*PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA*
*MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH*
*UNIVERSITY OF CONSTANTINE 2 – ABDELHAMID MEHRI*

**FACULTY OF NEW TECHNOLOGIES OF INFORMATION AND COMMUNICATION**

DEPARTMENT OF FUNDAMENTAL COMPUTER SCIENCE AND ITS APPLICATIONS

MASTER II – INFORMATION AND COMMUNICATION SCIENCES AND TECHNOLOGIES

A DISSERTATION ENTITLED

# PROMAN, AN AI-BASED SOLUTION FOR PROSTATE CANCER MANAGEMENT

## INDIVIDUALISED MEDICINE

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE MASTER'S DEGREE IN COMPUTER SCIENCE

BY

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JULY 2021

# Dedications

*This dissertation is dedicated to:*

*My father and mother for their endless support since the beginning of my academic path.*
*My sisters.*

*My friends, Aymen and Oussama for their encouragement and support.*
*All my classmates and professors.*

**Zinelabidine LEGHELIMI**

*I dedicate this work to my family, who gave me a decent education, her love made me who I am today:*

*To the man, my precious offer from the god, who owes my life, my success and all my respect: my dear father*

*To the woman who suffered without letting me suffer, who never said no to my demands and who spared no effort to make me happy: my adorable mother*

*To you my brother who have always supported and encouraged me during these years of study.*

*To all my friends who have always encouraged me, and to whom I wish more success.*

**Abdelmouhsen LECHEKHAB**

# Acknowledgements


## PERSONAL

Our sincere thanks go to our supervisors, Dr Kitouni for her valuable advice and guidance that helped us a lot in our work, and Mr Issam Eddine Chaib for his continuous assistance in every small and big thing regarding the graduation project or regarding our study path. We also thank the jury members for agreeing to discuss our dissertation.

We appreciate Dr Karra Issam, for his interest in our project, as well as his assistance in gathering the necessary information for our project and allocating his time to us despite his busyness. Thank you so much doctor. We appreciate and thank Mr Taxanna Mohammed for his valuable advice regarding the suitable way to promote our graduation project and create a start-up or innovative project.

## INSTITUTIONAL

We appreciate that "EHS-Daksi", the urology specialised hospital, allowed the urologist to work with us and hold several meetings that aided us greatly in collecting documents about prostate cancer despite the obstacles they face due to the Covid-19 pandemic. We would also like to thank the Ministry of Start-ups for the incentives it provides to holders of innovative projects, which encouraged us to apply for the "Innovative Project" label.

# Abstract of
# Proman, an AI-Based Solution for Prostate Cancer Management

Prostate cancer (PCa) has become a global health concern as it is classified among the deadliest cancers in men, and the death rate is raising in an alarming way even in developed countries. Studies have shown that men of African descent are more likely to develop PCa at younger age, factors that are less addressed in current clinical practices. In this regard, we developed "Proman", an AI-based solution that ensures the delivery of individualised, high-quality, and evidence-based care for people with PCa. Furthermore, it applies machine learning algorithms to assist health professionals in managing PCa by making appropriate decisions to provide consistent care to patients. We have obtained satisfactory results showing that AI techniques have great potential to improve current clinical practices by providing a second opinion to health professionals. We believe that our work will contribute to clinical recommendations that consider the unique characteristics of the African race.

*Keywords:* Prostate cancer, artificial intelligence, artificial neural network, recommender system, computer-aided diagnosis, supportive care

# Résumé du
# Proman, une solution basée sur l'IA pour la prise en charge du cancer de la prostate

Le cancer de la prostate (CaP) est devenu un problème de santé mondial car il est classé parmi les cancers les plus mortels chez l'homme, et le taux de mortalité augmente de manière alarmante, même dans les pays développés. Les études scientifiques ont montré que les hommes d'origine africaine sont plus susceptibles de développer un cancer de la prostate à un plus jeune âge, des facteur qui sont moins pris en compte dans les pratiques cliniques actuelles. À cet égard, nous avons développé "Proman", une solution basée sur l'IA qui assure la prestation de soins individualisés, de haute qualité et fondés sur des preuves scientifiques pour les personnes ayant un CaP. En outre, elle applique des algorithmes d'apprentissage automatique pour aider les professionnels de santé à prendre en charge le CaP en prenant des décisions appropriées pour fournir des soins cohérents aux patients. Nous avons obtenu des résultats satisfaisants montrant que les techniques d'IA ont un grand potentiel pour améliorer les pratiques cliniques actuelles en fournissant un deuxième avis aux professionnels de la santé. Nous pensons que notre travail contribuera à des recommandations cliniques qui tiennent en compte les caractéristiques uniques de la race africaine.

*Mots-clés :* Cancer de la prostate, intelligence artificielle, réseaux de neurones artificiels, système de recommandation, diagnostic assisté par ordinateur, soins de support

## ملخص للمذكرة تحت عنوان

## "بروومان"، حل للتكفل بمرضى سرطان البروستات باستعمال الذكاء الاصطناعي

أصبح سرطان البروستات مصدر قلق عالمي حيث يصنف من أكثر السرطانات فتكا بالرجال، خصوصا مع زيادة معدل الوفيات بمنحى مقلق حتى في الدول المتقدمة. أثبتت الدراسات أن الأشخاص ذوي الأصول الإفريقية هم أكثر عرض للإصابة بهذا المرض وفي سن مبكر وهذا ما لا يتم أخذه بعين الاعتبار في أغلب الممارسات السريرية الحالية. في هذا الصدد قمنا بتطوير نظام "بروومان"، نظام يستعمل الذكاء الاصطناعي لكي يضمن لمرضى سرطان البروستات، رعاية فريدة من نوعها ذات جودة ومبنية على أسس علمية صحيحة. علاوة على ذلك فهو يستعمل خوارزميات التعلم الآلي من أجل توجيه ومساعدة أخصائي الصحة في التكفل بمرضى سرطان البروستات واتخاذ القرارات المناسبة لتوفير رعاية متكاملة لهم. لقد تحصلنا على نتائج جد مرضية أظهرت لنا أن تقنيات الذكاء الاصطناعي تعتبر حلولا واعدة من أجل تقديم آراء ثانية لأخصائي الصحة. أين نعتقد بأن هذا سيساهم في تحسين الممارسات السريرية لكي تصبح أكثر ملائمة للعرق الإفريقي.



**الكلمات المفتاحية:** الذكاء الاصطناعي، التشخيص المدعم بالحاسوب، الشبكات العصبية، سرطان البروستات، الرعاية الداعمة، نظام التوصية

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# List of Acronyms

| | |
|---|---|
| ADC | Apparent Diffusion Coefficient |
| ADT | Androgen Deprivation Therapy |
| AFMS | Anterior Fibromuscular Stroma |
| AI | Artificiel Intelligence |
| ANN | Artificiel Neural Network |
| AS | Active Surveillance |
| BPH | Benign Prostatic Hyperplasia |
| CAD | Computer-Aided Diagnosis |
| CT | Computer Tomography |
| CV | Computer Vision |
| CZ | Central Zone |
| DCE | Dynamic Contrast-Enhanced |
| DL | Deep Learning |
| DRE | Digital Rectal Examination |
| DWI | Diffusion-weighted imaging |
| ESUR | European Society of Urogenital Radiology |
| GP | Grade Group |
| GS | Gleason Score |
| HT | Hormonal Therapy |
| KNN | K-Nearest-Neighbours |
| MDT | Multidisciplinary Team |
| ML | Machine Learning |
| mpMRI | multiparametric Magnetic Resonance Imaging |
| MRI | Magnetic Resonance Imaging |
| PCa | Prostate Cancer |
| PHI | Prostate Health Index |
| PI-RADS | Prostate Imaging and Reporting Data System |

PSA Prostate-Specific Antigen

PZ Peripheral Zone

RL Reinforcement Learning

ROI Region of Interest

RS Recommender System

RT Radiation Therapy

SVM Support Vector Machine

T2W T2-Weighted imaging

TNM tumour (T) classification, lymph node (N) status and the presence of metastases (M)

TRUS Transrectal Ultrasound

TURP Transurethral Resection of the Prostate

TZ Transition Zone

WW Watchful Waiting

*"There is no way to prepare for the moment a doctor looks you straight in the eyes and tells you, 'You probably have five years to live.' Or the next moment, when he slams his fists on his desk demonstratively and says, 'You need surgery immediately.' I know this because it happened to me, 18 years ago, after a biopsy of my prostate turned out to be positive for cancer."*

*– Ron Scolamiero, as told to Meghan Rabbitt*
*September 03, 2018*

# 1

# Introduction

## Contents

## 1. Context and Motivation

Prostate cancer is one of the most common cancers in Africa, with approximately 27,000 cases and 18,000 deaths recorded in Algeria in 2020. Today, with such a high number of deaths, PCa has become a real threat, especially for the elderly, who often do not receive the suitable care. Moreover, men with PCa face a number of challenges throughout their care pathway, which often impedes their recovery. Since the first meeting with the doctor, patients have problems understanding the overall care pathway and might obtain misinformation about PCa from the Internet that made them fall into depression and psychological crises.

Often patients newly diagnosed with PCa have a frightening image of the cancer and have difficulty remembering the doctor's instructions. Most of them are concerned about how to live with this new cancer, what should be done, and what should be avoided? And one of the frequently asked questions is "what should I eat?" as this is necessary in order to overcome the cancer and maintain a healthy condition. There are also many decisions that the patient must consider carefully before making, especially regarding the treatment plan that he must choose, as the information is insufficient and sometimes false due to the invasion of misinformation on the Internet that did not consider some risk factors such as the ethnic origin of the patient and his environment. Furthermore, patients feel uncomfortable in the absence of any communication with the doctor in the event of new symptoms appearing or questions about the cancer and a problem appears that the patient sees that his doctor considers him as nothing more than a medical record. This leads to a loss of trust between the doctor and the patient.

On the other hand, we will concentrate on resolving issues that concern health professionals, particularly urologists and radiologists, because their role is pivotal in the cancer pathway, either directly or indirectly. One of the difficulties that the urologist faces is the difficulty of managing PCa due to the large number of patient data that he requires and the complexity of the PCa pathway, which requires focus and time to manage well. Furthermore, because of the different lesions and information that must be provided in the report from one patient to the next, urologists have difficulty reading the reports he receives from the radiologist related to mpMRI.

The urologist also requires solutions to counteract any errors in his decisions. The mpMRI that the radiologist interprets is rather complicated for analysis, and the radiologist finds it difficult to classify lesions as benign or malignant, and whether they are cancer

related or not. He also tells the urologist that it is difficult for him to create a standardised report that includes all cases.

With the remarkable development that has appeared in Algeria in recent years and the widespread use of smart devices, and the authorities' interest in digitising the health sector. The creation of solutions based on technology and AI is necessary in order to advance the health sector and contribute to reducing the suffering of PCa patients and their health professionals.

Many researches and solutions have been proposed in order to solve the problems that are encountered in the pathway of PCa, among which we mention software solutions in order to help the patient manage his cancer, and to help the urologist in facing problems, and robotic solutions such as the use of robots in prostate removal operations and others, and also smart solutions represented in making interpretation of mpMRI images automatically. where we noticed that all the proposed solutions are directed to the European or American community, and we also noticed a complete absence of software directed to Africa or Algeria.

Where, after conducting a study of PCa in Algeria and the extent to which ideas that contribute to solving the previously mentioned problems, we decided to establish a system that is directed mainly to the patient, and takes into account the urologist and radiologist in order to contribute to the disposal of the problems they face These problems were controlled and confirmed after conducting meetings with a urologist and listening to some experiences of PCa patients.

## 2. Aim and Objectives

After analysing the majority of the issues and challenges that most stakeholders face, and based on our discussions with PCa patients, survivors, and urologists, we established the following objectives that must be achieved:

- Providing the patient with a mobile application that gives him permanent access to his medical records, allows him to track the progress of his medical condition, and keeps him informed by sending daily remainders.
- Help patients cope with PCa by giving personalised recommendations concerning lifestyle, health diet, and physical activities to do.
- Assisting the patient in making decisions about treatment plans and providing psychological care.

- Helping a urologist to manage his patients, monitor their progress, and make informed decisions.
- Provide the radiologist with an accurate tool that help him interpret images easily, in short period, and less effort.

## 3. Dissertation Outline

The remainder of this dissertation is structured as follows:

- Chapter 2: "**Background**" provides definitions of key terms related to our area of interest, as well as description of the various AI methods that can be used in the management of PCa.
- Chapter 3: "**Existing applications**", evaluates existing applications in the health care sector and discusses their benefits and limitations. Two case scenarios are presented to illustrates the ongoing challenges that patients and health professionals face on daily basis.
- Chapter 4: "**Proman**", in which we present our solution from the start (i.e., planning), passing by software design, until ML model selection. Furthermore, most features are presented in detail.
- Chapter 5: "**Implementation**", presents the tools and programming languages used to create the software, as well as displays some screenshots and a discussion of the results obtained.
- We conclude by enumerating Proman's features, explaining the implications of our findings, outlining our future plans, and by giving some recommendations and perspectives.

# Part 1. State of the art

Because our field of PCa management is still evolving, and several approaches and recommendations have emerged, some of which are even contradictory, a 'state of the art' part is essential to provide the theoretical foundation of the field, clarify key terms and concepts used in the field, review existing applications and the most relevant recent works, and discuss their achievements and limitations. This part contains two chapters as follows:

In the chapter "**Background**", we have provided a comprehensive overview of medical terms relevant to PCa management, in which we give interesting facts about cancer and examine to what extent the incidence cases are increasing. Next, we detail the current care pathway, including diagnosis exams and treatment options, as well as we draw attention to their potential side effects. We concluded the chapter by introducing a set of computer science and AI techniques that could contribute to solving problems that both healthcare professionals and patients face. Neural networks and recommender systems are two promising AI approaches.

