Expert System for Diagnosing Prostate Cancer Disease

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Abstract

Prostate cancer is one of the most spread cancer male diseases. Prostate cancer therapy such as operation of removing the prostate gland and tissues that surrounds it is a way more effective when the cancer is not spread beyond the organ itself. The purpose of this project is to build the expert system to predict diagnosis of prostate cancer disease with different categories and classification of patients. Our project's main goal is to diagnose prostate cancer at an early stage using the most efficient factors such as PSA (Prostate Specific Antigen), age, and PV (Prostate Volume). In order to have better health of patients and people awareness of the prostate cancer disease and to understand the disease risk, we will create Knowledge Database with facts and rules within the expert system. In this system we shall implement the model for predicting the diagnose where a system asks the patient diagnostic questions based on medical symptoms and factors that cause the prostate cancer disease. After answering on questions are done, the system should predict, and in one scenario, show diagnose to the patient using fuzzy logic to classify risk level of disease, or in second scenario tell a patient to visit a doctor for further test. The expert system will be created using Prolog software.

Keywords: prostate cancer, expert system, fuzzy logic, diagnosis

1. Introduction

As one of the most common malignancy in the world among male population, prostate cancer cure has two types of staging that could be done: Clinical Staging (before surgery) and Pathological Staging (after or during surgery). The highest chances of the cure of the prostate cancer in the Pathological Stage is when the cancer is restricted among the prostate (confined).

2. Literature Review

a. Paper (1): A fuzzy expert system design for diagnosis of prostate cancer

According to a research paper [1] , it was shown that the researchers developed a fuzzy expert system (FES) that simulate the expert doctor's behavior to diagnose patients for Prostate cancer based on three parameters as input; Prostate specific antigen (PSA), Age of the patient and Prostate volume (PV). The output after analyzing the input parameters will be the risk factor of having a prostate cancer (PCR), and the needs for taking a biopsy test.

The inputs and outputs were used are fuzzy inputs and outputs. The fuzzification is a process of categorize the crisp values into fuzzy values [2]. The fuzzy inputs were processed of the PSA are very low (VL), low (L), Middle (M), high(H), very high (VH). As for the age, the inputs are converted into (very young, young, middle age, old). Lastly, for the PV the inputs are converted into very small (VS), small (S), middle (M), high (H). Additionally, for the output, which is the PCR, the values were converted into very low (VL), low (L), middle (M), high (H), very high (VH). [1]. The system fails to acknowledge if the patient has cancer or not. However, it does provide a percentage of prostate cancer and assists the doctor in determining whether to do biopsy for the patient or not. Moreover, it can be used as a learning system for medical students.

b. Paper (2): Fuzzy Expert System for Prediction of Prostate Cancer

Fuzzy expert system also known as FES is a system that works based on the fuzzy logic approach. The system is designed to process input data given by the user which are predefined. The paper has used Mamdani (max - min) method. Each input by the user will trigger a rule to be fired in order to produce an output. The inputs that have been used by the paper are age, prostate volume, Prostate Specific Antigen (PSA), and Percentage of Free Prostate Specific Antigen. Each of these inputs has been categorized based on range [3].

The expert system designed in the paper works in a way that all the attributes are separated into three or more fuzzy sets. The system would check for any abnormal values entered by the user [3].

After taking into consideration all the input set by the user and following the rulesets. The expert system will calculate the risk of getting prostate cancer. The risk is also categorized into three sets which are low, middle, and high. Each set corresponds to a range of values [3]. The

researchers have used their system to diagnose 119 patients. 61 of them had prostate cancer. The expert system was able to diagnose with an accuracy of 68.91%.

c. Paper (3): A fuzzy logic-based method for prognostic decision making in breast and prostate cancers

The main idea for this research were to measure the performance between 3 methods for prognostic classification for prostate and breast cancers. But for the sake of our project we will highlight on prostate cancer [4]. The 3 methods were as following:

1. Traditional statistical method
2. Neural network method
3. Fuzzy method

The results of highest predictions accuracy were as following

a) The traditional statistical method achieved 65.9% predictive accuracy.
b) The neural network method achieved 63.4% predictive accuracy.
c) The Fuzzy method achieved 68.3% predictive accuracy.

The results of prognostic markers subsets which achieved the highest predictive accuracy were as following:

1. Traditional statistical method
    - {Gleason score, skeletal metastasis, tumor stage, P53 gene immunostaining, BCL2 gene immunostaining, treatment type}
    - {Gleason score, skeletal metastasis, tumor stage, treatment type}
2. Neural network method
    - {skeletal metastasis, tumor stage, P53 gene immunostaining, BCL2 immunostaining, treatment type}
    - {BCL2 gene immunostaining, treatment type, serum PSA}
3. Fuzzy method
    - {Gleason score, skeletal metastasis, P53 gene immunostaining, treatment type, serum PSA}

We concluded that there are no enormous contrasts between indexes values when they excluded P53 gene immunostaining from the model. Consequently, we can conclude that the subset {Gleason score, skeletal metastasis, P53 gene immunostaining, treatment type, serum PSA} is the ideal subset as their assessment is concerned. In addition, there is only one common marker in these subsets which is treatment type, which may show the significant of it. However, the Fuzzy method shows that serum PSA might be the main marker because the predictive accuracy decreases whenever they removed the serum PSA from the model so we infer that treatment type and serum PSA are the main markers to prostate cancer prognosis as when they are taken out from the model the corresponding accuracy reach it lowest [4].

d. Paper (4): Fuzzy expert system for predicting pathological stage of prostate cancer

The purpose of this research is to analyze the performance and efficiency of the expert system with different categories and classification of patients, patients with confined and non-confined prostate cancer. The method used relies on Fuzzy Set Theory, where fuzzy expert system is implemented with appropriate rules and functions by a genetic algorithm where randomly generated chromosome consist of fuzzy rule-based system. [5]. The main aim of this research is to analyze the use of expert system combining, one of the most efficient factors (Prostate-specific antigen (PSA), clinical stage, and Gleason score) to predict the diagnose of prostate cancer. The essential tools for making medical decision are predictive tools which helps to choose the most appropriate and suitable actions. [5]

Eventually, based on the expert system rules and the range of entered attributes (factors) within the expert system including factors: PSA, Gleason score and clinical stage, generic algorithm will analyze and predict prostate cancer diagnose. [5]

e. Paper (5): Application of soft sets to diagnose the prostate cancer risk

According to this study [6], the researcher has used the fuzzy sets for prediction of prostate cancer risk. Using those sets, they tried to make the relation of weather their symptoms predict cancer or not. The major factors of the prostate cancer that this research paper take care the most are PSA (Prostate Specific Antigen), PV (Prostate Volume) and Age.

The research uses different methodologies and phases to create various types of sets based on different values for entered attributes (factors), to get the final outcome of the expert system.

Those rules and sets could be classified as diagnosis and fuzzification of the sets, fuzzy set to soft sets, soft rules, and rules generation [7]. They created the model using those listed factors, rules and sets which will determine patient risk of the prostate cancer. For more details about those rules refer to the original research paper [7], and to the rest of the papers for additional details in general.

3. Expert System Analysis and Design

After reviewing the literature studies, we decided to develop an expert system to diagnose prostate cancer. The system will be a rule-based system that has an inference engine and knowledge base to diagnose prostate cancer. Consequently, the system will ask the patient diagnostic questions. These questions have been selected based on the literature studies that have been discussed in previous sections of this document.

The question will start from general diagnostic questions up to the clinical questions. The patient will have to answer these questions. After that, the system will predict the likelihood of having the diseases or not, and whether he needs to do a biopsy test or not.

3.1 Questions of The System

The inputs of the system will be a series of question as listed in Table 1. The questions are divided into two parts. The first part, which are questions 1-10, are general questions which or usually symptoms and are asked by doctors in initial visits. The second part contains technical questions that could require further tests.

