctness of approximately 42%).

Advantages of the system:

- Increased productivity (find solutions much faster than human).
- Availability of expertise (human expert can't be at one place all the time).
- Can be used by non specialist doctors.
- May be useful to the beginner doctors, because it contains detailed information about the three heart diseases.
- The system has ability to explain and justify its conclusions.

Limitations of the system:

- The information about medication must be refreshed frequently.
- The system cannot deal with incomplete and noisy data.
- Effective only for narrow specific area (just only the three heart diseases).
- The system cannot learn from experience or adapt to new environments without human intervention.
- The system cannot deal with fuzzy information (continuous data).

Conclusion

This study proposed new expert system for diagnosing and prescribing treatments for three of the heart diseases (Myocardial infarction, Angina and Rheumatic fever) using the technology of expert system. This system has an ability to justify and explain its conclusions.

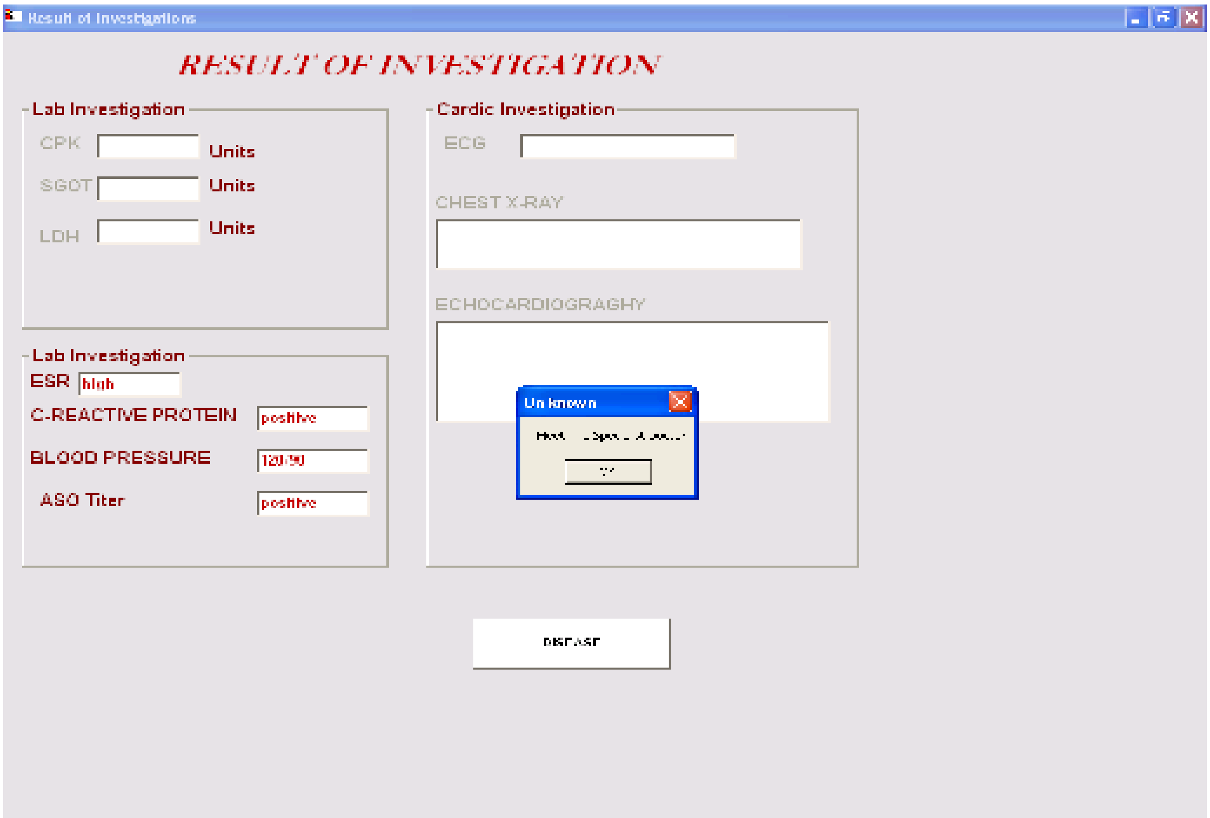

Figure 7. Recommendation for the patient to meet specialist physician.

Table 2. Performance comparison.

Expert system	Disease	Investigations
The proposed expert system	Heart diseases	57%
MYCIN	Infectious blood diseases	65%
[7]	Eye diseases	42%

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