To provide a clearer overview of the PCa management field, we present in the "**Existing Applications**" chapter a review of the literature, in which the results of an exhaustive evaluation of existing applications designed to help patients cope with cancer as well those aiding healthcare professionals in their daily duties were presented. The review was using one of the most common evaluation measures for mobile apps and other criteria that we thought were useful for assessing web and desktop apps. It had identified several limitations that had either not been well addressed or have not been examined at all. These limitations revealed numerous gaps that our work intends to fill in as well as allowed us to express the problem more accurately via two case scenarios.

*"By augmenting human performance, AI has the potential to markedly improve productivity, efficiency, workflow, accuracy and speed, both for doctors and patients … What I am most excited about is using the future to bring back the past: To restore the care in health care"*

*— Dr Eric Topol, a cardiologist and the founder and director of the Scripps Research Translational Institute*
*March 11, 2019*

# 2

# Background

## Abstract

Prostate Cancer (PCa) is the fifth leading cause of death among men, with over 300 thousand men died prematurely due to the disease in 2020. The rapid growth in cancer incidence and mortality worldwide can be explained by the fact that PCa is associated with several risk factors and symptoms that often appear at an advanced stage. To date, the most common diagnostic pathway in clinical practice has been the use of screening tests followed by some type of targeted biopsy. However, on the one hand, this pathway has resulted in overtreatment as well as misdiagnosis of clinically significant PCa. On the other hand, the interpretation of *multiparametric magnetic resonance imaging* (mpMRI) has remained a challenge because radiologists' experience is critical in distinguishing benign from malignant conditions. As a result, researchers are looking for new techniques to analyse digital prostate images (particularly mpMRI) and thus reduce the complexity of PCa diagnosis. AI can play a crucial role at several stages of the cancer care pathway, including early detection and diagnosis, by extracting many features from medical imaging and revealing disease characteristics that are impossible to appreciate by the naked eye. It can also be used in PCa treatment to provide personalised care while reducing treatment costs.

## Contents

With 1.4 million new cases per year (Sung et al., 2021), **prostate cancer** (in short, PCa) is one of the most critical global health issues, and its management remains one of the most complex and contentious topics in health care. Therefore, an improvement in how care is provided to PCa patients is needed, with AI-based approaches have been identified as a promising solution to alleviate these problems.

Before discussing the broad range of options in which AI can be used, Section 1 presents some medically checked facts that clarify why this disease is becoming a global health care concern in various countries. Next, an overview of the most common stages of the PCa care pathway is discussed, along with some of the controversial concerns that they raise are explored. Section 2 describes AI methods that could be applied in all fields of PCa management from early detection to post-treatment follow-up.

# Section 1. PROSTATE CANCER

## 1. General Information

This subsection explains the concepts that are widely used in our subject of interest, mainly PCa. It also describes symptoms and possible complications of the disease and presents some interesting statistical facts.

### 1.1. *Prostate*

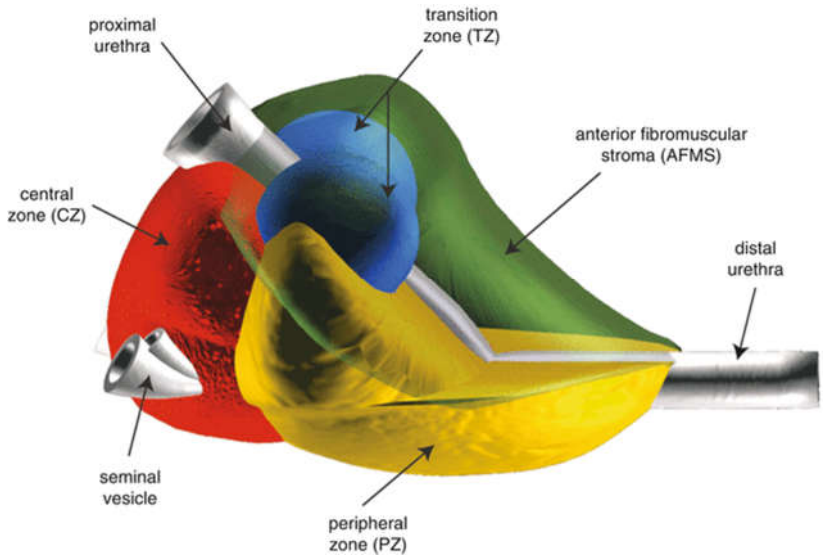
The *prostate* is defined by the American *National Cancer Institute* (National Cancer Institute, 2020):

> A walnut-sized gland that is a part of the male reproductive system, located just below the bladder and in front of the rectum. It surrounds part of the urethra and secretes a white-coloured fluid which is a part of the semen.

On imaging, the prostate is divided into three major zones, namely the *peripheral zone* (PZ), the *transition zone* (TZ), the *central zone* (CZ), and the *anterior fibromuscular stroma* (AFMS). The proximal prostatic urethra is connected to the TZ, which surrounds it both anteriorly and posteriorly, as shown in Figure 2.1. The CZ lies behind the TZ, and it stretches from the seminal vesicles to the proximal prostatic urethra. The PZ covers both the central and transition zones, as well as a significant part of the mid gland and apex of the prostate, encompassing the distal prostatic urethra almost entirely. Finally, the AFMS covers the anterior surface of the prostate. It is entirely non-glandular and is composed of stromal and fibrous tissue.

**Figure 2.1**

*Anatomy of the Prostate.*




*Note. The image describes Anatomical drawing sagittal view of prostate. From Anatomy of the Prostate, by Radiology Key, 2018 ( https://radiologykey.com/anatomy-of-the-prostate/).*

The TZ is just a tiny disk of tissue covering the proximal prostatic urethra in younger men (less than 35–40 years old), while the CZ is much more prominent, forming nearly 25% of the gland ("Read. MRI Prostate," 2020, pp. 5–6). As men age, the TZ undergoes significant nodular hypertrophy, flattening the central zone and pushing it superiorly towards the base. Consequently, the prostate may block the flow of urine from the bladder, causing sexual function issues – this is known as *benign prostatic hyperplasia* (BPH). Other, more aggressive types of prostatic disease exist, in which this section focuses on the so-called **prostate cancer**.

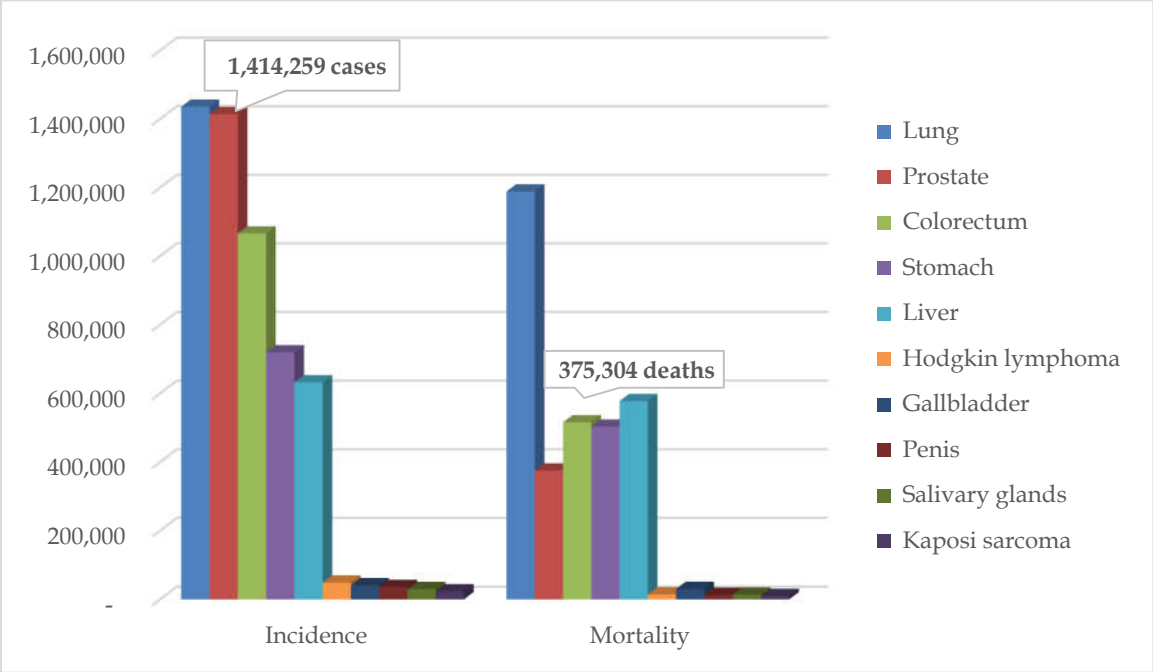
## 1.2. *Facts About PCa*

Prostate cancer is a disease in which malignant cells form in the prostate tissues (American Cancer Society, 2020). These cells can start growing out of control and spread in the body (i.e., cancer has metastasised), making cancer difficult to be cured with treatments.

According to the *Global Cancer Observatory* (Sung et al., 2021), PCa is the second most common cancer in males (apart from common skin cancers) and the fifth leading cause of cancer death in 2020, with over 1.4 million new cases and 375 thousand deaths worldwide (see Figure 2.2).

**Figure 2.2**

*Estimated Number of PCa Incidence and Deaths Among Men Worldwide in 2020.*



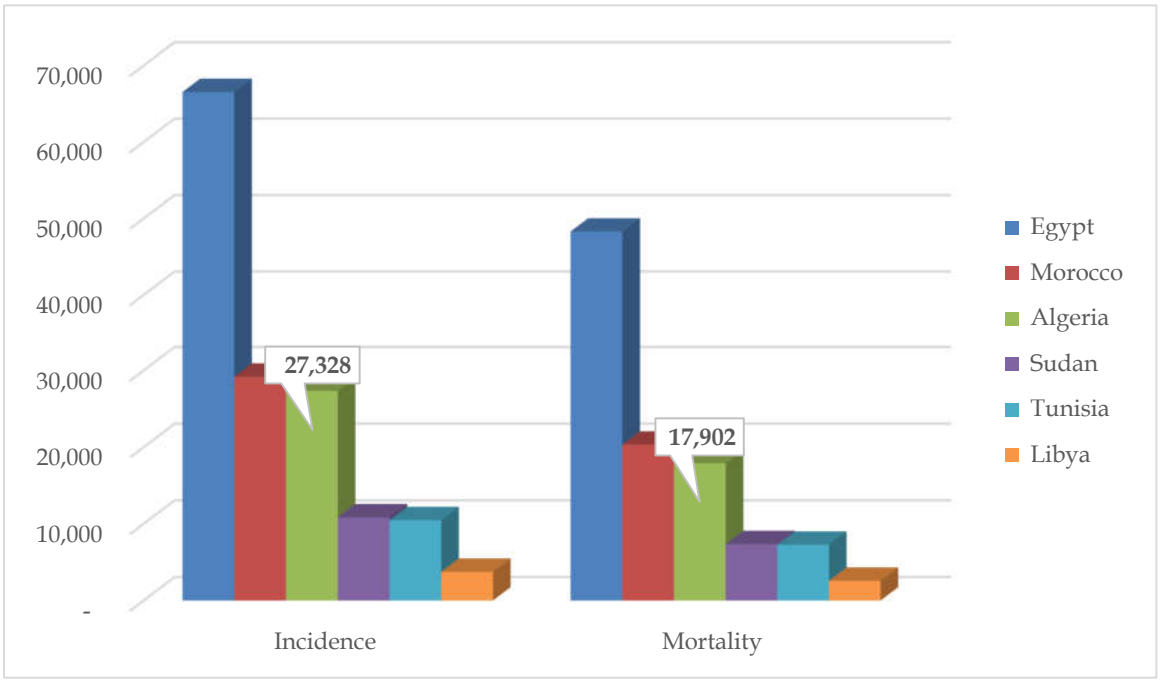

*From "Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries," by Sung, H., Ferlay, J., Siegel, R. L., Laversanne, M., Soerjomataram, I., Jemal, A., & Bray, F., 2, CA: A Cancer Journal for Clinicians, (https://doi.org/10.3322/caac.21660).*

The same statistics had claimed that incidence rates vary from 6.3 to 83.4 per 100,000 men across regions, with the highest rates found in Northern and Western Europe, the Caribbean, Australia/New Zeeland, Northern America, and Southern Africa and the lowest rates in Asia and Northern Africa. These variations in incidence rates may be due to differences in the diagnostic practices used and disparities in health care access.

During the last decade, rapidly increasing trends have been also found in Northern and sub-Saharan Africa. In Algeria, more than 27,000 men have been diagnosed with PCa, with 65.5% of them dying.

**Figure 2.3**

*Estimated Number of PCa Incidence and Deaths Among Men in North Africa in 2020.*




*From "Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries," by Sung, H., Ferlay, J., Siegel, R. L., Laversanne, M., Soerjomataram, I., Jemal, A., & Bray, F., 2, CA: A Cancer Journal for Clinicians, (https://doi.org/10.3322/caac.21660).*

### 1.2.1. Symptoms

PCa usually has no early warning signs, so that the disease may stay asymptomatic for several years. If signs do appear, they are frequently related to non-cancerous conditions such as the enlargement and inflammation of the prostate gland (American Society of Clinical Oncology, 2020; Doru Paul, 2020). Frequent urination, urgency or the need to urinate during the night are all common symptoms. Men can also experience trouble beginning to urinate, as well as a decrease in urination force. Some uncommon symptoms include finding blood in the urine or semen, as well as the sudden occurrence of erectile dysfunction. Other symptoms may also occur due to complications of PCa, such as back and hip pain if cancer spreads to the bones.