Table 1: Questions for Planned Expert System

# of Question	Question
Q1	Are you experiencing frequent urinations?
Q2	Is there pain while urinating?
Q3	Are you experiencing difficulties when urinating?
Q4	Have you noticed blood in urine?
Q5	Are you experiencing weak urination flow? (takes long time to urinate)
Q6	Do you feel unexpected pain back, hips and other bones?
Q7	Have you experienced unexpected weight loss?
Q8	Have you experienced swelling or fluid buildup in the legs or feet?
Q9	Do you feel discomfort while sitting?
Q10	How old are you?

Q11	What is your prostate volume?
Q12	What is your PSA (Prostate-specific antigen)?

i. General Questions

Questions from 1-10 that are listed in Table 1 usually are experienced by prostate cancer [8].

ii. Technical Questions

Questions 11 and 12 are from clinical tests and have been applied in almost all the literature studies that have been discussed previously. For the prostate volume, the average size of a healthy male is 20-30 ml [8]. As for PSA, any value that is greater than 18 should be considered as a risk [5].

3.2 The Output of The System

The output of the system will be a risk factor that indicates if the patient likely going to have the disease or not. Figure 1 demonstrates the flow of the system.

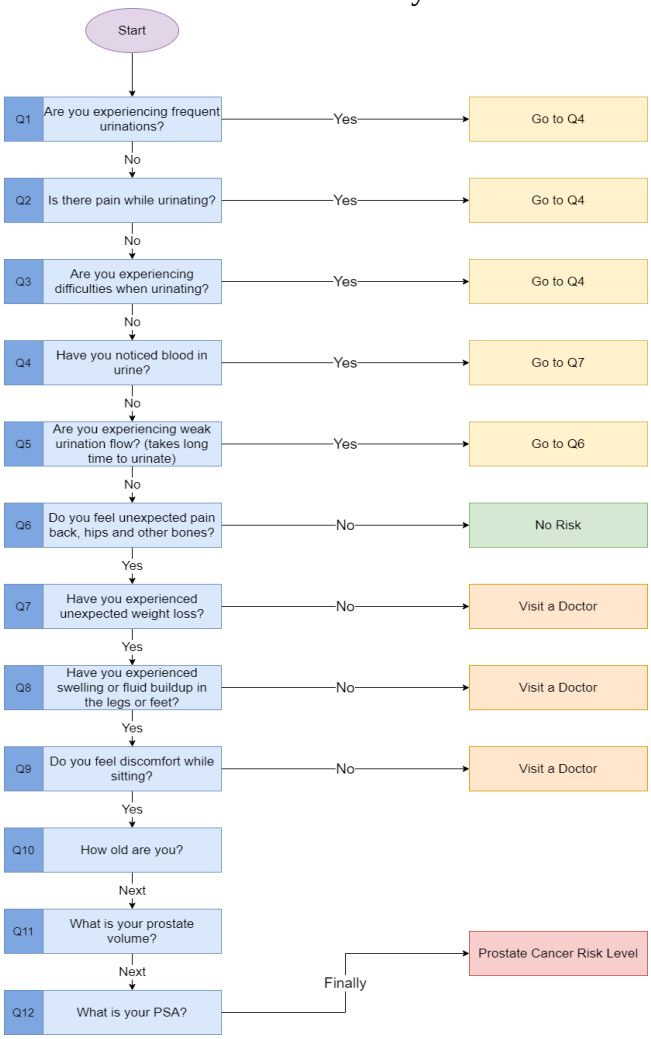


Figure 1: Planned Expert System Flowchart

4. Implementation and Testing

This project was made from a deep search for prostate cancer. Implementing it using an expert system for diagnosing patients. This expert system was implemented in Prolog software (AMD64, Multi-threaded, version 8.2.1). Referring to literature studies in chapter 2 to help us define the solution for the project problem statement. This system used the fuzzy approach that we have seen that suitable for our system based on literature studies.

Narrowing the literature reviews and analyzing it to generate 9 yes/no questions, and 3 questions with inputs that require deep analysis. It consists of 125 rules created from 3 attributes PV (Prostate volume), PSA (Prostate-specific antigen), and age. Each of them containing 5 categories shown in Table 2, which generated 5×5×5 = 125 in total.

Some of the generated rules are:

R1: IF a patient is Very Young and has Prostate Volume (PV) Very Small and PSA level is Very Low THEN Prostate Cancer Risk Level is Very Low

R2: IF a patient is Very Young and has Prostate Volume (PV) Very Small and PSA level is Low THEN Prostate Cancer Risk Level is Very Low

R3: IF a patient is Very Young and has Prostate Volume (PV) Very Small and PSA level is Middle THEN Prostate Cancer Risk Level is Low

R4: IF a patient is Very Young and has Prostate Volume (PV) Very Small and PSA level is High THEN Prostate Cancer Risk Level is Medium

R5: IF a patient is Very Young and has Prostate Volume (PV) Very Small and PSA level is Very High THEN Prostate Cancer Risk Level is Medium

…

R125: IF a patient is Very Old and has Prostate Volume (PV) Very Large and PSA level is Very High THEN Prostate Cancer Risk Level is Very High

Table 2: Attributes and Categories of the Expert System

AGE	Range	PV	Range	PSA	Range
Very Young	20 - 30	Very Small	20-30	Very Low	0 - 10
Young	31 - 40	Small	31-40	Low	11 - 20
Middle Age	41 - 60	Medium	41-80	Middle	21 - 30
Old	61 - 80	Large	81-100	High	31 -40
Very Old	81 - 100	Very Large	101-120	Very High	41 -50

Table 3: Category Tags Used in the Prolog

AGE	Range	PV	Range	PSA	Range
VY	20 - 30	VS	20-30	VLO	0 - 10
Y	31 - 40	S	31-40	LO	11 - 20
MA	41 - 60	ME	41-80	MI	21 - 30
O	61 - 80	LA	81-100	H	31 -40
VO	81 - 100	VL	101-120	VH	41 -50

4.1. System specification

This expert system can run in average personal computers. But for sake of our system, we developed this system with the following specifications:

Table 4: System specifications

Operating System	Windows 10 Home SL
Version	2004 OS build 19041.630
System manufacture	Lenovo
System Model	Lenovo Ideapad
System type	x64-based PC
Processor	Intel® Core™ i5-3230M 2.6Ghz
Physical memory	16 GB. DDR3

4.2. Testing

In this section, we will run the expert system to cover cases with different scenarios leading to various result, such as *NO RISK, VISIT A DOCTOR*, and determining the risk levels (Very Low, Low, Medium, High, Very High). Scenarios shown in Table 5 will be demonstrated in the following subsections.

Table 5: Expert System Diagnosis Scenarios

NO RISK	VISIT A DOCTOR
Prostate Cancer Risk Level	
VERY LOW-LEVEL RISK	LOW LEVEL RISK
MEDIUM LEVEL RISK	HIGH LEVEL RISK
VERY HIGH-LEVEL RISK	/

- **NO RISK Scenario**

```
**********************************************************************
**  >> WELCOME TO THE PROSTATE CANCER DIAGNOSTIC EXPERT SYSTEM <<     **
**                                                                   **
**     Please answer following questions in order to diagnose you!   **
**********************************************************************
----------------------------------------------------------------------
Are you experiencing frequent urinations? (yes/no):
|: no.
Is there pain while urinating? (yes/no):
|: no.
Are you experiencing difficulties when urinating? (yes/no):
|: no.
Have you noticed blood in urine? (yes/no):
|: no.
Are you experiencing weak urination flow? [takes long time to urinate] (yes/no):
|: no.
Do you feel unexpected pain back, hips and other bones? (yes/no):
|: no.

******************************************************
Prostate Cancer Risk Level:  -->> NO RISK <<--
******************************************************
>> END OF DIAGNOSIS! <<
true .
```

Figure 2: No Risk Scenario

Figure 2 shows that when the user answers the questions (Q1-Q6) related with symptoms with NO. This scenario will lead to the NO RISK result based on system rules.