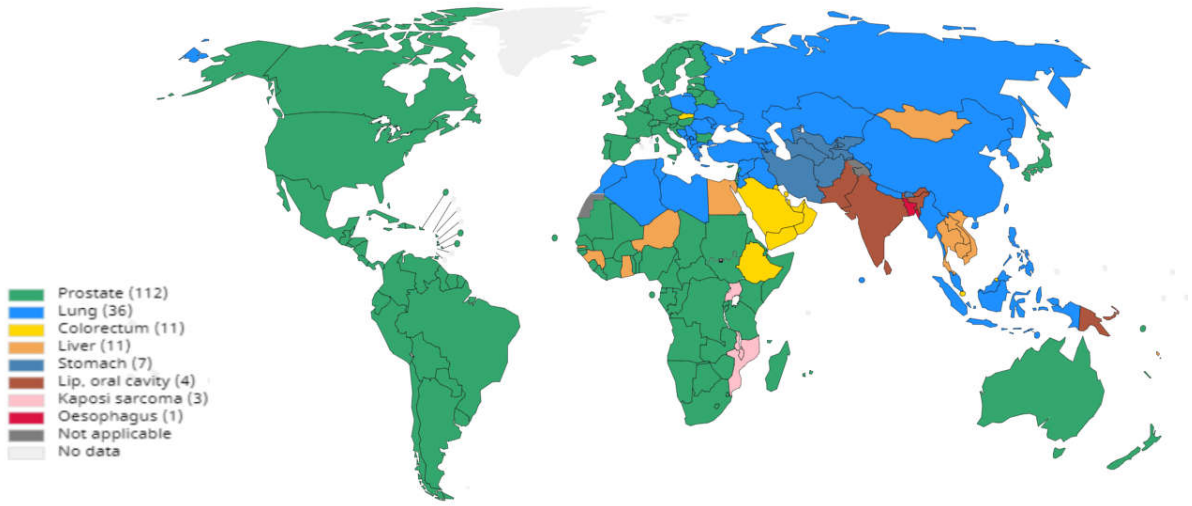
### 1.2.2. Causes and Risk Factors

Although the precise cause(s) has yet to be determined, most PCa incidences are believed to be caused by various factors that work together. The following are some of the well-established risk factors of the disease:

- **Age:** after the age of 50, the risk of PCa increases dramatically, with about 80% of men are diagnosed after the age of 65 years (American Cancer Society, 2020).
- **Race:** according to the same statistics, black men have a greater risk of PCa than do men of other races and are more likely to develop the disease at a young age (Doru Paul, 2020).
- **Geographical location:** due to the more significant proportion of older men in the general population, this disease is more common in some areas of the world, especially in North America, Europe, and Australia.

**Figure 2.4**

*Estimated Number of New Cases in 2020 of Top Cancer per Country Worldwide.*

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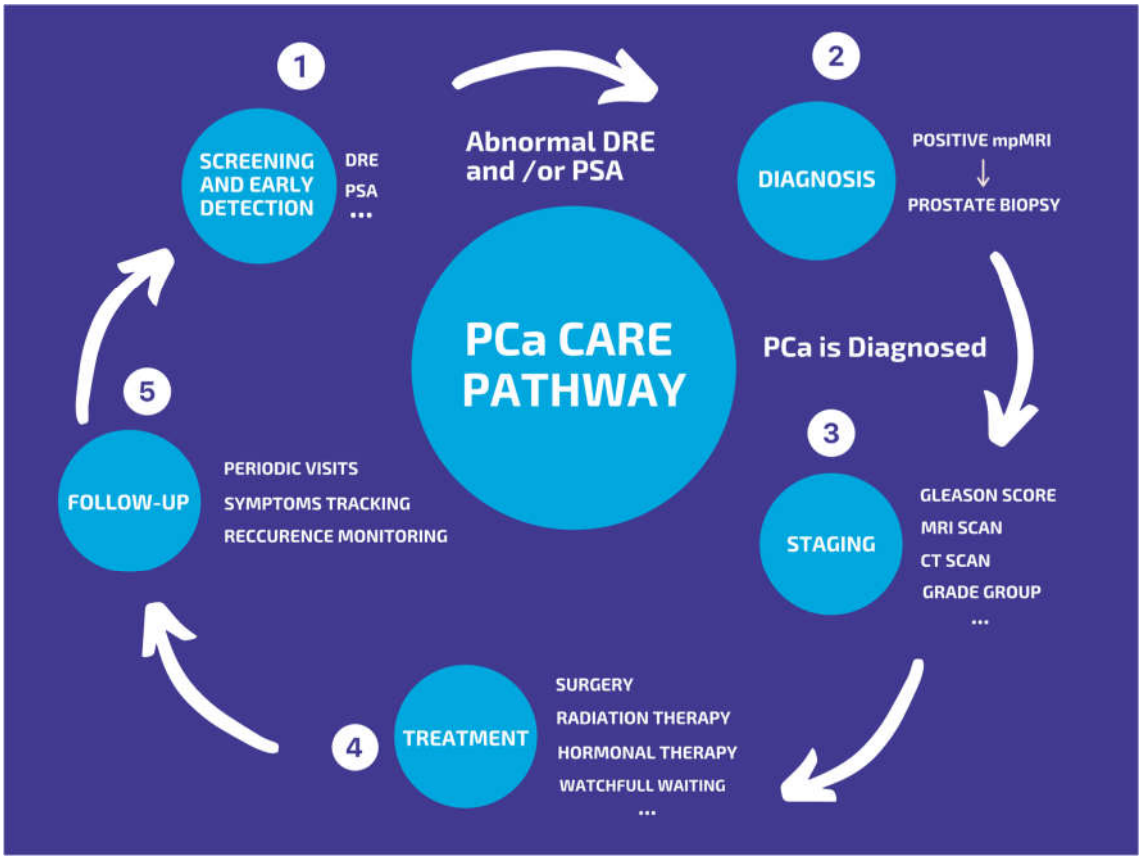
Researchers are also looking into potential connections to environmental exposures to pesticides and herbicides, diet, vitamin D deficiency, and even sexual activity (Doru Paul, 2020). A family history of this malignancy and certain specific genetic mutations are linked to the development of PCa at a younger age. Although there is no proven method to prevent PCa completely, current clinical practices assume that the risk of developing cancer can be reduced by making healthy lifestyle choices such as doing physical activities and eating well-balanced diets. Furthermore, early detection and personalised care improve PCa survival rates significantly.

## 2. Prostate Cancer Care Pathway

The appropriate care pathway is intended to guide the delivery of consistent, safe, high-quality and evidence-based care for people with PCa (Cancer Council Australia, 2021). The pathway outlines five key stages of the patient journey; while these stages appear in a linear model, in practice, patient care does not always occur in this manner but depends on the specific situation.

**Figure 2.5**

*The Current PCa Care Pathway.*




As depicted in Figure 2.5 the most common stages of the PCa care pathway are as follows:

1. When a patient exhibits specific symptoms of PCa, he usually consults a general practitioner (GP). The latter performs a physical examination of the patient's body to look for signs of the disease and then refers the patient to a urologist for further examination; the urologist orders certain screening tests to detect abnormalities.
2. If the tests are positives, he performs specific diagnostic procedures to determine the location of cancerous lesions.
3. In case a PCa is diagnosed, further tests are done in order to stage cancer.

4. After that, the treatment process should begin. As a result, a multidisciplinary team (MDT) selects the most suitable treatment option based on the obtained examination results.
5. The patient will have to visit his urologist periodically to monitor cancer progression and determine whether or not the treatment was effective. In case of a cancer recurrence after initial treatment, another treatment option should be used.

The following subsections give more details about the standard tests and procedures used mainly in PCa management: early detection, diagnosis and staging, treatment, and follow-up care.

## 2.1. *Screening and Early Detection*

*Early detection* of PCa is used to look for cancer before a man develops any symptoms or signs, whereas a PCa *screening* looks at the entire asymptomatic population. The procedure is recommended for men at the age of 50 or even at age 40 or 45 for men who are at higher risk of PCa ("Early Diagnosis and Treatment of Cancer: Prostate Cancer," 2010, pp. 1–2; Rozet et al., 2020, p. 141). However, there is insufficient or conflicting evidence to suggest that population screening reduces mortality from PCa (National Cancer Institute, 2020; Rozet et al., 2020, p. 140).

Although there are no standard or routine early detection methods of PCa, two methods are commonly used to detect PCa consist of performing a *digital rectal exam* and measuring serum PSA concentration.

### 2.1.1. Digital Rectal Exam

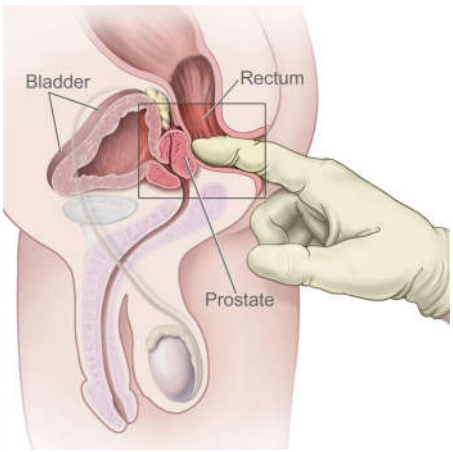
*Digital rectal exam* (DRE) is an exam of the rectum, in which the doctor inserts a lubricated, gloved finger into the rectum, as shown in Figure 2.6, to palpate the prostate gland through the rectal wall and check for lumps or abnormal areas (National Cancer Institute, 2019).

Although the DRE can be somewhat uncomfortable, it is still crucial to be used before or along with the PSA test (Rozet et al., 2020, p. 141). According to some studies (Richie et al., 1993), a suspect DRE alone[1] had detected PCa in about 18% of all patients, regardless of the PSA level.

[1] Most prostate cancers are located in the PZ of the prostate and may be detected by DRE when the volume is about 0.2 mL or larger.

**Figure 2.6**

*The Procedure of DRE.*




*From "Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries," by Sung, H., Ferlay, J., Siegel, R. L., Laversanne, M., Soerjomataram, I., Jemal, A., & Bray, F., 2, CA: A Cancer Journal for Clinicians, (https://doi.org/10.3322/caac.21660).*

### 2.1.2. Prostate-Specific Antigen Blood Test

A PSA test measures the level of a substance called PSA (stands for *prostate-specific antigen*) in the bloodstream. This substance is a protein produced by cells of the prostate gland. The results are expressed in nanograms of PSA per millilitre of blood (ng/mL).

The average concentration of PSA in serum is relatively low—0.2 to 4.0 ng/mL—("Early Diagnosis and Treatment of Cancer: Prostate Cancer," 2010). Higher PSA levels may only indicate a higher risk of PCa because the PSA substance may also be elevated in men who have an infection or inflammation of the prostate and may also temporarily been affected by certain sports and medications[1].

[1] Due to the fact that roughly 3 out of 4 men with elevated PSA will not have cancer (Prostate Cancer Research, 2019).

**Table 2.1**

*The List of PSA Reference Values.*

| Age (years) | PSA upper limit (ng/mL) |
|---|---|
| *Less than 40* | Less than or equal to 2 |
| *40-49* | Less than or equal to 2.5 |
| *50-59* | Less than or equal to 3.5 |
| *60-69* | Less than or equal to 4.5 |
| *70-79* | Less than or equal to 6.5 |
| *80 and over* | Less than or equal to 7.2 |

*Reprinted from https://www.verywellhealth.com/psa-prostate-specific-antigen-velocity-2782267.*
*Copyright 2019 by Schmitz, M.*
*Adapted from https://www.mayocliniclabs.com/test-catalog/Clinical+and+Interpretive/64061.*
*Copyright 2019 by Mayo Clinic Laboratoires.*

Besides, it is worthy to note that there is controversy about using the PSA test for screening[1] (American Society of Clinical Oncology, 2020; National Cancer Institute, 2019). On the one hand, the PSA test helps detect early-stage PCa, especially in those with many risk factors, which helps some get the treatment they need before cancer grows and spreads. On the other hand, PSA screening may find very slow-growing prostate cancers that would never threaten someone's life –finding these cancers is called *overdiagnosis*[2]. As a result, screening for PCa using PSA may lead to *overtreatment* [3], which can cause side effects and seriously affect a person's quality of life.

In brief, screening tests cannot diagnose PCa; instead, they let doctors know if further testing to look for the disease is required.

## 2.2. *Diagnosis and Staging*

A diagnosis of PCa is often initially suspected when screening tests reveal abnormalities. Diagnostic tests may be required to determine whether a PCa is present and,

[1] According to (Prostate Cancer Research, 2019), about 1 in 7 prostate cancers can be missed during PSA screening (commonly known as *false-negative test*)

[2] Overdiagnosis can be defined as the detection of cancer that would otherwise not become clinically manifest over a patient's lifetime or not result in cancer-related death (Sandhu & Andriole, 2012).

[3] Overtreatment is some unnecessary treatments like treating a cancer that would have gone away on its own or never caused any symptoms. It may lead to problems and harmful side effects from cancer therapies that are not needed (National Cancer Institute, 2019).

if so, how aggressive it is and what treatment option is more appropriate. Depending on the patient's risk factors, the following tests, procedures, and scans may be performed to confirm a diagnosis of PCa:

- As previously mentioned, a DRE is required before a biopsy in order to locate abnormalities.
- *Blood and urine biomarkers* are used to decide whether a prostate biopsy is required.
- *Prostate biopsy* is the only sure way to determine if a tumour is cancerous.
- *Imaging tests* are performed to determine if the cancer has metastasised.

### 2.2.1. Biomarkers

A *biomarker* is a substance found in the blood, urine, or body tissues of a person with cancer (American Society of Clinical Oncology, 2020). It is produced by the tumour or by the body in response to cancer. The use of several biomarkers could reduce the likelihood of diagnosing clinically insignificant lesions while missing fewer clinically significant cancers. *PSA density* (PSAd), *PCa Gene 3* (PCA3), 4Kscore, and *prostate health index* (PHI) are the most commonly used biomarker tests for PCa.

Indeed, advances in imaging have led to the development of new imaging techniques, especially *multiparametric MRI* (mpMRI). There is a plethora of evidence that mpMRI can enhance PCa management in general, particularly the diagnosis pathway. More information on this emerging technique and its role in providing more accurate PCa care is presented in the following sub-section.

### 2.2.2. mpMRI for PCa Diagnosis

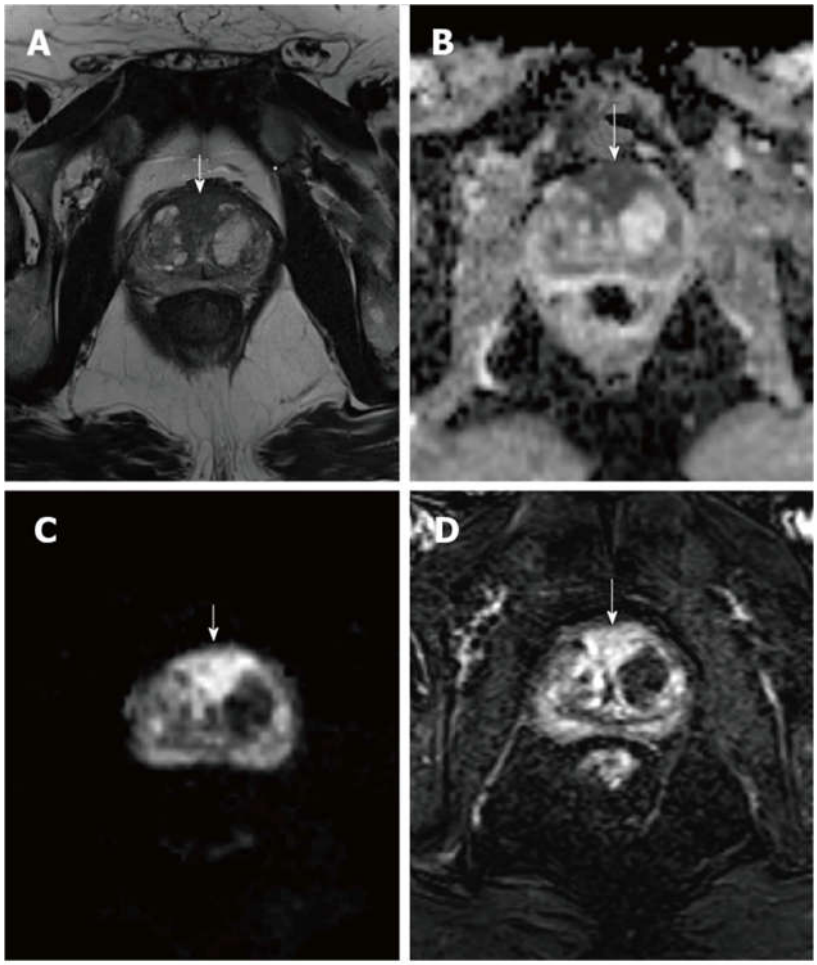
A multiparametric MRI is a particular type of MRI scan that creates more detailed pictures of the prostate than a standard MRI scan. Because of its high ability to localise prostate tumours and determine their size, aggressiveness and invasiveness (Johnson et al., 2014), mpMRI is increasingly recommended as a first-line diagnosis. Notably, the performance of mpMRI can vary depending on the population being studied, the execution of the MRI itself, the experience of the radiologist, and whether additional biomarkers are considered (Stabile et al., 2020). As a result, the *European Society of Urogenital Radiology* (ESUR) established consensus-based guidelines for the acquisition, interpretation and structured reporting of prostate MRI known as *Prostate Imaging and Reporting Data System* (PI-RADS) – more details are provided below.

mpMRI has many sequences, including the anatomic *T1 weighted* and *T2 weighted* imaging combined with functional imaging techniques, for instance, *diffusion-weighted*

*imaging* and *dynamic contrast-enhanced imaging* ("Read. MRI Prostate," 2020, Chapter 4). The sequences used in mpMRI are briefly discussed in the glossary.

**Figure 2.7**

*mpMRI of a Cancerous Prostate.*




*Note. T2W axial image (A) shows a hypointense lesion at TZ and AFMS; ADC map (B) and DWI image (C) show a marked hypo- and hyperintensity, respectively; DCE image (D).*
*From "Magnetic resonance imaging for prostate cancer before radical and salvage radiotherapy: What radiation oncologists need to know" by Couñago, F., Sancho, G., Catalá, V., Hernández, Di., Recio, M., Montemuiño, S., Hernández, J. A., Maldonado, A., & Del Cerro, E., 2017. World Journal of Clinical Oncology, 8(4), pp. 305–319 (https://doi.org/10.5306/wjco.v8.i4.305).*

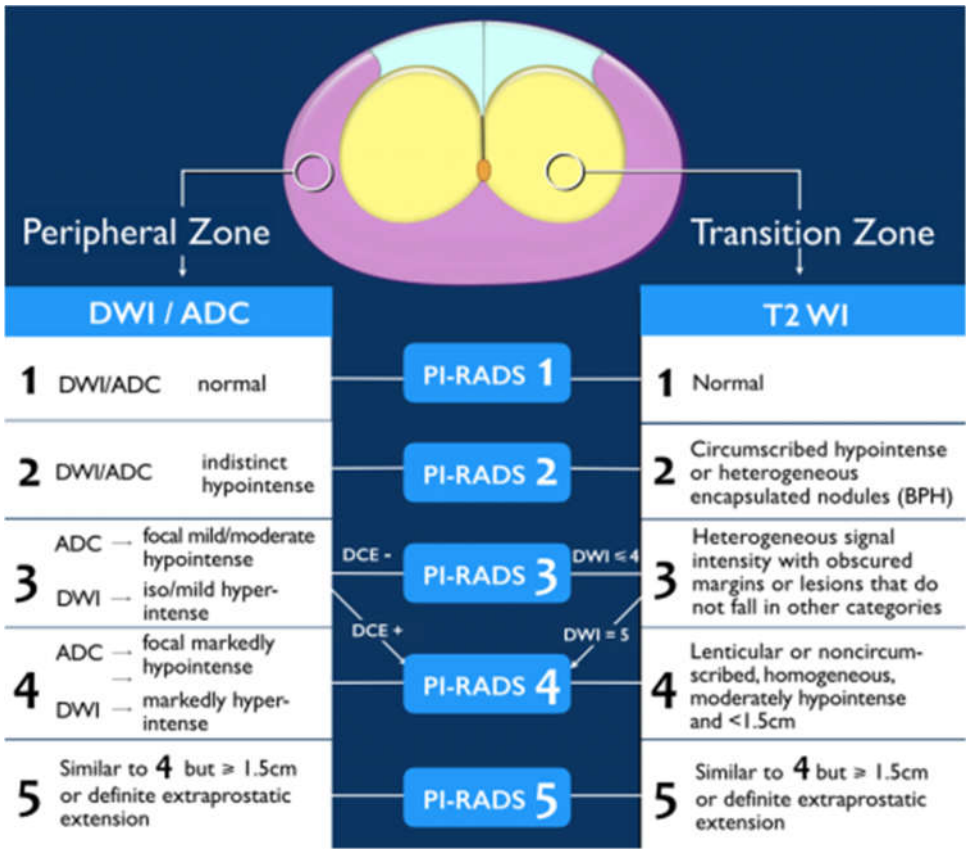
It is worth noting that the other mpMRI sequences are not commonly used in routine clinical practice. Their use is currently being debated owing to the increased costs and the duration of MRI acquisition.

The *International Community of Radiologists and Urologists* had worked to standardise prostate MRI reporting and interpretation ("Read. MRI Prostate," 2020, Chapter 4). Their

efforts had led to consensus guidelines in the form of PI-RADS recommendations, the second version of which was released in 2015. As shown in Figure 2.8, PI-RADS v2.1 defines primary and secondary mpMRI sequences for both peripheral and transition zones, enumerates findings on these sequences that are benign or have an increased probability of cancer and recommends an overall 1–5 scoring system, where a score of 1 indicates a very low probability of cancer and a score of 5 indicates a very high probability of clinically significant cancer.

**Figure 2.8**

*PI-RADS sequence assessment.*




*From Prostate Cancer - PI-RADS v2, Van Loenhout, R., Zijta, F., Smithuis, R., & Schoots, I., 2018, (https://radiologyassistant.nl/abdomen/prostate/prostate-cancer-pi-rads-v2)*

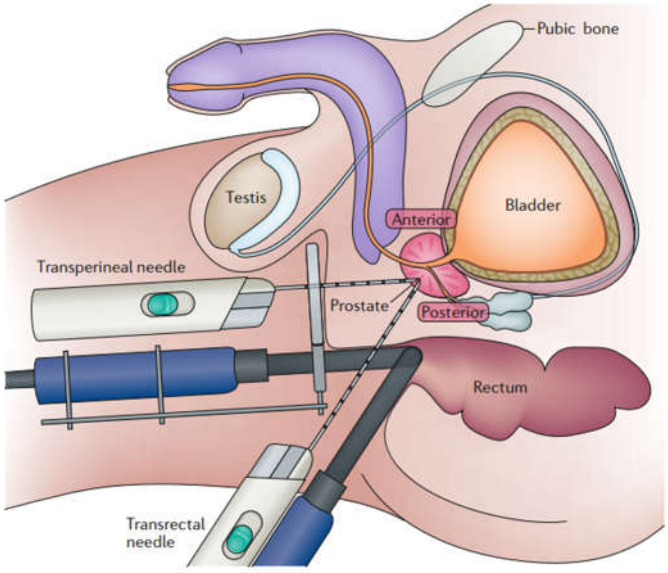
### 2.2.3. Prostate Biopsy

As mentioned above, a prostate biopsy may be performed if a screening test is abnormal or abnormalities are observed on *transrectal ultrasound* (TRUS). During a biopsy, small amounts of tissue are removed from the prostate using a special needle. The samples are then sent to a laboratory for a microscopic examination by a pathologist to determine the presence of PCa cells. On the one hand, each biopsy technique can be performed using either

a *transrectal* or *transperineal* approach (see Figure 2.9). In a transperineal biopsy, the needle is inserted through the skin behind the testicles (an area known as the *perineum*). A transrectal biopsy involves inserting the needle through the rectum.

**Figure 2.9**

*Transrectal Versus Transperineal Approach.*




*From "Multiparametric MRI for prostate cancer diagnosis: current status and future directions", by Stabile, A., Giganti, F., Rosenkrantz, A. B., Taneja, S. S., Villeirs, G., Gill, I. S., Allen, C., Emberton, M., Moore, C. M., & Kasivisvanathan, V., 2020, Nature Reviews Urology, 17(1), 41–61. (https://doi.org/10.1038/s41585-019-0212-4).*

On the other hand, different strategies for performing prostate biopsy have been used in clinical practices, for instance, *random 12-core biopsy*, *TRUS-guided biopsy*, and *MRI-fusion biopsy*.

### 2.2.4. Grading and Staging

The cancer grade describes how abnormal cancerous cells appear under a microscope, how aggressive the cancer is, and how quickly the cancer is likely to grow and spread. The ***Gleason score*** (GS) is the most commonly used system for PCa grading, in which a pathologist examines prostate tissue samples to find the two main cell patterns (National Cancer Institute, 2020). The primary pattern describes the most common tissue pattern, while the secondary pattern describes the following most common pattern. Each pattern is given a grade from 1 to 5, with 1 resembling normal prostate tissue and 5 resembling abnormal prostate tissue. The two Gleason grades are then added to get the GS,

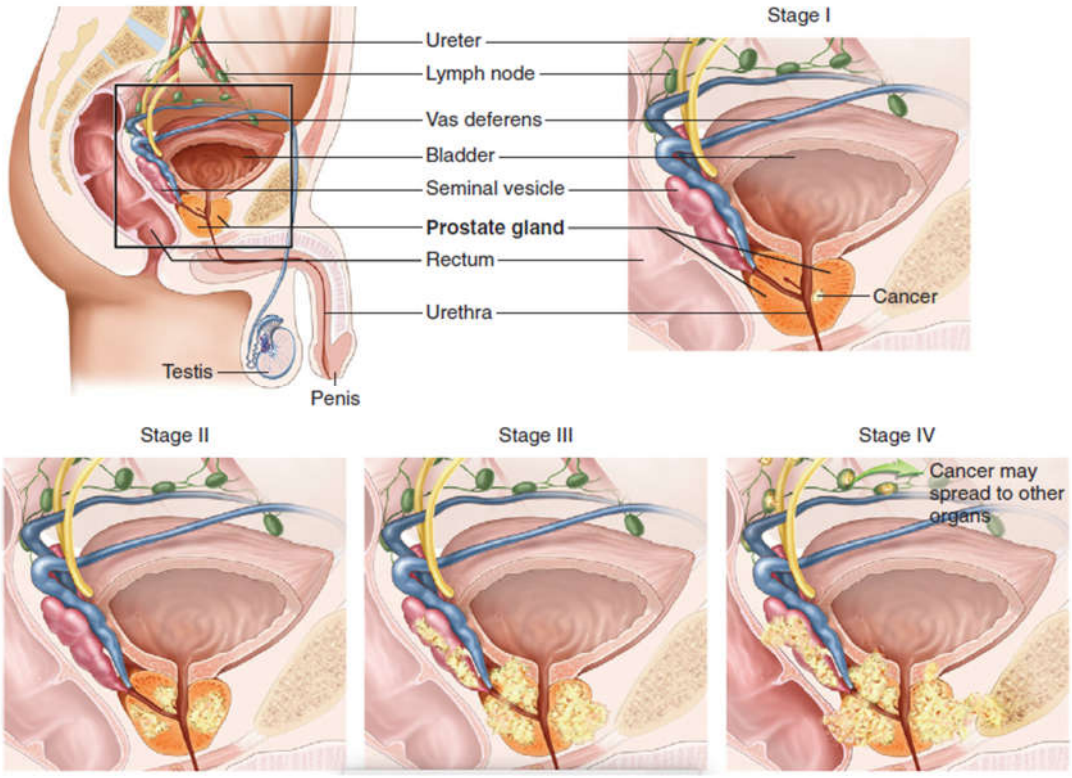
which ranges from 2 to 10. Gleason scores are organised into *Grade Groups* to make them understandable.