- **VISIT DOCTOR Scenario**

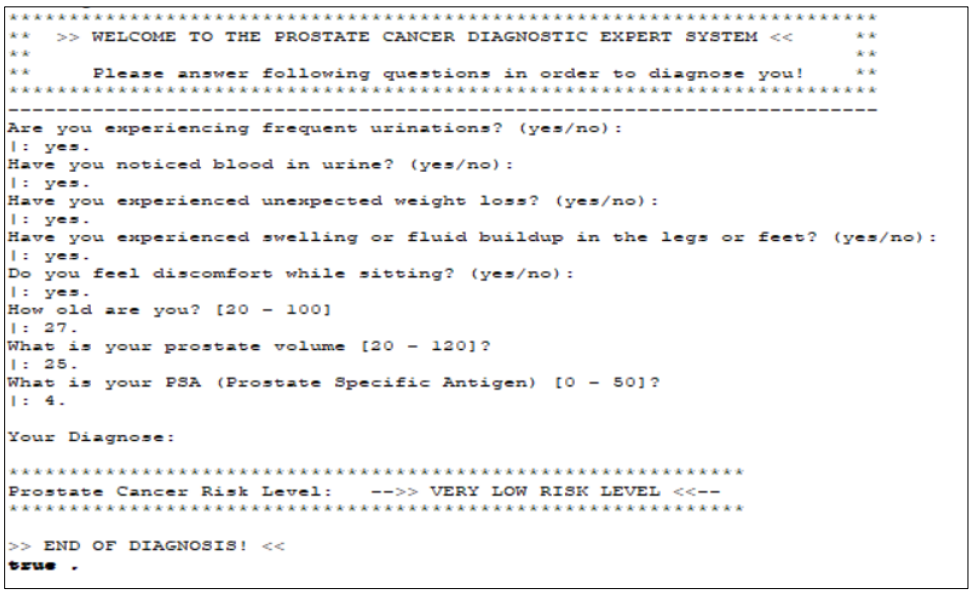
```
**********************************************************************
**  >> WELCOME TO THE PROSTATE CANCER DIAGNOSTIC EXPERT SYSTEM <<     **
**                                                                   **
**     Please answer following questions in order to diagnose you!   **
**********************************************************************
----------------------------------------------------------------------
Are you experiencing frequent urinations? (yes/no):
|: no.
Is there pain while urinating? (yes/no):
|: no.
Are you experiencing difficulties when urinating? (yes/no):
|: no.
Have you noticed blood in urine? (yes/no):
|: yes.
Have you experienced unexpected weight loss? (yes/no):
|: yes.
Have you experienced swelling or fluid buildup in the legs or feet? (yes/no):
|: yes.
Do you feel discomfort while sitting? (yes/no):
|: no.

******************************************************
Diagnose:            -->> VISIT DOCTOR <<--
******************************************************
>> END OF DIAGNOSIS! <<
```

Figure 3: Visit Doctor Scenario

Figure 3 shows that when the user answers the questions related with her/his symptoms(Q1-Q3) with NO, (Q4, Q7, Q8) with YES. This case will lead the user to the VISIT DOCTOR result based on system rules.

- **VERY LOW RISK Scenario**



```
**********************************************************************
**  >> WELCOME TO THE PROSTATE CANCER DIAGNOSTIC EXPERT SYSTEM <<     **
**                                                                   **
**      Please answer following questions in order to diagnose you!  **
**********************************************************************
----------------------------------------------------------------------
Are you experiencing frequent urinations? (yes/no):
|: yes.
Have you noticed blood in urine? (yes/no):
|: yes.
Have you experienced unexpected weight loss? (yes/no):
|: yes.
Have you experienced swelling or fluid buildup in the legs or feet? (yes/no):
|: yes.
Do you feel discomfort while sitting? (yes/no):
|: yes.
How old are you? [20 - 100]
|: 27.
What is your prostate volume [20 - 120]?
|: 25.
What is your PSA (Prostate Specific Antigen) [0 - 50]?
|: 4.

Your Diagnose:

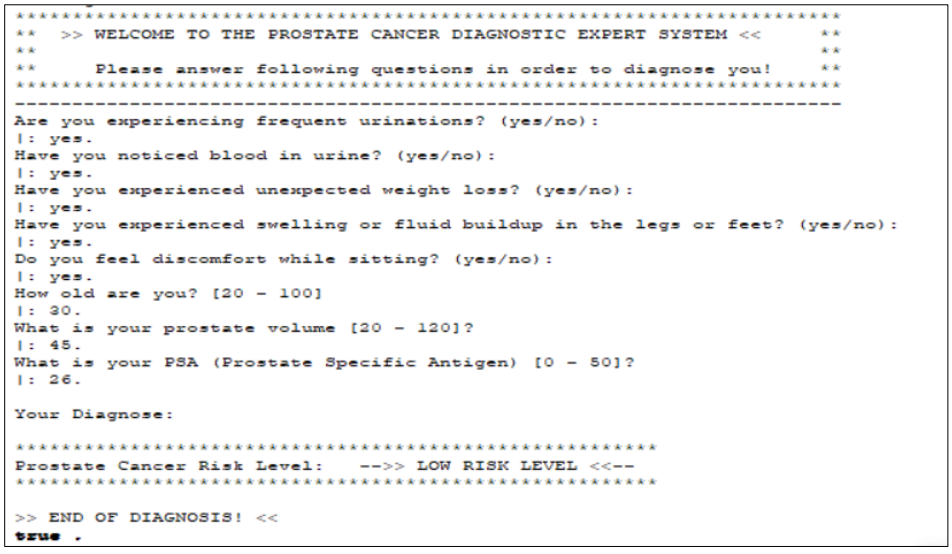
**************************************************************
Prostate Cancer Risk Level:    -->> VERY LOW RISK LEVEL <<--
**************************************************************

>> END OF DIAGNOSIS! <<
true .
```

Figure 4 : Very Low Risk Scenario

Figure 4 shows the case that the user redirected to the input question, and based on the rules of the system, the input (Age = 27, PV= 25, PSA=4) will lead to a Very Low Risk result.

- **LOW RISK Scenario**



```
**********************************************************************
**  >> WELCOME TO THE PROSTATE CANCER DIAGNOSTIC EXPERT SYSTEM <<     **
**                                                                   **
**      Please answer following questions in order to diagnose you!  **
**********************************************************************
----------------------------------------------------------------------
Are you experiencing frequent urinations? (yes/no):
|: yes.
Have you noticed blood in urine? (yes/no):
|: yes.
Have you experienced unexpected weight loss? (yes/no):
|: yes.
Have you experienced swelling or fluid buildup in the legs or feet? (yes/no):
|: yes.
Do you feel discomfort while sitting? (yes/no):
|: yes.
How old are you? [20 - 100]
|: 30.
What is your prostate volume [20 - 120]?
|: 45.
What is your PSA (Prostate Specific Antigen) [0 - 50]?
|: 26.

Your Diagnose:

**************************************************************
Prostate Cancer Risk Level:    -->> LOW RISK LEVEL <<--
**************************************************************

>> END OF DIAGNOSIS! <<
true .
```

Figure 5 : Low Risk Scenario

Figure 5 shows the case that the user redirected to the input question, and based on the rules of the system, the input (Age = 30, PV= 45, PSA=26) will lead to a Low-Risk result.

- **MEDIUM RISK Scenario**

```
?- diagnose.
**************************************************************************
**  >> WELCOME TO THE PROSTATE CANCER DIAGNOSTIC EXPERT SYSTEM <<      **
**                                                                      **
**      Please answer following questions in order to diagnose you!     **
**************************************************************************
--------------------------------------------------------------------------
Are you experiencing frequent urinations? (yes/no):
|: yes.
Have you noticed blood in urine? (yes/no):
|: yes.
Have you experienced unexpected weight loss? (yes/no):
|: yes.
Have you experienced swelling or fluid buildup in the legs or feet? (yes/no):
|: yes.
Do you feel discomfort while sitting? (yes/no):
|: yes.
How old are you? [20 - 100]
|: 32.
What is your prostate volume [20 - 120]?
|: 24.
What is your PSA (Prostate Specific Antigen) [0 - 50]?
|: 33.

Your Diagnose:

**************************************************************
Prostate Cancer Risk Level:    -->> MEDIUM RISK LEVEL <<--
**************************************************************
```

Figure 6 : Medium Risk Scenario

Figure 6 shows the case that the user redirected to the input question, and based on the rules of the system, the input (Age = 32, PV= 24, PSA=33) will lead to a Medium Risk result.

- **HIGH RISK Scenario**

```
**************************************************************************
**  >> WELCOME TO THE PROSTATE CANCER DIAGNOSTIC EXPERT SYSTEM <<      **
**                                                                      **
**      Please answer following questions in order to diagnose you!     **
**************************************************************************
--------------------------------------------------------------------------
Are you experiencing frequent urinations? (yes/no):
|: yes.
Have you noticed blood in urine? (yes/no):
|: yes.
Have you experienced unexpected weight loss? (yes/no):
|: yes.
Have you experienced swelling or fluid buildup in the legs or feet? (yes/no):
|: yes.
Do you feel discomfort while sitting? (yes/no):
|: yes.
How old are you? [20 - 100]
|: 37.
What is your prostate volume [20 - 120]?
|: 105.
What is your PSA (Prostate Specific Antigen) [0 - 50]?
|: 43.

Your Diagnose:

**************************************************************
Prostate Cancer Risk Level:    -->> HIGH RISK LEVEL <<--
**************************************************************

>> END OF DIAGNOSIS! <<
true .
```

Figure 7 : High Risk Scenario

Figure 7 shows the case that the user redirected to the input question, and based on the rules of the system, the input (Age = 37, PV= 105, PSA=43) will lead to a High-Risk result.

- **VERY HIGH-RISK Scenario**

```
?- diagnose.
**************************************************************************
**  >> WELCOME TO THE PROSTATE CANCER DIAGNOSTIC EXPERT SYSTEM <<      **
**                                                                      **
**      Please answer following questions in order to diagnose you!     **
**************************************************************************
--------------------------------------------------------------------------
Are you experiencing frequent urinations? (yes/no):
|: yes.
Have you noticed blood in urine? (yes/no):
|: yes.
Have you experienced unexpected weight loss? (yes/no):
|: yes.
Have you experienced swelling or fluid buildup in the legs or feet? (yes/no):
|: yes.
Do you feel discomfort while sitting? (yes/no):
|: yes.
How old are you? [20 - 100]
|: 85.
What is your prostate volume [20 - 120]?
|: 117.
What is your PSA (Prostate Specific Antigen) [0 - 50]?
|: 45.

Your Diagnose:

**********************************************************************
Prostate Cancer Risk Level:    -->> VERY HIGH RISK LEVEL <<--
**********************************************************************

>> END OF DIAGNOSIS! <<
true .
```

Figure 8 : Very High-Risk Scenario

Figure 8 shows the case that the user redirected to the input question, and based on the rules of the system, the input (Age = 85, PV= 117, PSA=45) will lead to a High-Risk result.

5.0 Analysis of Results & Discussion / Results and Evaluation

Our system is a rule-based system that asks the user general and technical diagnostic questions and returns a percentage of the risk factor of having prostate cancer based on the user's input values. After we finished constructing the rules and tested them, we found out that the system is providing a reasonable percentage of the risk factor of having prostate cancer. However, the evaluation should be done by going through real data of real patients. Unfortunately, we could not do that due to the lack of datasets or actual patients' data to check whether our expert system is performing accurately or not. Additionally, we went through our literature reviews to find the same datasets the other researchers worked on, but we were not able to obtain the same datasets since they used local datasets that are not available publicly. Therefore, we took another approach to evaluate our system which is by making the rules according to different medical resources that uses almost the same kind of data to check whether the patient have prostate cancer or not. In another word, we investigated how doctors diagnose prostate cancer on real patient, what are the clinical tests they do on the patients to diagnose prostate cancer, and how they provide the risk factor of having prostate cancer.

After we obtained all the needed information, we constructed the rules. The rules we constructed as mentioned in previous sections are divided into 2 categories. The main addition we added is the non-clinical level question that could help indicate that the user could suffer from a risk of prostate cancer. Despite doing 5 literature reviews, none of them took into consideration such question that could also help indicate whether the patient has a potential risk of prostate cancer or not.

Due to the fact that we were unable to find records of patients with similar answers of our rules, we were not able to fully evaluate the expert system. However, hypothetically speaking, rules that were applied in the papers covered in then literature review section are implemented as is in our expert system. Additionally, we added more relevant attributes to our system with no conflict to the rules in the papers, and therefore, it should give higher accuracy of diagnosing patients.

6.0 Conclusion and Recommendation

The implemented system is capable of providing the risk factor of having prostate cancer. However, it is highly recommended to test these rules further on real data. It could be a long plan with a hospital were the doctors could ask patient about symptoms shown in rules 1-10 and recording it. This could help in stress testing the accuracy of the system.

7.0. Acknowledgement

We are grateful to Allah for blessing us with an opportunity to work on this project that could benefit the community, mankind as a whole and especially doctors who work on saving lives and work on treating patients with prostate cancer. We would also like to thank Dr. “Aadam Olatunji” for guiding us through this journey and teaching us the concept behind artificial intelligence and how to construct this system.

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Appendix

Prolog code of the Expert System for Diagnosing Prostate Cancer Risk Level

```
%EXPERT SYSTEM FOR DIAGNOSING PROSTATE CANCER
diagnose:-
    write('**************************************************************************'),nl,
    writeln('**  >> WELCOME TO THE PROSTATE CANCER DIAGNOSTIC EXPERT SYSTEM <<     **'),
    writeln('**                                                                      **'),
    write('**     Please answer following questions in order to diagnose you!    **'),
    nl,
    write('**************************************************************************'),nl,
    writeln('--------------------------------------------------------------------------'),
    writeln('Are you experiencing frequent urinations? (yes/no): '),
    read(X),
    answer_q1(X).

answer_q1(Ans):-
        Ans == yes,
        writeln('Have you noticed blood in urine? (yes/no): '),
        read(X),
        answer_q4(X).

answer_q1(Ans):-
       Ans == no,
       writeln('Is there pain while urinating? (yes/no): '),
       read(X),
       answer_q2(X);
       Ans == yes,
       Ans = no,
       answer_q3(Ans).

answer_q2(Ans):-
    Ans == no,
    writeln('Are you experiencing difficulties when urinating? (yes/no): '),
    read(X),
    answer_q3(X);
    Ans == yes,
    Ans = no,
    answer_q3(Ans).

answer_q3(Ans):-
    Ans == no,
    writeln('Have you noticed blood in urine? (yes/no): '),
    read(X),
    answer_q4(X);
    Ans = yes,
    writeln('Have you noticed blood in urine? (yes/no): '),
    read(X),
    answer_q4(X).

answer_q4(Ans):-
    Ans == no,
    writeln('Are you experiencing weak urination flow? [takes long time to urinate] (yes/no): '),
    read(X),
    answer_q5(X);
    Ans == yes,
    writeln('Have you experienced unexpected weight loss? (yes/no): '),
    read(X),
    answer_q7(X).

answer_q5(Ans):-
    Ans == no,
```

```
    writeln('Do you feel unexpected pain back, hips and other bones? (yes/no): '),
    read(X),
    answer_q6(X);
    Ans == yes,
    writeln('Do you feel unexpected pain back, hips and other bones? (yes/no): '),
    read(X),
    answer_q6(X).

answer_q6(Ans):-
    Ans == no,
    nl,
    write('*************************************************'),nl,
    write('Prostate Cancer Risk Level: '),
    writeln(' -->> NO RISK <<--'),
    write('*************************************************'),nl,
    end_system;
    Ans == yes,
    answer_q4(Ans).
answer_q7(Ans):-
    Ans == no,nl,
    write('*************************************************'),nl,
    writeln('Diagnose:           -->> VISIT DOCTOR <<--'),
    write('*************************************************'),nl,
    end_system;
    Ans == yes,
    writeln('Have you experienced swelling or fluid buildup in the legs or feet? (yes/no): '),
    read(X),
    answer_q8(X).

answer_q8(Ans):-
    Ans == no,nl,
    write('*************************************************'),nl,
    writeln('Diagnose:           -->> VISIT DOCTOR <<--'),
    write('*************************************************'),nl,
    end_system;
    Ans == yes,
    writeln('Do you feel discomfort while sitting? (yes/no): '),
    read(X),
    answer_q9(X).

answer_q9(Ans):-
    Ans == no,
    nl,
    write('*************************************************'),nl,
    writeln('Diagnose:           -->> VISIT DOCTOR <<--'),
    write('*************************************************'),nl,
    end_system;
    Ans == yes,
    writeln('How old are you? [20 - 100] '),
    read(Age),
    writeln('What is your PV (Prostate Volume) [20 - 120]? '),
    read(PV),
    writeln('What is your PSA (Prostate Specific Antigen) [0 - 50]? '),
    read(PSA),
    prostate_cancer_diagnose(Age, PV, PSA).
```