As explained in Table B.1, the International Society of Urological Pathology (ISUP) suggested a new classification that contains 5 prognostic groups, since the Gleason score does not differentiate between the score 7 (mainly 3) and 7 (mainly 4). Since prostate cancers can differ significantly in their tendency to grow or spread, staging is vital in choosing the best treatments, determining the risk of recurrence, and estimating the prognosis of the disease (Doru Paul, 2020). Staging describes how much cancer is in the body, where it is located, and what cancer subtype exists. Two central classification systems for clinical staging exist today, are the D'Amico and the TNM classification systems.

***TNM Classification.*** Historically, *tumour* (T) classification, *lymph node* (N) status, and the presence of *metastases* (M) have been the cornerstones of staging for solid tumours. Based on cancer test results, the doctor assigns a score to each letter. These scores will be combined to assign the stage (for example, it might look like this: 'T2, N1, M0'). As illustrated in Figure 2.10, PCa is described as '*localised*' (stage I), '*locally advanced*' (stage II), '*regional*' (stage III), or '*metastatic*' (stage IV).

**Figure 2.10**

*The Stages of PCa According to the TNM Classification System.*



***D'Amico Classification.*** This classification system categorises patients into three risk-based recurrence groups: low-, intermediate-, and high- risk, using such measures as blood PSA levels, Gleason grades, and tumour stages via T-scores (Doru Paul, 2020).

**Table 2.2**

*D'Amico Risk Groups.*

| | Low-Risk | Intermediate-Risk | High-Risk |
|---|---|---|---|
| *PSA level* | Less than 10 ng/mL | 10 to 20 ng/mL | More than 20 ng/mL |
| *Gleason Score* | Six or lower | 7 | Eight or higher |
| *Tumour Stage* | T1 or T2a | T2b | T2c or T3a |

*Reprinted from https://www.verywellhealth.com/prostate-cancer-4142361. Copyright 2020 by Doru Paul.*

*Adapted from French ccAFU guidelines – update 2020-2022 : prostate cancer (136–251) by Rozet, F., Mongiat-Artus, P., Hennequin, C., Beauval, J.-B., Beuzeboc, P., Cormier, L., Fromont-Hankard, G., Mathieu, R., Ploussard, G., Renard-Penna, R., Brenot-Rossi, I., Bruyere, F., Cochet, A., Crehange, G., Cussenot, O., Lebret, T., Rebillard, X., Soulié, M., Brureau, L., & Méjean, A., 2020, Progrès En Urologie.*

*Adapted from Early Diagnosis and Treatment of Cancer: Prostate Cancer (1st ed.), by Su., Li-Ming, 2010, Elsevier Inc.*

Mainly, cancer staging goals are to assess prognosis and facilitate informed decision-making regarding available treatment options. Unfortunately, the exclusive use of the TNM staging system has limited relevance for predicting outcomes and directing therapy for men with clinically localised PCa. Further tests, such as a CT scan (*computer tomography*), MRI, or bone scan, may be done to look for the spread of PCa to nearby tissues, as well as distant tissues such as bone (American Society of Clinical Oncology, 2020; Doru Paul, 2020). These tests are often unnecessary for early prostate cancers, in which we will describe the most two commonly used imaging tests in clinical practice for PCa diagnosis.

## 2.3. *Treatment and Follow-Up*

Treating PCa requires different types of doctors –members of the MDT– who often work together to create an overall treatment plan. Some members will be with the patient throughout the cancer treatment, while others will only be there for parts of it.

### 2.3.1. Watchful Waiting and Active Surveillance

In men with comorbidity and a limited life expectancy, treatment of localised PCa may be postponed to avoid unnecessary treatment and side effects. The two ways of monitoring PCa are *watchful waiting* (WW) and *active surveillance* (AS).

Watchful waiting consists of providing follow-up for patients with PCa and palliative treatment only for those who become symptomatic or metastatic (Rozet et al., 2020, pp. 151–152). In contrast to WW, active surveillance is a curative treatment option that shifts the possible timing of treatment while remaining watching closely for any sign that cancer may be growing or changing. The patient will have frequent doctor visits and tests, such as DRE, PSA tests, and biopsies. If these tests show that cancer is growing or changing in any way, the doctor could recommend an active treatment to treat cancer (U.S. Department of Health and Human Services, 2011, p. 8). The validity of this approach has been confirmed by several recommendations to do well with patients having low-risk PCa (Rozet et al., 2020, pp. 151–152).

### 2.3.2. Surgery

Patients in good health and whose tumour has not spread beyond the prostate gland are typically treated with surgery to remove the tumour. The following three types of surgery are used (Doru Paul, 2020; National Cancer Institute, 2020): *radical prostatectomy* (RP), *pelvic lymphadenectomy*, and *transurethral resection of the prostate* (TURP).

As with any surgery, there is a potential for side effects and complications after prostatectomy. Possible complications, which may be temporary, include bleeding, loss of bladder control, and infertility. Despite these risks, surgery's success rate is very high if all cancer gets removed (American Academy of Family Physicians, 2020).

### 2.3.3. Radiation Therapy

*Radiation therapy* (RT) uses high-energy x-rays or other types of radiation to damage and kill cancer cells or keep them from growing (National Cancer Institute, 2020; Speight et al., n.d.). It can be delivered from outside the body using *external beam* RT or inside the body using *brachytherapy*. RT may be used as the primary treatment for PCa (*curative therapy*); after surgery as an *adjuvant therapy* to treat any remaining cancer cells that remain; or as a *palliative treatment* to improve symptoms, but not to cure cancer (American Society of Clinical Oncology, 2020; Mottet et al., 2020, pp. 7–10; U.S. Department of Health and Human Services, 2011, pp. 9–10; 13).

Unfortunately, RT can injure or destroy normal cells, which can cause some side effects such as fatigue, sexual changes, and urinary problems that may worsen with age (Massachusetts General Hospital, 2013; Prostate Cancer Research, n.d.).

### 2.3.4. Hormone Therapy

*Hormone therapy* (HT) is a cancer treatment that removes hormones or blocks their action and stops cancer cells from growing (American Society of Clinical Oncology, 2020; National Cancer Institute, 2020). Drugs, surgery, or other hormones are used to reduce the number of male sex hormones, called *androgens* that can cause PCa to grow. This treatment is called *androgen deprivation therapy* (ADT).

HT does not cure PCa but is a mainstay for controlling its growth. It may be recommended in the following circumstances (Speight et al., n.d.): (a) *in conjunction with radiation*, primarily for men with certain risk factors; (b) *after radiation or surgery*, when PSA rises (particularly if not believed to be a localised recurrence); (c) *as therapy* for men with advanced PCa who are unsuitable for radiation or surgery.

Erectile dysfunction, cholesterol level changes, impaired sexual function, and weakened bones may occur in men treated with HT (National Cancer Institute, 2020). Other side effects include diarrhoea, nausea, learning and memory problems, and itching.

### 2.3.5. Supportive Care

Living with PCa involves much more than selecting the best treatments. It includes dealing with physical side effects and the diverse emotions and life changes that can accompany a diagnosis of cancer. For this reason, a health care professional will be assigned

to support the patient after treatment. In addition, the patient will have follow-up appointments and check-ups afterwards to monitor for recurrence or re-growth of the cancer cells somewhere in the body.

Many epidemiologic studies, as well as laboratory, intervention, and case-control studies, suggest that diet may be a critical factor in the transformation of a latent or slow-growing focus into a more aggressive form that necessitates invasive treatment (“Early Diagnosis and Treatment of Cancer: Prostate Cancer,” 2010, Chapter 11).

After addressing the tests and procedures used to manage PCa, we can now consider the potential of AI methods to support doctors in improving results for PCa patients and what ML methods can do for the PCa pathway.

# Section 2. COMPUTERISED METHODS

*Leo Cherne*[1] once said: "*The computer is incredibly fast, accurate, and stupid. Man is unbelievably slow, inaccurate, and brilliant. The marriage of the two is a force beyond calculati*on" (Cherne, 1977, as cited in Garland, 1982). This powerful combination is already revolutionising health care, including urological imaging and the industry is investing heavily in AI applications (Goldenberg et al., 2019; Suarez-Ibarrola et al., 2020; Valavanidis, 2020).

In this section, we will give more details about computer-based technologies like machine learning, deep learning, and computer vision that are broadly used in the medical industry.

## 1. Key Terms Definitions

### 1.1. *Artificial Intelligence*

The term *artificial intelligence* (AI) commonly refers to the ability of a computer or machine to mimic the capabilities of the human mind, such as reasoning, learning, decision-making, and problem-solving (IBM, 2020). While several definitions of AI have emerged over the last few decades, we refer to the one given in one of the leading textbooks on the subject, which defines AI as 'the ability of a machine to independently replicate processes typical of human cognitive function in *deciding* on an *action* in response to its *perceived environment* in order to achieve a predetermined *goal*' (Russell & Norvig, 2020, Chapter 1).

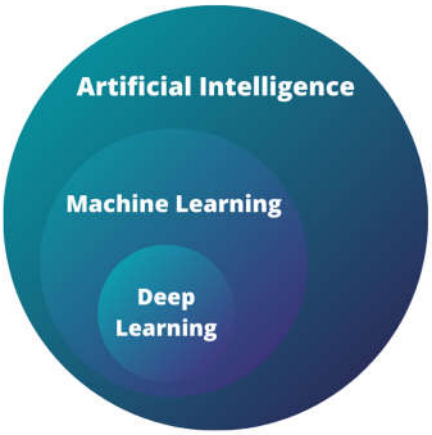
> Another definition provided by *John McCarthy* (Mccarthy, 2004) is as follows:
> AI is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.

In today's world, we are surrounded by computer-based AI technology: personalised advertising, search engines, speech and facial recognition, and so much more. In particular, AI has been revolutionising and reshaping health care systems by performing complex tasks in medical diagnosis, robotic intervention, advanced genome sequencing, and it is expected to play a significant role in transforming oncology practice.

[1] A former Chair of the *President's Intelligence Advisory Board*. He was an American economist, public servant, and four-decade head of the *International Rescue Committee*.

**Figure 2.11**

*The Relationship Between AI, ML and DL.*




The Figure 2.11 depicts a schematic overview of the field as a whole, indicating how AI, ML, and DL relate. The distinguishing characteristics of each field are covered in the following sub-sections.

## 1.2. *Machine Learning*

*Machine learning* (ML) involves the development of algorithms, by which computers may learn from data and perform predictions without previous specific programming (Cuocolo et al., 2019). To do so, the algorithms analyse the data and its properties using probabilistic and statistical tools to determine the actions as well as computers modify or adapt these actions to improve their accuracy, which is measured by how well the chosen actions reflect the correct ones (Zicari, 2016, p. 10).

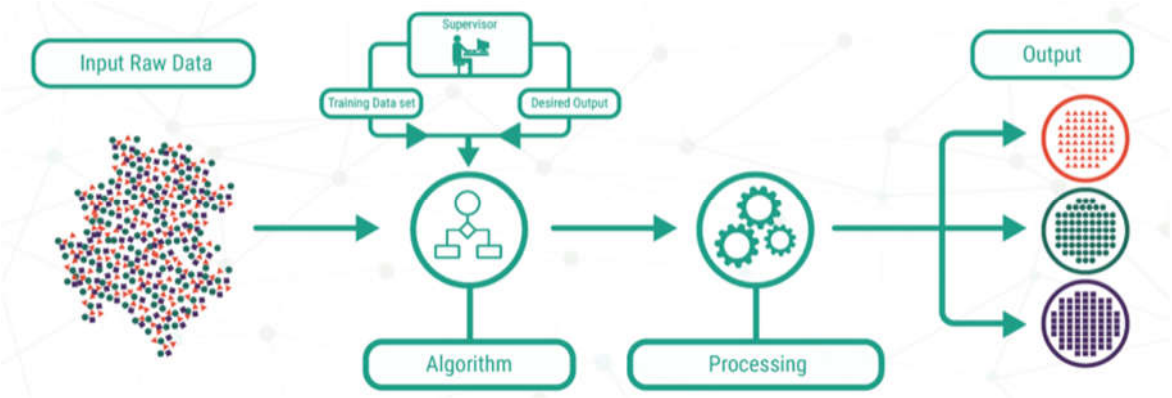
ML techniques can be broadly classified according to the type of label and the type of feature (Goldenberg et al., 2019). Based on labels, ML can be classified into three paradigms: *supervised*, *unsupervised*, and *reinforcement learning*. Whereas based on features, ML can be classified into *handcrafted* or *non-handcrafted* feature-based techniques.

### 1.2.1. Supervised Learning

Supervised learning is the search for algorithms that have been trained on explicit data sets that have been labelled by experts in order to produce general hypotheses and then make predictions about future instances (Kotsiantis, 2007). Examples of such algorithms include *K-nearest-neighbours* (KNN) *linear* and *logistic regression*, *random forests*, and *support vector machines* (SVM).