The following code consists of 125 rules of the expert system for diagnosing the prostate cancer risk level and the fuzzy logic outputs, implemented in the PROLOG software.

```
% 125 RULES FOR PCR LEVEL,
prostate_cancer_diagnose(Age, PV,
PSA):-
%------------------------------%

    % VERY LOW RISK LEVEL
    % Rule 1, #1
    Age >=20, Age =<30,PAge = vy,
    PV >=20, PV =<30,  PPV = vs,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 2, #2
    Age >=20, Age =<30, PAge = vy,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 6, #3
    Age >=20, Age =<30,PAge = vy,
    PV >=31, PV =<40,  PPV = s,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 7, #4
    Age >=20, Age =<30, PAge = vy,
    PV >=31, PV =<40,   PPV = s,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 11, #5
    Age >=20, Age =<30,PAge = vy,
    PV >=41, PV =<80,  PPV = me,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 12, #6
    Age >=20, Age =<30, PAge = vy,
    PV >=41, PV =<80,   PPV = me,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 21, #7
    Age >=20, Age =<30,PAge = vy,
    PV >=101, PV =<120,PPV = vla,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 26, #8
    Age >=31, Age =<40,PAge = y,
    PV >=20, PV =<30,  PPV = vs,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 27, #9
    Age >=31, Age =<40,PAge = y,
    PV >=20, PV =<30,  PPV = vs,
    PSA >=11, PSA =<20,PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 31, #10
    Age >=31, Age =<40,PAge = y,
    PV >=31, PV =<40,  PPV = s,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;


    % Rule 32, #11
    Age >=31, Age =<40, PAge = y,
    PV >=31, PV =<40,   PPV = s,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 36, #12
    Age >=31, Age =<40,PAge = y,
    PV >=41, PV =<80,  PPV = me,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 41, #13
    Age >=31, Age =<40,PAge = y,
    PV >=81, PV =<100, PPV = la,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 46, #14
    Age >=31, Age =<40,PAge = y,
    PV >=101, PV =<120,PPV = vla,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 51, #15
    Age >=41, Age =<60,PAge = ma,
    PV >=20, PV =<30,  PPV = vs,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 56, #16
    Age >=41, Age =<60,PAge = ma,
    PV >=31, PV =<40,  PPV = s,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 61, #17
    Age >=41, Age =<60,PAge = ma,
    PV >=41, PV =<80,  PPV = me,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 76, #18
    Age >=61, Age =<80,PAge = o,
    PV >=20, PV =<30,  PPV = vs,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;
%------------------------------%

%------------------------------%
    % LOW RISK LEVEL
    % Rule 3, #19
    Age >=20, Age =<30, PAge = vy,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 8, #20
    Age >=20, Age =<30, PAge = vy,
    PV >=31, PV =<40,   PPV = s,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 13, #21
    Age >=20, Age =<30, PAge = vy,
    PV >=41, PV =<80,   PPV = me,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;


    % Rule 16, #22
    Age >=20, Age =<30, PAge = vy,
    PV >=81, PV =<100, PPV = la,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 17, #23
    Age >=20, Age =<30, PAge = vy,
    PV >=81, PV =<100,  PPV = la,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 22, #24
    Age >=20, Age =<30, PAge = vy,
    PV >=101, PV =<120, PPV = vla,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 28, #25
    Age >=31, Age =<40, PAge = y,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 33, #26
    Age >=31, Age =<40, PAge = y,
    PV >=31, PV =<40,   PPV = s,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 37, #27
    Age >=31, Age =<40, PAge = y,
    PV >=41, PV =<80,   PPV = me,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 42, #28
    Age >=31, Age =<40, PAge = y,
    PV >=81, PV =<100,  PPV = la,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 47, #29
    Age >=31, Age =<40, PAge = y,
    PV >=101, PV =<120, PPV = vla,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 52, #30
    Age >=41, Age =<60, PAge = ma,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 53, #31
    Age >=41, Age =<60, PAge = ma,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 57, #32
    Age >=41, Age =<60, PAge = ma,
    PV >=31, PV =<40,   PPV = s,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 62, #33
    Age >=41, Age =<60, PAge = ma,
    PV >=41, PV =<80,   PPV = me,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 66, #34
    Age >=41, Age =<60,PAge = ma,
    PV >=81, PV =<100, PPV = la,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;
```

```
    % Rule 71, #35
    Age >=41, Age =<60,PAge = ma,
    PV >=101, PV =<120,PPV = vla,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 77, #36
    Age >=61, Age =<80, PAge = o,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 81, #37
    Age >=61, Age =<80,PAge = o,
    PV >=31, PV =<40,  PPV = s,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 82, #38
    Age >=61, Age =<80, PAge = o,
    PV >=31, PV =<40,   PPV = s,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 86, #39
    Age >=61, Age =<80,PAge = o,
    PV >=41, PV =<80,  PPV = me,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

   % Rule 87, #40
    Age >=61, Age =<80, PAge = o,
    PV >=41, PV =<80,   PPV = me,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 91, #41
    Age >=61, Age =<80,PAge = o,
    PV >=81, PV =<100, PPV = vla,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 101, #42
    Age >=81, Age =<100,PAge = vo,
    PV >=20, PV =<30,  PPV = vs,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 102, #43
    Age >=81, Age =<100,PAge = vo,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 106, #44
    Age >=81,Age =<100,PAge = vo,
    PV >=31, PV =<40,  PPV = s,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;
%-------------------------------%


%-------------------------------%
    % MEDIUM RISK LEVEL
    % Rule 4, #45
    Age >=20, Age =<30, PAge = vy,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 5, #46
    Age >=20, Age =<30, PAge = vy,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 9, #47
    Age >=20, Age =<30, PAge = vy,
    PV >=31, PV =<40,   PPV = s,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 10, #48
    Age >=20, Age =<30, PAge = vy,
    PV >=31, PV =<40,   PPV = ss,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 14, #49
    Age >=20, Age =<30, PAge = vy,
    PV >=41, PV =<80,   PPV = me,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 18, #50
    Age >=20, Age =<30, PAge = vy,
    PV >=81, PV =<100,  PPV = la,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 19, #51
    Age >=20, Age =<30, PAge = vy,
    PV >=81, PV =<100,  PPV = la,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 23, #52
    Age >=20, Age =<30, PAge = vy,
    PV >=101, PV =<120, PPV = vla,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 29, #53
    Age >=31, Age =<40, PAge = y,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 34, #54
    Age >=31, Age =<40,  PAge = y,
    PV >=31, PV =<40,    PPV = s,
    PSA >=31, PSA =<40,  PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 38, #55
    Age >=31, Age =<40, PAge = y,
    PV >=41, PV =<80,   PPV = me,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 39, #56
    Age >=31, Age =<40, PAge = y,
    PV >=41, PV =<80,   PPV = me,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 43, #57
    Age >=31, Age =<40, PAge = y,
    PV >=81, PV =<100, PPV = la,
    PSA >=21, PSA =<30,PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 44, #58
    Age >=31, Age =<40, PAge = y,
    PV >=81, PV =<100,  PPV = la,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 48, #59
    Age >=31, Age =<40, PAge = y,
    PV >=101, PV =<120, PPV = vla,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

   % Rule 49, #60
    Age >=31, Age =<40, PAge = y,
    PV >=101, PV =<120, PPV = vla,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 54, #61
    Age >=41, Age =<60, PAge = ma,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 58, #62
    Age >=41, Age =<60, PAge = ma,
    PV >31, PV =<40,    PPV = s,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 63, #63
    Age >=41, Age =<60, PAge = ma,
    PV >=41, PV =<80,   PPV = me,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 67, #64
    Age >=41, Age =<60, PAge = ma,
    PV >=81, PV =<100,  PPV = la,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 72, #65
    Age >=41, Age =<60, PAge = ma,
    PV >=101, PV =<120, PPV = vla,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 78, #66
    Age >=61, Age =<80, PAge = o,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;


    % Rule 83, #67
    Age >=61, Age =<80, PAge = o,
    PV >=31, PV =<40,   PPV = s,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 88, #68
    Age >=61, Age =<80, PAge = o,
    PV >=41, PV =<80,   PPV = me,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 92, #69
    Age >=61, Age =<80, PAge = o,
    PV >=81, PV =<100,  PPV = la,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;
```

```
    % Rule 96, #70
    Age >=61, Age =<80,PAge = o,
    PV >=101, PV =<120,PPV = vla,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 97, #71
    Age >=61, Age =<80, PAge = o,
    PV >=101, PV =<120, PPV = vla,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 103, #72
    Age >=81, Age =<100,PAge = vo,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 104, #73
    Age >=81, Age =<100,PAge = vo,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 107, #74
    Age >=81, Age =<100,PAge = vo,
    PV >=31, PV =<40,   PPV = s,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 108, #75
    Age >=81, Age =<100,PAge = vo,
    PV >=31, PV =<40,   PPV = s,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 111, #76
    Age >=81, Age =<100,PAge = vo,
    PV >=41, PV =<80,   PPV = me,
    PSA >=0, PSA =<10,  PSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 112, #77
    Age >=81, Age =<100,PAge = vo,
    PV >=41, PV =<80,   PPV = me,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 116, #78
    Age >=81, Age =<100,PAge = vo,
    PV >=81, PV =<100,  PPV = la,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 117, #79
    Age >=81, Age =<100,PAge = vo,
    PV >=81, PV =<100,  PPV = la,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 121, #80
    Age >=81, Age =<100,PAge = vo,
    PV >=81, PV =<100,  PPV = la,
    PSA >=0, PSA =<10, PPSA = vlo,
    risk_level(PAge,PPV,PPSA),
    end_system;
%--------------------------------%


%--------------------------------%
    % HIGH RISK LEVEL
    % Rule 15, #81
    Age >=20, Age =<30, PAge = vy,
    PV >=41, PV =<80,   PPV = me,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 20, #82
    Age >=20, Age =<30, PAge = vy,
    PV >=81, PV =<100,  PPV = la,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 24, #83
    Age >=20, Age =<30, PAge = vy,
    PV >=101, PV =<120, PPV = vla,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 25, #84
    Age >=20, Age =<30, PAge = vy,
    PV >=101, PV =<120, PPV = vla,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 30, #85
    Age >=31, Age =<40, PAge = y,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 35, #86
    Age >=31, Age =<40, PAge = y,
    PV >=31, PV =<40,   PPV = s,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 40, #87
    Age >=31, Age =<40, PAge = y,
    PV >=41, PV =<80,   PPV = me,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 45, #88
    Age >=31, Age =<40, PAge = y,
    PV >=81, PV =<100,  PPV = la,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 50, #89
    Age >=31, Age =<40, PAge = y,
    PV >=101, PV =<120, PPV = vla,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 55, #90
    Age >=41, Age =<60, PAge = ma,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 59, #91
    Age >=41, Age =<60, PAge = ma,
    PV >=31, PV =<40,   PPV = s,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 60, #92
    Age >=41, Age =<60, PAge = ma,
    PV >=31, PV =<40,   PPV = s,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 64, #93
    Age >=41, Age =<60, PAge = ma,
    PV >=41, PV =<80,   PPV = me,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 65, #94
    Age >=41, Age =<60, PAge = ma,
    PV >=41, PV =<80,   PPV = me,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 68, #95
    Age >=41, Age =<60, PAge = ma,
    PV >=81, PV =<100,  PPV = la,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 69, #96
    Age >=41, Age =<60, PAge = ma,
    PV >=81, PV =<100,  PPV = la,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 73, #97
    Age >=41, Age =<60, PAge = ma,
    PV >=101, PV =<120, PPV = vla,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 79, #98
    Age >=61, Age =<80, PAge = o,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 80, #99
    Age >=61, Age =<80, PAge = o,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 84, #100
    Age >=61, Age =<80, PAge = o,
    PV >=31, PV =<40,   PPV = s,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;


    % Rule 89, #101
    Age >=61, Age =<80, PAge = o,
    PV >=41, PV =<80,   PPV = me,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 93, #102
    Age >=61, Age =<80, PAge = o,
    PV >=81, PV =<100,  PPV = la,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 94, #103
    Age >=61, Age =<80, PAge = o,
    PV >=81, PV =<100,  PPV = la,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 98, #104
    Age >=61, Age =<80, PAge = o,
    PV >=101, PV =<120, PPV = vla,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
```

```
    end_system;

    % Rule 105, #105
    Age >=81, Age =<100,PAge = vo,
    PV >=20, PV =<30,   PPV = vs,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 109, #106
    Age >=81, Age =<100,PAge = vo,
    PV >=31, PV =<40,   PPV = s,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 113, #107
    Age >=81, Age =<100,PAge = vo,
    PV >=41, PV =<80,   PPV = me,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 118, #108
    Age >=81, Age =<100,PAge = vo,
    PV >=81, PV =<100,  PPV = la,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 122, #109
    Age >=81, Age =<100,PAge = vo,
    PV >=101, PV =<120, PPV = vla,
    PSA >=11, PSA =<20, PPSA = lo,
    risk_level(PAge,PPV,PPSA),
    end_system;
%-------------------------------%

%-------------------------------%
    % VERY HIGH RISK LEVEL
    % Rule 70, #110
    Age >=41, Age =<60, PAge = ma,
    PV >=81, PV =<100,  PPV = la,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 74, #111
    Age >=41, Age =<60, PAge = ma,
    PV >=101, PV =<120, PPV = vla,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 75, #112
    Age >=41, Age =<60, PAge = ma,
    PV >=101, PV =<120, PPV = vla,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 85, #113
    Age >=61, Age =<80, PAge = o,
    PV >=31, PV =<40,   PPV = s,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 90, #114
    Age >=61, Age =<80, PAge = o,
    PV >=41, PV =<80,   PPV = me,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 95, #115
    Age >=61, Age =<80, PAge = o,
    PV >=81, PV =<100,  PPV = la,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 99, #116
    Age >=61, Age =<80, PAge = o,
    PV >=101, PV =<120, PPV = vla,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 100, #117
    Age >=61, Age =<80, PAge = o,
    PV >=101, PV =<120, PPV = vla,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 110, #118
    Age >=81, Age =<100,PAge = vo,
    PV >=31, PV =<40,   PPV = s,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 114, #119
    Age >=81, Age =<100,PAge = vo,
    PV >=41, PV =<80,   PPV = me,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 115, #120
    Age >=81, Age =<100,PAge = vo,
    PV >=41, PV =<80,   PPV = me,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

   % Rule 119, #121
    Age >=81, Age =<100,PAge = vo,
    PV >=81, PV =<100,  PPV = la,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 120, #122
    Age >=81, Age =<100,PAge = vo,
    PV >=81, PV =<100,  PPV = la,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 123, #123
    Age >=81, Age =<100,PAge = vo,
    PV >=101, PV =<120, PPV = vla,
    PSA >=21, PSA =<30, PPSA = mi,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 124, #124
    Age >=81, Age =<100,PAge = vo,
    PV >=101, PV =<120, PPV = vla,
    PSA >=31, PSA =<40, PPSA = h,
    risk_level(PAge,PPV,PPSA),
    end_system;

    % Rule 125, #125
    Age >=81, Age =<100,PAge = vo,
    PV >=101, PV =<120, PPV = vla,
    PSA >=41, PSA =<50, PPSA = vh,
    risk_level(PAge,PPV,PPSA),
    end_system.
%---------------------------------%




risk_level(Age,PV, PSA):-
%---------------------------------%

    % VERY LOW RISK LEVEL
    % Rule 1, #1
    Age = vy, PV = vs, PSA = vlo,
    very_low_risk;
    % Rule 2, #2
    Age = vy, PV = vs, PSA = lo,
    very_low_risk;
    % Rule 6, #3
    Age = vy, PV = s, PSA = vlo,
    very_low_risk;
    % Rule 7, #4
    Age = vy,  PV = s, PSA = lo,
    very_low_risk;
    % Rule 11, #5
    Age = vy,  PV = me, PSA = vlo,
    very_low_risk;
    % Rule 12, #6
    Age = vy, PV = me, PSA = lo,
    very_low_risk;
    % Rule 21, #7
    Age = vy, PV = vla,PSA = vlo,
    very_low_risk;
    % Rule 26, #8
    Age = y, PV = vs, PSA = vlo,
    very_low_risk;
    % Rule 27, #9
    Age = y,  PV = vs, PSA = lo,
    very_low_risk;
    % Rule 31, #10
    Age = y, PV = s, PSA = vlo,
    very_low_risk;
    % Rule 32, #11
    Age = y, PV = s, PSA = lo,
    very_low_risk;
    % Rule 36, #12
    Age = y, PV = me, PSA = vlo,
    very_low_risk;
    % Rule 41, #13
    Age = y, PV = la, PSA = vlo,
    very_low_risk;
    % Rule 46, #14
    Age = y, PV = vla, PSA = vlo,
    very_low_risk;
    % Rule 51, #15
    Age = ma, PV = vs, PSA = vlo,
    very_low_risk;
    % Rule 56, #16
    Age = ma, PV = s, PSA = vlo,
    very_low_risk;
    % Rule 61, #17
    Age = ma, PV = me,PSA = vlo,
    very_low_risk;
    % Rule 76, #18
    Age = o, PV = vs, PSA = vlo,
    very_low_risk;
%---------------------------------
%

%---------------------------------
%
    % LOW RISK LEVEL
    % Rule 3, #19
    Age = vy, PV = vs, PSA = mi,
    low_risk;
    % Rule 8, #20
    Age = vy, PV = s, PSA = mi,
    low_risk;
    % Rule 13, #21
    Age = vy,  PV = me, PSA = mi,
    low_risk;
    % Rule 16, #22
    Age = vy,  PV = la, PSA = vlo,
    low_risk;
    % Rule 17, #23
    Age = vy, PV = la, PSA = lo,
    low_risk;
    % Rule 22, #24
    Age = vy, PV = vla, PSA = lo,
    low_risk;
    % Rule 28, #25
    Age = y,  PV = vs, PSA = mi,
    low_risk;
    % Rule 33, #26
    Age = y, PV = s,PSA = mi,
    low_risk;
    % Rule 37, #27
    Age = y,  PV = me, PSA = lo,
    low_risk;
    % Rule 42, #28
```

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    Age = y,  PV = la, PSA = lo,
    low_risk;
    % Rule 47, #29
    Age = y, PV = vla, PSA = lo,
    low_risk;
    % Rule 52, #30
    Age = ma, PV = vs, PSA = lo,
    low_risk;
    % Rule 53, #31
    Age = ma, PV = vs, PSA = mi,
    low_risk;
    % Rule 57, #32
    Age = ma, PV = s, PSA = lo,
    low_risk;
    % Rule 62, #33
    Age = ma,  PV = me, PSA = lo,
    low_risk;
    % Rule 66, #34
    Age = ma,  PV = la, PSA = vlo,
    low_risk;
    % Rule 71, #35
    Age = ma, PV = vla,PSA = vlo,
    low_risk;
    % Rule 77, #36
    Age = o, PV = vs, PSA = lo,
    low_risk;
    % Rule 81, #37
    Age = o, PV = s,PSA = vlo,
    low_risk;
    % Rule 82, #38
    Age = o, PV = s, PSA = lo,
    low_risk;
    % Rule 86, #39
    Age = o, PV = me, PSA = vlo,
    low_risk;
    % Rule 87, #40
    Age = o, PV = me, PSA = lo,
    low_risk;
    % Rule 91, #41
    Age = o,  PV = vla, PSA = vlo,
    low_risk;
    % Rule 101, #42
    Age = vo, PV = vs,PSA = vlo,
    low_risk;
    % Rule 102, #43
    Age = vo,PV = vs,PSA = lo,
    low_risk;
    % Rule 106, #44
    Age = vo,PV = s,PSA = vlo,
    low_risk;
%---------------------------------%