**Figure 2.12**

*A Schematic Overview of Supervised Learning.*



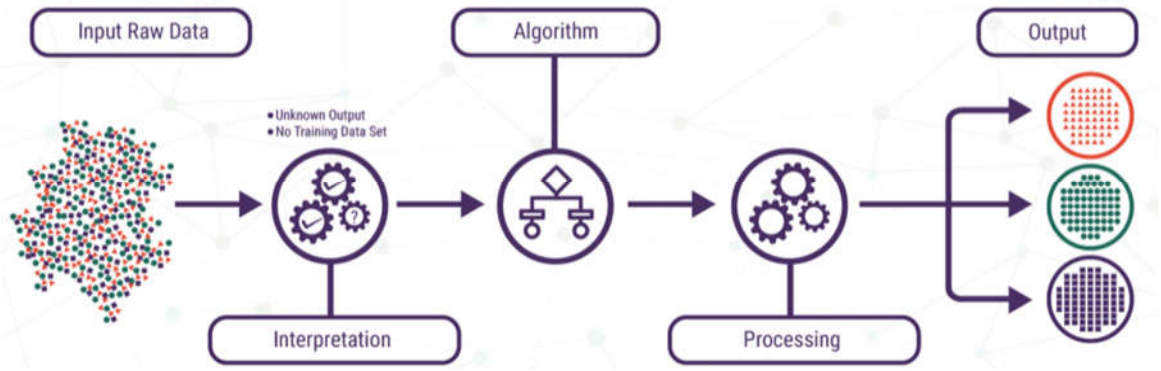

*From Why Unsupervised Machine Learning is the Future of Cybersecurity, by Mezic, A., 2020, TechNative (https://technative.io/why-unsupervised-machine-learning-is-the-future-of-cybersecurity/)*

### 1.2.2. Unsupervised Learning

In unsupervised learning, ML algorithms use a dataset without labels and try to discover hidden patterns or data groupings without the need for human intervention (Goldenberg et al., 2019; IBM, 2020). Such algorithms are utilised for three main tasks: *clustering*, *association rules*, and *dimensionality reduction*.

**Figure 2.13**

*A Schematic Overview of Unsupervised Learning.*



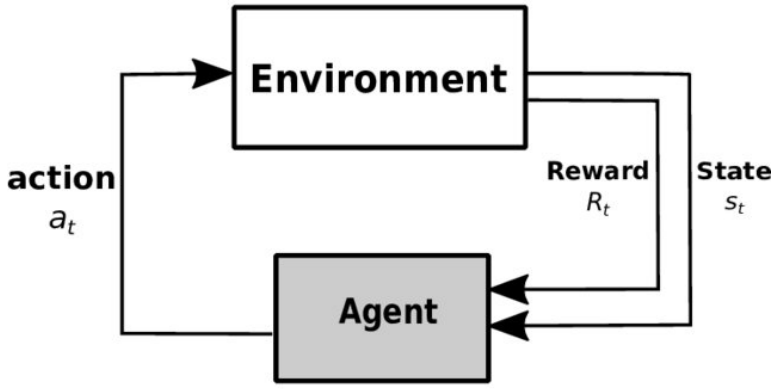

*From Why Unsupervised Machine Learning is the Future of Cybersecurity, by Mezic, A., 2020, TechNative (https://technative.io/why-unsupervised-machine-learning-is-the-future-of-cybersecurity/)*

### 1.2.3. Reinforcement Learning

Reinforcement learning (RL) is an approach through which intelligent programs, known as *agents*, acts in an environment to constantly adapt and predict the features at a future step based on past and present features (Gourav & Kaur, 2020; IBM, 2020). Based on the prediction, the feedback might be positive, also known as *rewards*, or negative, also called *punishments*. The agent eventually learns a policy for choosing the action to take at each stage in order to maximise the expected return, which is usually the sum of predicted future rewards (Goldenberg et al., 2019).

**Figure 2.14**

*The Reinforcement Learning Cycle.*




*From "A Machine Learning Approach for Power Allocation in HetNets Considering QoS", by Amiri, R., Mehrpouyan, H., Fridman, L., Mallik, R., Nallanathan, A., & Matolak, D., 2018.*

## 1.3. *Artificial Neural Network*

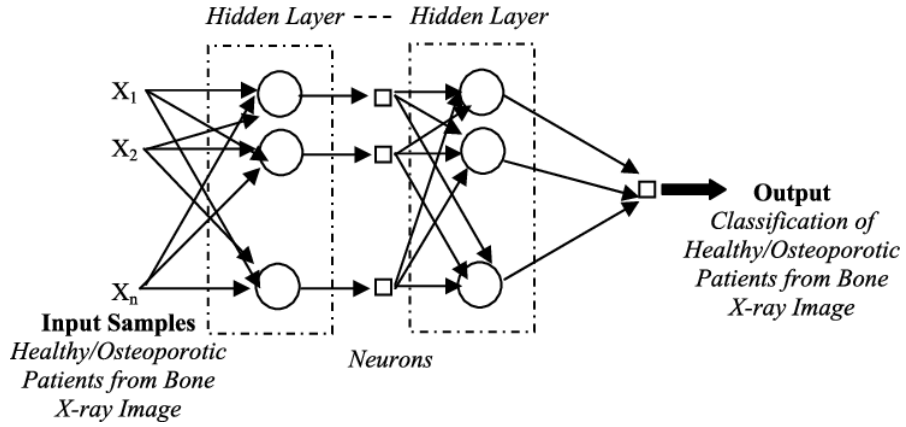
*Artificial neural networks* (ANNs) are well-suited to solving classification problems, but they can also be used for regression or clustering. Due to the fact that they are inspired by the sophisticated functionality of human brains where hundreds of billions of interconnected neurons process information in parallel, ANNs are very suited to solve problems that people are good at but computers are not (Bhargava, 2020, p. 150). These problems include pattern recognition and forecasting (which requires the recognition of trends in data). Interestingly, unlike the human capability in pattern recognition, the ANN's capability is unaffected by factors such as fatigue, working conditions, emotional state, and compensation (Vrahatis et al., 2000).

An ANN consists of three layers: an *input* layer of neurons (or nodes, units), one or two (or even three) *hidden* layers of neurons, and a final layer of *output* neurons (S.-C. Wang,

2003). An example is shown in Figure 2.15, where it is looking for an answer to the question "Is the patient healthy or osteoporotic?".

**Figure 2.15**

*A Typical Architecture of an ANN.*




*From "Classification of the trabecular bone structure of osteoporotic patients using machine vision", by Singh, A., Dutta, M. K., Jennane, R., & Lespessailles, E., 2017, Computers in Biology and Medicine, 91, 148–158 (https://doi.org/10.1016/j.compbiomed.2017.10.011).*

## 2. Recommender Systems

*Recommender systems* (RSs) are software tools and techniques that provide suggestions for items that may be useful to a user (Ricci et al., 2011). The suggestions are for various decision-making processes, such as what items to buy, what movie to watch, or what diet to follow. The basic idea of RSs is to utilize various data sources to infer customer interests (Aggarwal, 2016, pp. 1–3). The *user* is the entity to whom the recommendation is made, and the product being recommended is also referred to as an *item*.

The basic models for RSs work with two kinds of data (Aggarwal, 2016, Chapter 1), which are (a) the user-item interactions, such as ratings or buying behaviour; and (b) the attribute information about the users and items such as textual profiles or relevant keywords. Methods that use the former are called *collaborative filtering* methods, while methods that use the latter are called *content-based recommender* methods. Some recommender systems combine these different aspects to create *hybrid* systems.

Although RSs are often used to increase access to items such as shopping sites (e.g. AliExpress and eBay) and service sites (e.g. Netflix and Google), they have also become used in health care to assist both patients and doctors in making the right decision (Sezgin & Özkan, 2013).

# 3. Computer Vision

*Computer vision* (CV) deals with enabling computers, devices, or machines in general to see[1], understand, interpret, or manipulate what is being seen (Gollapudi, 2019, p. 14). To do so, CV transforms data from a still or video camera into either a decision (e.g. there are lesions in the MRI image) or a new representation (e.g. converting a colour image into a grayscale image) (Bradski & Kaehler, 2008, p. 2).

Nowadays, CV technology is everywhere; it is becoming ubiquitous in our daily lives. It has been also used in the medical field, especially to assist medical practitioners and doctors in finding conspicuous parts in medical imaging. In this regard, a promising technology that is designed to improve the accuracy of radiologists while reducing time spent on image interpretation has emerged (Firmino et al., 2016; Nishikawa, 2010).

A *Computer-aided detection and diagnosis* (CAD) system is a class of computer systems that helps health practitioners to accurately interpreting medical images and making quick decisions (Castellino, 2005; Firmino et al., 2016; Halalli & Makandar, 2018).CAD systems are classified into two main types: *computer-aided detection* (CADe) systems and *computer-aided diagnosis* (CADx) systems (Firmino et al., 2016; Nishikawa, 2010).

Despite the fact that the techniques used in CADe and CADx algorithms are similar, there are significant differences in the input data and in the output of the algorithms (Nishikawa, 2010). In particular, CADe algorithms identify and mark the location of lesions in a medical image, whereas CADx algorithms classify the lesions, for example, outputs whether a known lesion is malignant or benign. Furthermore, the two techniques differ in the desired outcomes. CADe systems aim to help radiologists avoid missing a cancer, while CADx systems can assist radiologists in deciding whether a patient should have a biopsy or not. In simple terms, CADe systems are used for screening, while CADx systems are used for diagnosis.

In this regard, CAD had shown promising results in diagnosing most cancer types, as well as other chronic diseases (Sharma et al., 2013). CADe and CADx systems continue to develop in terms of accuracy and user interface. It is expected that CADe and eventually CADx will play an increasingly important role in PCa imaging soon.

## CONCLUSION

This chapter has covered general information and facts concerning PCa, as well as the key techniques used in the care pathway, in which it enumerates their benefits and

[1] This means enabling machines to process digital visual data, which can include images, videos, and beyond.

drawbacks. We have also showed the importance of mpMRI as a promising procedure for improving diagnosis accuracy, as well as some of its main technical challenges. In the second section, the most common AI methods are presented through which we can contribute to improve the overall care pathway, particularly in the diagnosis and treatment steps.

In the next chapter, we will look at various software solutions that are developed to assist health professionals in managing PCa and providing appropriate care to patients. In addition, we will draw attention to their limitations and to current occurred issues.

*"All wealth comes from adding value, from producing more, better, cheaper, faster, and easier than someone else."*

*– Brian Tracy, a motivational public speaker, 2004*

# 3

# Existing Applications

## Abstract

Revolution that occurred in the field of Information Technology (IT) in the past led to its application in many fields, including the health care sector. At the outset, the focus was on facilitating the work of health professionals through the development of electronic health records (EHRs) and CAD systems. With recent technology advancements and the emergence of smart mobile devices, many mobile applications have been developed with the goal of informing a patient, facilitating his life, monitoring his condition, and reminding him of upcoming appointments. Although these applications have solved many problems, there are still some issues to be resolved. Interestingly, AI is thought to play a vital role in easing clinical practices of health professionals in order to provide personalised care for patients with PCa, as well as in providing psychological care for them and assisting them in coping with the cancer.

## Contents

The majority of scientific studies from various countries showed that early detection and precise diagnosis of the stage of cancer might have considerably improved patient overall care and decreased undesirable side effects of medical therapies (Valavanidis, 2020). Still, PCa is one of the biggest causes of cancer deaths in males worldwide, with 84 different countries having it as the most diagnosed cancer. Consequently, there are many software and scientific works have been proposed to solve problems faced and contribute in enhancing the overall care provided to patients with PCa. As some of them focused on facilitating the patient's journey with the cancer and others on assisting the health professionals in their work, a quality evaluation based on different measures was conducted in order to determine the advantages and disadvantages of each application.

In addition, the chapter discusses recent scientific works that use ML methods to manage PCa and presents their achievements and limitations through a comparative study. Finally, two scenarios were presented to illustrate the gaps that should be addressed.

## Section 1. Related Applications

In the app market, there are numerous applications that aid in the management of cancer in general and PCa in particular. They were designed to: (a) help patients to cope with and overcome cancer; (b) allow doctors to provide care quickly, to easily manage patients' medical records, and to reduce medical errors; and (c) assist radiologists in determining the location of lesions and estimating their volumes, grades, and stages.

The next sub-sections will review the existing literature regarding commercially available applications for PCa. To do so, a search for software-based solutions was conducted between February and April 2021, in which several keywords were entered into the search engines of Bing and Google as well as *Apple App* and *Google Play* stores. The search yielded a total of 577 applications (106 mobile applications and 471 desktop /web applications), of which only those that appeared to meet certain inclusion criteria were included for a final review (a total of 14 applications). It is worth noting that we were unable to obtain a demo version of certain applications, thus they were reviewed solely on the basis of their descriptions, while others were downloaded for further assessment.

### 1. Applications for Patients

Mobile applications have been mentioned as having the ability to raise patient awareness and serve as adjuncts to standard clinical care procedures (Chang et al., 2018; Jamnadass et al., 2020; Nabi et al., 2020; Owens et al., 2019; Sundberg et al., 2021; H. Wang et al., 2020).

## 1.1. *Search Strategy*

The majority of the applications presented hereafter are PCa-related mobile applications. They had been found by searching in Google and iOS app stores using the following words: 'prostate', 'cancer', 'prostate cancer', 'cancer coping', 'cancer risk calculator', 'cancer support' 'PCa personalised care', 'prostate care', and 'cancer care'. The search resulted in 106 mobile apps, which were then selected and reviewed using the process outlined below.