%---------------------------------%
    % MEDIUM RISK LEVEL
    % Rule 4, #45
    Age = vy,  PV = vs,  PSA = h,
    medium_risk;
    % Rule 5, #46
    Age = vy,PV = vs,PSA = vh,
    medium_risk;
    % Rule 9, #47
    Age = vy,  PV = s,   PSA = h,
    medium_risk;
    % Rule 10, #48
    Age = vy,  PV = ss,  PSA = vh,
    medium_risk;
    % Rule 14, #49
    Age = vy,  PV = me,  PSA = h,
    medium_risk;
    % Rule 18, #50
    Age = vy,  PV = la, PSA = mi,
    medium_risk;
    % Rule 19, #51
    Age = vy,  PV = la, PSA = h,
    medium_risk;
    % Rule 23, #52
    Age = vy, PV = vla, PSA = mi,
    medium_risk;
    % Rule 29, #53
    Age = y,  PV = vs,  PSA = h,
    medium_risk;
    % Rule 34, #54
    Age = y,  PV = s,   PSA = h,
    medium_risk;
    % Rule 38, #55
    Age = y,  PV = me,  PSA = mi,
    medium_risk;
    % Rule 39, #56
    Age = y,  PV = me,  PSA = h,
    medium_risk;
    % Rule 43, #57
    Age = y,  PV = la,  PSA = mi,
    medium_risk;
    % Rule 44, #58
    Age = y,  PV = la,  PSA = h,
    medium_risk;
    % Rule 48, #59
    Age = y,  PV = vla, PSA = mi,
    medium_risk;
   % Rule 49, #60
    Age = y,  PV = vla, PSA = h,
    medium_risk;
    % Rule 54, #61
    Age = ma,  PV = vs, PSA = h,
    medium_risk;
    % Rule 58, #62
    Age = ma,  PV = s,  PSA = mi,
    medium_risk;
    % Rule 63, #63
    Age = ma, PV = me,  PSA = mi,
    medium_risk;
    % Rule 67, #64
    Age = ma,  PV = la, PSA = lo,
    medium_risk;
    % Rule 72, #65
    Age = ma, PV = vla, PSA = lo,
    medium_risk;
    % Rule 78, #66
    Age = o,  PV = vs,  PSA = mi,
    medium_risk;
    % Rule 83, #67
    Age = o,  PV = s,   PSA = mi,
    medium_risk;
    % Rule 88, #68
    Age = o,  PV = me,  PSA = mi,
    medium_risk;
    % Rule 92, #69
    Age = o,   PV = la, PSA = lo,
    medium_risk;
    % Rule 96, #70
    Age = o,  PV = vla, PSA = vlo,
    medium_risk;
    % Rule 97, #71
    Age = o,  PV = vla, PSA = lo,
    medium_risk;
    % Rule 103, #72
    Age = vo,  PV = vs, PSA = mi,
    medium_risk;
    % Rule 104, #73
    Age = vo,   PV = vs, PSA = h,
     medium_risk;
    % Rule 107, #74
    Age = vo,   PV = s,  PSA = lo,
    medium_risk;
    % Rule 108, #75
    Age = vo,   PV = s,  PSA = mi,
    medium_risk;
    % Rule 111, #76
    Age = vo,   PV = me,PSA = vlo,
    medium_risk;
    % Rule 112, #77
    Age = vo,   PV = me, PSA = lo,
    medium_risk;
    % Rule 116, #78
    Age = vo,   PV = la,PSA = vlo,
    medium_risk;
    % Rule 117, #79
    Age = vo,   PV = la, PSA = lo,
    medium_risk;
    % Rule 121, #80
    Age = vo,   PV = la,PSA = vlo,
    medium_risk;
%---------------------------------%