## 1.2. *Inclusion and Exclusion Criteria*

We reviewed the descriptions of each app for the inclusion criteria to determine whether it (a) was available in English, French, or Arabic; (b) targeted patients rather than health professionals; (c) included information about PCa care pathway; and (d) used to track symptoms or to communicate with care providers. Apps were excluded if they were duplicated across app stores; in this case, the Android app was kept for assessment because it is typically more popular than that found in the iOS app store. When the description could not be used to identify the criterion, the app was downloaded for further evaluation.

Only eight apps met the inclusion criteria for full evaluation. Some of these apps were dysfunctional, paid, or included outdated information (since all of the apps included in our final review were updated after 2018, which made them consistent with recent recommendations that propose using mpMRI in diagnosis). This left four apps for inclusion in our final review, in which each application was assessed, and the following information was retrieved from the app's description (if available): application name, developer, the date of release and of last update, platform (Android or iOS), pricing, star ratings and number of reviews from Google Play Store, and other usage statistics.

## Cancer.net Mobile


**Developer**
American Society of Clinical Oncology

**Countries of use**
Worldwide

**Languages supported**
English & Spanish

**Released** in 2012
**Last updated on** May 2020

| | |
|---|---|
| **Cost** | Free |
| **Downloads** | +10K |
| **Reviews** | 255 |

**Summary**
The application helps patients with cancer and their companions by providing oncologist-approved information about most types of cancers and guiding them through all stages of the care pathway. It had received a gold award from the "*Fall 2019 Digital Health Awards*" and had been nominated for the "*Best Use of an App*" in 2020.

**Key Features**
- Assist the patient to comprehend his care journey, its side effects, and how to live with the cancer.
- Aid him in keeping track of occurred symptoms and sharing the log with his care team.
- Give the patient the ability to communicate with care givers by asking questions and recording answers.
- Allow him log medication intake and to import health data from the *Apple Health* app.

**Links**
- **Available on the App Store and for Android phone on Google Play.**
- **For more information online, visit https://www.cancer.net/.**

## ChemoWave: Cancer health app


**Developer**
Treatment Technologies & Insights

**Countries of use**
Worldwide

**Languages supported**
English, French, Spanish, and German

**Released** in 2013
**Last updated** on May 2021

| | |
|---|---|
| **Cost** | In-app purchases |
| **Downloads** | +5K |
| **Reviews** | 52 |

**Summary**
The application was built to guide patients by providing health insights that allow them collaborate more effectively with their support team and better control any side effects that may occur during cancer treatment and chemotherapy.

**Key Features**
- Provide AI-enabled personal insights based on correlations in symptoms, mood and treatment activities.
- Allow the patient to keep track of his symptoms and to set medication reminders.
- Enable him to share his everyday physical and emotional wellbeing with doctors via email.
- Help him understand his care progress by displaying interactive charts and by explaining all the steps of the treatment journey.

**Links**
- **Available on the App Store and for Android phone on Google Play.**
- **For more information online, visit https://chemowave.com/.**

## My Prostate Cancer Coach

(4.5 of 5)

**Developer**
Genomic Health

**Countries of use**
Worldwide

**Languages supported**
English

**Released** on July 2015
**Last updated** on April 2018

| | |
|---|---|
| **Cost** | Free |
| **Downloads** | +10K |
| **Reviews** | 99 |

**Summary**
The purpose of the application is to help patients, especially those who have been newly diagnosed with PCa to better understand their condition and learn about the available treatment options.

**Key Features**
- Give access to videos and other useful resources about PCa treatment.
- Provide the patient with a personalised treatment guide prepared by distinguished professors of urology to assist him understand the various treatment options.
- Aid him in remembering essential appointments with the doctor and preparing for the next regular consultation.
- Allow the patient to update his journal by adding images and recording notes from conversations.

**Links**
- **Available on the App Store and for Android phone on Google Play.**
- **For more information online, visit https://www.myprostatecancercoach.org/.**

## OWise - Prostate Cancer Support

(N/A)

**Developer**
PX Health care

**Countries of use**
UK and the Netherlands

**Languages supported**
English & Nederland

**Released** in 2021

**Last updated** on April 2021

| | |
|---|---|
| **Cost** | Free |
| **Downloads** | +50 |
| **Reviews** | None |

**Summary**
The application was developed to support patients with PCa and to provide medically checked information as well as practical guidance to cope with the cancer.

**Key Features**
- Generate personalised reports based on the patient's profile and assists him in choosing the right pathway.
- Provide a clear overview of the treatment plan.
- Track symptoms and side effects to help health practitioners better understand the patient's wellbeing.
- Allow the patient to keep track of his forthcoming appointments and suggests a personalised list of questions to ask the doctor.
- Enable taking notes, recording doctor discussions, and storing private photos in a lockable diary.

**Links**
- **Available on the App Store and for Android phone on Google Play.**
- **For more information online, visit https://owise.uk/prostate/.**

## 1.3. *Review and Discussion*

The four mobile applications described above all have one feature in common: they provide patients with broad information about their illness and how to deal with it. A further evaluation of the apps' quality was conducted using some evaluation criteria extracted from the *Mobile Application Rating Scale* (MARS)[1]. This methodology includes 23 evaluation criteria, covering 5 dimensions.

The evaluation criteria used per dimension are: (a) *engagement,* which assesses whether the application is fun, interesting, customisable, interactive, and well-targeted to audience; (b) *functionality*, which examines the performance of the app, ease of use, transition between screens, and gestural design; (c) *aesthetics*, which assesses graphic design, visual appeal, and stylistic coherence of the app; (d) *information*, which evaluates the quality of the content based on its credibility and readability (whether the content could be understood by the general population, and whether it is multilingual); whereas the fifth criteria *subjective quality* had been ignored because it depends on an overall star rating of the application and to avoid any subjective evaluation.

In addition, other criteria inspect app functions that concerns cancer management had been used: (e) *follow-up*, which examines whether the app allows patients to understand the overall care pathway and whether it can be used to meet with care providers and view their advice; (f) AI-*usage*, which examines the extent to which AI is used (to help choose a treatment option, to obtain psychological care, and to assist in coping with PCa).

As depicted in **Error! Reference source not found.**, each evaluation criterion was rated from 1 to 5 (1=*inadequate*, 2=*poor*, 3=*acceptable*, 4=*good*, 5=*excellent*). It can also be rated as not applicable (N/A) in case of missing information. An in-depth spreadsheet provides more details about the evaluation process is available in Table A.1 in the appendices.

[1] The MARS is one of the most widely used tools to evaluate the quality of mobile health applications (Amor-García et al., 2020; Terhorst et al., 2020).

**Figure 3.1**

*Results of the final review of patient-centric applications.*


Although most of the applications reviewed were informative, they did not pay much attention to their users' individual statuses and to age groups to which they belonged. Because patients with cancer are often elderly, their psychological and physical conditions must be considered in order to provide accurate care. These conclusions are completely consistent with a recent research made by (Jamnadass et al., 2020), who assert that PCa applications are still in their infancy and will require additional development before being widely integrated into conventional clinical practice. Such assertion was based on the fact that they found several issues in medical apps including data protection, content readability, and a lack of information update. They did, however, assume that if such applications are developed appropriately, they have the potential to play key roles in modern-day PCa management.

Regardless of the potential benefits of cancer management apps in general, and PCa apps in particular, inaccurate, outdated or confusing information can have a devastating impact on the lives of patients. Moreover, this review suggests that the majority of existing applications did not address the following elements, which we believe are crucial to aiding patients in managing their care:

- Use AI to help patients choose the appropriate treatment option.
- Assist them in dealing with cancer by recommending healthy diets and physical activities.
- Encourage patients to interact with the application more by sharing their stories with others who have the same cancer, as well as giving them access to their medical records and allowing them to follow the care journey step by step.
- Allow patients to meet with their care providers online, especially if a physical presence is not possible.

## 2. Applications for Doctors

Managing paper medical records can be an exhausting for care providers, according to *Annals of Internal Medicine* (Han et al., 2019) "Doctor burnout costs the US $4.6 billion each year and triples the likelihood of expensive medical errors", and with the patients' desire for quick access to their data having to visit the doctor's office, Electronic Health Records (EHR) became a necessity.

### 2.1. *Search Strategy*

Most of the applications listed below are not PCa-specific. They were found by conducting searches in Google and Bing search engine using the following words: 'application for urologist', 'urology-assistant applications', 'EMR applications for urology', 'EHR applications for urology', 'top EHR systems', to name a few. The search resulted in 471 EHR apps, which were then selected and reviewed using the process outlined below.

### 2.2. *Inclusion and Exclusion Criteria*

We reviewed the app descriptions for the inclusion criteria to see if the application (a) was available in English, French, or Arabic; (b) targeted urology clinics; and (c) used to manage medical records of patients and monitor their progress. Apps were excluded if they offered only a very limited number of urology-specific features or if their descriptions could not be used to identify the evaluation criteria. Other apps that had not been updated since a long period (more than five years) or had been removed from the market were also excluded from the final review.

This left six apps to be considered in our final review, in which each application was evaluated and the following information was obtained from the app's description (if available): application name, developer, the date of release, cost, targeted audience, deployment (on premise or cloud), and other real-world usage statistics.

## NextGen Health care

Developer
**NextGen Enterprise**

Countries of use
**USA**

Languages supported
**English**

Audience
**Multi-speciality practices**

Released in **1994**

| | |
|---|---|
| Cost | **$449/month** |
| Users | **N/A** |
| Deployment | **Cloud** |

**Summary**

It is clinical practice software that fully incorporates practice management solutions such as specialty-specific content, electronic payment, and a patient portal.

**Key Features**

- Alert the doctor if anything abnormal happens to the patient.
- Provide real-time records analytics to identify gaps in care and solve them in order to improve patient well-being and increase revenue.
- Allow doctors to conduct virtual visits and patients to access their medical records through a patient portal.
- Support billing and payment operations.

**Links**

- **For more information online, visit https://www.nextgen.com/.**
- **A mobile version is available.**

## Praxis

Developer
**Infor-Med**

Countries of use
**USA**

Languages supported
**English**

Audience
**Multi-speciality practices**

Released in **1996**

| | |
|---|---|
| Cost | **259$ feature/month** |
| Users | **N/A** |
| Deployment | **On-premise** |

**Summary**

It is certified EHR system that uses AI to learn how each doctor works and adapts to his specific requirements. It is 'template-free', which means that everything within the system is presented in the doctor's own words and preferred order. It has long been regarded as the best American EHR system.

**Key Features**

- Allow the doctor to schedule appointments and keep track of current and active diagnoses.
- Facilitate compliance tracking to ensure that operations run smoothly and that everyone follows procedures.
- Allow the doctor to write e-prescriptions and keep the list of medications up to date.
- Identify patient-specific education resources and make them available to the patient as needed.
- Provide a summary of the care record of patients referred to another provider or setting.

**Links**

- **For more information online, visit https://www.praxisemr.com/.**

## NueMd

Developer
**Advanced MD**

Countries of use
**USA**

Languages supported
**English**

Audience
**Multi-speciality practices**

| | |
|---|---|
| Cost | **$149/month** |
| Users | **24K** |
| Deployment | **Cloud** |

**Summary**

It is a cloud-based practice management tool that allows doctors to view their patients' records, reminds them of upcoming appointments, and provides medical billing services.

**Key Features**

- Allow for the management of medical records and the viewing of patients' progress via charts.
- Allow the doctor to easily share information with other providers and laboratory systems.
- Allow him to electronically send prescriptions to pharmacies and schedule follow-up appointments.
- Include a patient portal through which he could control his own health and build personal relationships with care providers.

**Links**

- **For more information online, visit https://nuemd.com/.**
- **A mobile version is available on the App Store.**

## AthenaOne

Developer
**Athena Health**

Countries of use
**Worldwide**

Languages supported
**English**

Audience
**Multi-speciality practices**, **labs**, and **imaging centres**

Released in **2017**

| | |
|---|---|
| Cost | **Quote-based** |
| Users | **N/A** |
| Deployment | **On-premise** and **Cloud** |

### Summary

It is a cloud-based solution that combines three key services for medical practice management in a single packaged offering, namely *athenaCollector*, *athenaClinicals*, and *athenaCommunicator*. It was the top-rated mobile application for electronic health records in the App Store.

### Key Features

- Allow for the management of medical records and the viewing of patients' progress via charts.
- Enable scheduling of medical appointments as well as viewing of a quick snapshot of previous follow-ups.
- Allow a health practitioner to electronically send prescriptions to pharmacies and view laboratory results.
- Enable care coordination among multiple practitioners.
- Give access to patients via a web portal through which they can conduct online consultations.

### Links

- **For more information online, visit https://www.athenahealth.com/solutions/athenaone.**
- **a mobile version is available on the App Store.**

## Intelligent Medical Software

Developer
**Meditab**

Countries of use
**Worldwide**

Languages supported
**English**

Audience
**Multi-speciality practices**

Released in **2017**

| | |
|---|---|
| Cost | **199$ feature/month** |
| Users | **41K** |
| Deployment | **Cloud** |

### Summary

This EHR software includes numerous functions such as practice management, e-prescribing, mobile EHR, a patient portal, practice reporting and analytics, and communication tools. It enables health care practitioners to collect data about patients and share it across a variety of health care settings. Medical history, demographics, blood test results, medication history, allergies, and billing details are just a few of the critical details covered by this software.

### Key Features

- Allow the doctor to obtain clinical information about a patient and displays the progress of his illness in charts.
- Automate check-in visits and allows the practitioner to schedule medical appointments.
- Provide specialised templates and custom health forms.
- Ease the collection of medical lab tests and the integration with other medical devices.
- Help practices manage their billing processes.