%---------------------------------%
    % HIGH RISK LEVEL
    % Rule 15, #81
    Age = vy,  PV = me,  PSA = vh,
    high_risk;
    % Rule 20, #82
    Age = vy,  PV = la,  PSA = vh,
    high_risk;
    % Rule 24, #83
    Age = vy,  PV = vla, PSA = h,
    high_risk;
    % Rule 25, #84
    Age = vy,  PV = vla, PSA = vh,
    high_risk;
    % Rule 30, #85
    Age = y,   PV = vs, PSA = vh,
    high_risk;
    % Rule 35, #86
    Age = y,   PV = s,  PSA = vh,
    high_risk;
    % Rule 40, #87
    Age = y, PV = me, PSA = vh,
    high_risk;
    % Rule 45, #88
    Age = y, PV = la, PSA = vh,
    high_risk;
    % Rule 50, #89
    Age = y, PV = vla, PSA = vh,
    high_risk;
    % Rule 55, #90
    Age = ma, PV = vs,PSA = vh,
    high_risk;
    % Rule 59, #91
    Age = ma, PV = s, PSA = h,
    high_risk;
    % Rule 60, #92
    Age = ma, PV = s, PSA = vh,
    high_risk;
    % Rule 64, #93
    Age = ma, PV = me, PSA = h,
    high_risk;
    % Rule 65, #94
    Age = ma, PV = me, PSA = vh,
    high_risk;
    % Rule 68, #95
    Age = ma, PV = la,PSA = mi,
    high_risk;
    % Rule 69, #96
    Age = ma, PV = la,PSA = h,
    high_risk;
    % Rule 73, #97
    Age = ma, PV = vla, PSA = mi,
    high_risk;
    % Rule 79, #98
    Age = o, PV = vs, PSA = h,
    high_risk;
    % Rule 80, #99
    Age = o, PV = vs, PSA = vh,
    high_risk;
    % Rule 84, #100
    Age = o, PV = s, PSA = h,
    high_risk;
    % Rule 89, #101
    Age = o, PV = me, PSA = h,
    high_risk;
    % Rule 93, #102
    Age = o, PV = la, PSA = mi,
    high_risk;
    % Rule 94, #103
    Age = o,   PV = la, PSA = h,
    high_risk;
    % Rule 98, #104
    Age = o,   PV = vla, PSA = mi,
    high_risk;
    % Rule 105, #105
    Age = vo,  PV = vs, PSA = vh,
    high_risk;
    % Rule 109, #106
    Age = vo,  PV = s, PSA = h,
    high_risk;
    % Rule 113, #107
    Age = vo, PV = me,PSA = mi,
    high_risk;
    % Rule 118, #108
```

```
    Age = vo, PV = la,  PSA = mi,
    high_risk;
    % Rule 122, #109
    Age = vo, PV = vla, PSA = lo,
    high_risk;
%-------------------------------%


%-------------------------------%
    % VERY HIGH RISK LEVEL
    % Rule 70, #110
    Age = ma, PV = la, PSA = vh,
    very_high_risk;
    % Rule 74, #111
    Age = ma, PV = vla, PSA = h,
    very_high_risk;
    % Rule 75, #112
    Age = ma, PV = vla, PSA = vh,
    very_high_risk;
    % Rule 85, #113
    Age = o,PV = s, PSA = vh,
    very_high_risk;
    % Rule 90, #114
    Age = o, PV = me,PSA = vh,
    very_high_risk;
    % Rule 95, #115
    Age = o, PV = la, PSA = vh,
    very_high_risk;
    % Rule 99, #116
    Age = o, PV  = vla, PSA = h,
    very_high_risk;
    % Rule 100, #117
    Age = o, PV = vla, PSA = vh,
    very_high_risk;
    % Rule 110, #118
    Age = vo, PV = s,PSA = vh,
    very_high_risk;
    % Rule 114, #119
    Age = vo,PV = me, PSA = h,
    very_high_risk;
    % Rule 115, #120
    Age = vo,PV = me,PSA = vh,
    very_high_risk;
    % Rule 119, #121
    Age = vo, PV = la, PSA = h,
    very_high_risk;
    % Rule 120, #122
    Age = vo,  PV = la,  PSA = vh,
    very_high_risk;
    % Rule 123, #123
    Age = vo,PV = vla, PSA = mi,
    very_high_risk;
    % Rule 124, #124
    Age = vo, PV = vla, PSA = h,
    very_high_risk;
    % Rule 125, #125
    Age = vo, PV = vla, PSA = vh,
    very_high_risk.

%-------------------------------%
```

```
%PROSTATE CANCER RISK LEVEL OUTPUTS

very_low_risk:-
    nl,
    write('Your Diagnose:'),nl,nl,
    write('************************************************************'),nl,
    writeln('Prostate Cancer Risk Level:   -->> VERY LOW RISK LEVEL <<--'),
    write('************************************************************'),nl,nl.


low_risk:-
    nl,
    write('Your Diagnose:'),nl,nl,
    write('********************************************************'),nl,
    writeln('Prostate Cancer Risk Level:   -->> LOW RISK LEVEL <<--'),
    write('********************************************************'),nl,nl.

medium_risk:-
    nl,
    write('Your Diagnose:'),nl,nl,
    write('********************************************************'),nl,
    writeln('Prostate Cancer Risk Level:   -->> MEDIUM RISK LEVEL <<--'),
    write('********************************************************'),nl,nl.

high_risk:-
    nl,
    write('Your Diagnose:'),nl,nl,
    write('********************************************************'),nl,
    writeln('Prostate Cancer Risk Level:   -->> HIGH RISK LEVEL <<--'),
    write('********************************************************'),nl,nl.

very_high_risk:-
    nl,
    write('Your Diagnose:'),nl,nl,
    write('************************************************************'),nl,
    writeln('Prostate Cancer Risk Level:   -->> VERY HIGH RISK LEVEL <<--'),
    write('************************************************************'),nl,nl.

end_system:-
    write('>> END OF DIAGNOSIS! <<').
```