**Links**

– **For more information online, visit https://www.meditab.com/.**

– **A mobile version is available on the App Store and for Android phone on Google Play.**

## UroChartEHR

Developer
**IntrinsiQ**

Countries of use
**USA**

Languages supported
**English**

Audience
**Urology**

Released in **2017**

| | |
|---|---|
| Cost | **N/A** |
| Users | **88 company** |
| Deployment | **Cloud** |

**Summary**

It is a web-based solution designed to improve the urology workflow. It offers several services, including practice management, EHR, medical billing, and telehealth. It had been certified as an EHR software by the American *secretary of health and human services*.

**Key Features**

– Allow the urologist to easily review patients' medical information owing to a timeline feature that chronologically graphs their data.

– Facilitate and support his workflow via customisable flowcharts.

– Integrate an e-prescribing solution that delivers clinical decision support information and drug interaction alerts.

– Ensure that health care providers coordinate in a secure manner.

– Include a patient portal through which he can see his medical records and interact with care providers.

**Link**

– **For more information online, visit https://www.intrinsiq.com/urology-ehr-solution.**

– **A mobile version is available.**

## 2.3. *Review and Discussion*

Medical records management is a feature that is included in any EHR software. It enables doctors to simply explore patients' medical data and follow their progress. Other aspects vary from application to application, such as electronic prescription, billing systems, communication patterns and even AI-based technologies. As a result, when evaluating such medical apps, all of these distinctions must be taken into consideration.

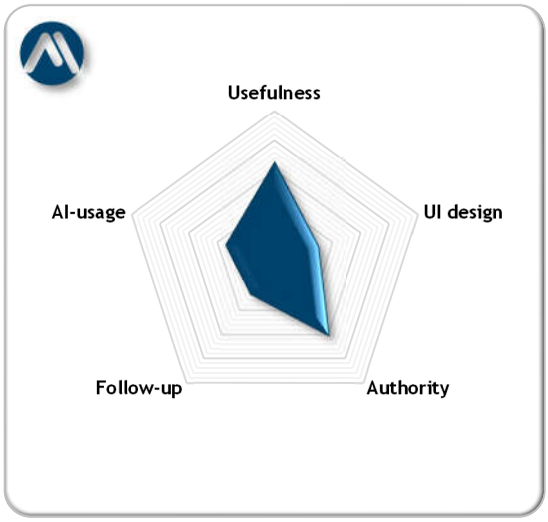
Our final evaluation was based on criteria that we considered were required for the solutions to be effective. The evaluation criteria are: (a) *usefulness*, which examines whether the application makes routine tasks easier, is relevant to the doctor's speciality, and has the potential to be used in current clinical practice; (b) UI *design*, which assesses ease of use, graphics, layout, and responsivity of the app; and (c) *authority*, to assess whether the developers of the app are credible, qualified, and intellectually rigorous enough to create such medical application.

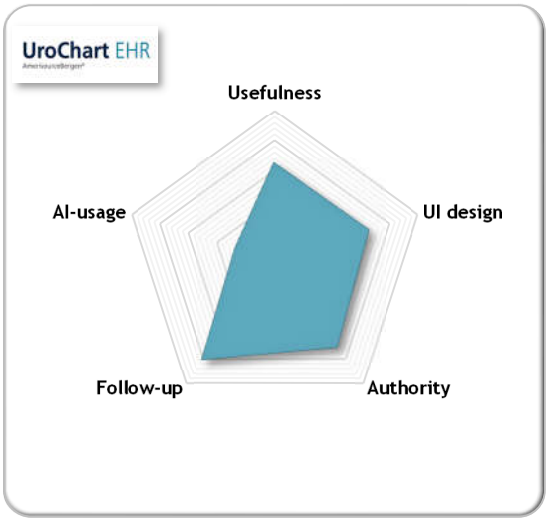
In addition, two other criteria were used to examine app functions related to cancer management: (d) *follow-up*, which assesses whether the app allows doctors to track patients' progress and whether it can be used to stay in touch and provide medical advice; (e) AI-*usage*, which examines the extent to which AI is used (to aid making decisions and help selecting the suitable treatment option).

As depicted in **Error! Reference source not found.**, each evaluation criterion was rated from 1 to 5 (1=*inadequate*, 2=*poor*, 3=*acceptable*, 4=*good*, 5=*excellent*). It can also be rated as not applicable (N/A) in case of missing information. An in-depth spreadsheet provides more details about the evaluation process is available in Table A.2 in the appendices.

**Figure 3.2**

*Results of the final review of EHR applications.*




Despite the fact that EHR software improves the accuracy of data recorded in a health record and help health practitioners with their workflows, we found that there are still certain concerns that need to be addressed. For instance, most EHR software suffer from a poor UI design, which leads to an undesirable user experience and a waste of time. Moreover, some applications provide an "all-in-one" system that combines functions from numerous medical specialities while ignoring the fact that some each speciality has its unique practice (e.g., the care pathway could differ from a speciality to another). As a result, speciality-specific solutions should be considered.

Our review confirmed previous results from surveys conducted by the American Medical Association (iSalus Healthcare, 2021), which revealed that EHR systems scored an average grade of "F" on the usability scale, with doctors spending up to two hours on their EHR for every hour spent with a patient.

Furthermore, patients in modern day society expect their doctors to interact with them in a timely and efficient manner. In this respect, useful EHR software must allow doctors to communicate with and engage their patients. In addition, AI-assisted automation and data analytics have become a game changer on cancer management, as it can automate time-consuming administrative tasks, provide access to vital patient insights, and improve overall practice effectiveness. A fascinating benefit that has been dealing with caution as AI might pose some ethical challenges and cause plenty of issues.

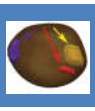
# 3. Applications for Radiologists

## 3.1. *Search Strategy*

The majority of the applications listed below are intended to be used for PCa interpretation. They were found by conducting searches in Google and Bing search engine using the following words: 'prostate MRI interpretation, 'AI-based prostate MRI', 'automatic mpMRI analysis, 'intelligent application for prostate MRI', to name a few.

## 3.2. *Inclusion and Exclusion Criteria*

We reviewed the app descriptions for the inclusion criteria to see if the application (a) was available in English, French, or Arabic; (b) targeted prostate mpMRI; and (c) provide computer-aided image interpretation. Apps were excluded if they offered only a very limited number of PCa-specific features or if their descriptions could not be used to identify the evaluation criteria. This left four apps to be considered in our final review, in which each application was evaluated and the following information was obtained from the app's description (if available): application name, developer, countries of use, the date of release, cost, deployment (on premise or cloud), and certifications.



### ProFuse MRI Software

Developer
**Vision Medical**

Countries of use
**Australia and New Zealand**

Languages supported
**English**

Released in **2017**

| | |
|---|---|
| Cost | **Quote-based** |
| Deployment | **On-premise** |
| Certification | **FDA** |

**Summary**

This system was created to help radiologists view mpMRI images. It is a part of a radiology suite that includes *MRI guided prostate biopsy* and *pathology guided focal therapy*.

**Key Features**

- Providing the radiologist with a 3D DICOM viewer.
- Generating automatic prostate contouring.
- Analysing images histograms.
- Assisting the radiologist in the preparation of standard PI-RADS reports.
- Allowing pathology results to be integrated into MRI for treatment planning.

**Links**

- **For more information online, visit ProFuse MRI Software.**

## DynaCAD Prostate

Developer
**Philips**

Countries of use
**Worldwide**

Languages supported
**English**

Released in **2017**

Cost **Quote-based**
Deployment **On-premise**
Certification **FDA**

**Summary**
It is a software that act as a workflow roadmap tool, organising and guiding the radiologist through series of sequential actions that should be performed in order to make a diagnosis. It also provides them with an automatic interpretation to help them make the right decisions. Following the case completion, key images, statistical data, and prostate PI-RADS reports can be immediately sent to PACS for archiving.

**Key Features**
– Process and displaying 3D images in custom hanging protocols.
– Generate automatic mpMRI interpretation and prostate segmentation.
– Produce interactive PI-RADS v2 reports.
– Display previous biopsy targets and provide valuable feedback.

**Links**
– **For more information online, visit DynaCAD Prostate Software.**

## Ezra Prostate AI

Developer
**Ezra**

Countries of use
**Worldwide**

Languages supported
**English**

Released in **2019**

Cost **Quote-based**
Deployment **On-premise** and **Cloud**
Certification **FDA**

**Summary**
This software was developed for early detection of cancer by processing MRI scans using AI. In October 2020, it had received *FDA 510(k)* clearance for its AI-based prostate MRI segmentation. It is the first prostate AI-based solution to ever be approved by the FDA.

**Key Features**
– Allow the radiologist to visualise mpMRI images.
– Give precise prostate volume measurements.
– Provide a semi-automatic lesion segmentation.
– Automate lesion quantification by measuring its size, grade, and PI-RADS score.
– Generate automatic 3D volume rendering of the prostate gland and lesions.

**Links**
– **For more information online, visit https://ezra.com/prostate-ai/.**

## Quantib Prostate

Developer
**Quantib**

Countries of use
**Worldwide**

Languages supported
**English**

Released on **Oct. 2020**

| | |
|---|---|
| Cost | **Quote-based** |
| Deployment | **On-premise** and **Cloud** |
| Certification | **CE mark** and **FDA** |

**Summary**

It is a system that assists radiologists in providing better patient care and analyse MRI scans. It is used for prostate MRI scans with suspicious PCa.
The **FDA** cleared and **CE marked** the *zero-footprint* feature that provides a workflow for detecting abnormalities on MRI prostate scans.

**Key Features**

- Help the radiologist to review previous imaging exams if they exist.
- Automate the detection of lesions and PI-RADS scoring.
- Help the radiologist to visualise T2w sequences, manually measure prostate in 3D and calculate PSA density.
- Facilitate report management by generating standard report and allowing team members to share them.

**Links**

- **For more information online, visit Quantib Prostate Software.**

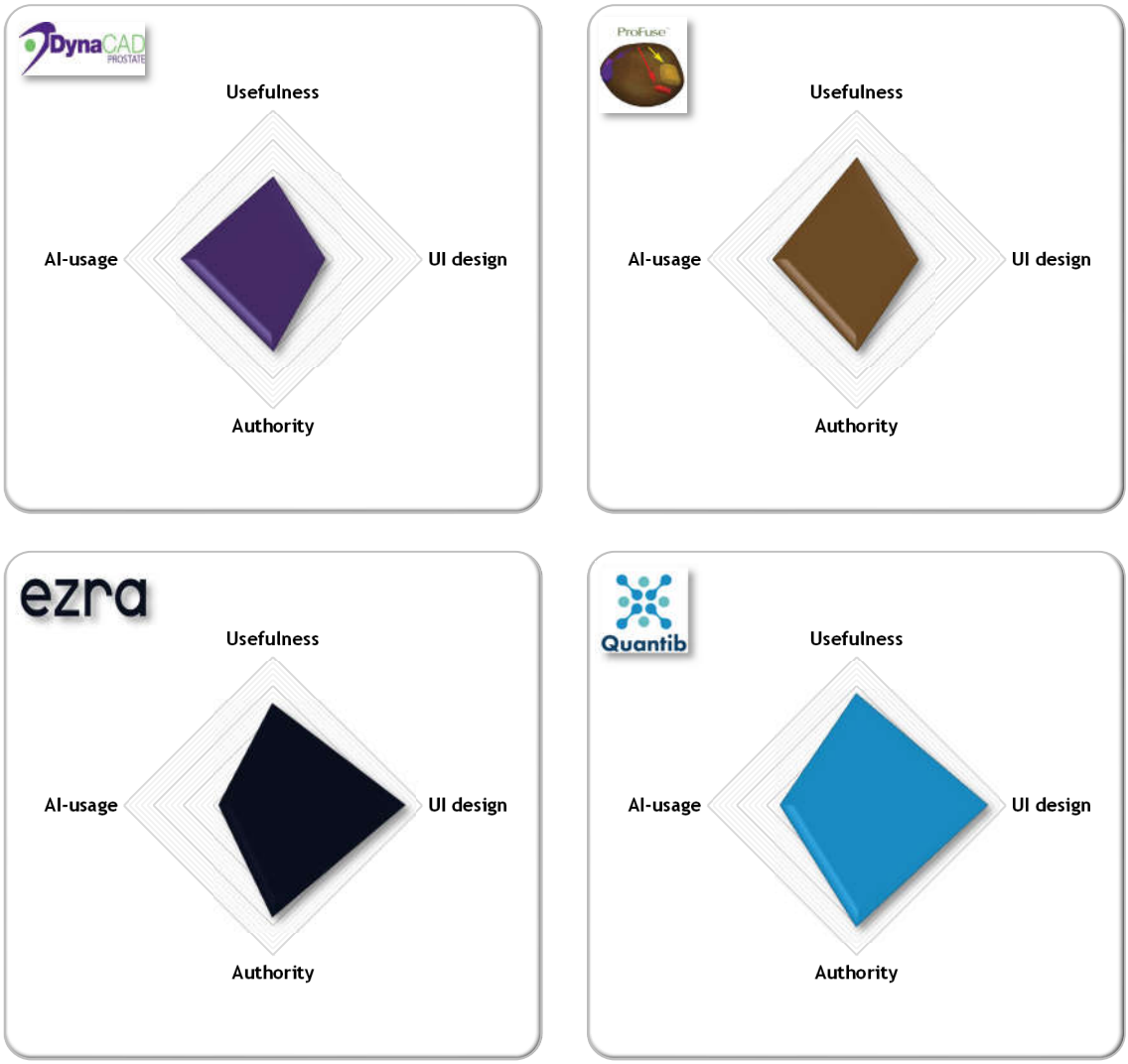
## 3.3. *Review and Discussion*

There is still no a common evaluation scale for applications developed for radiologists, due to the fact that the applications come in a variety of forms, each with its own distinct features. In this regard, our final evaluation was based on criteria that we thought were required for the solutions to be effective. The evaluation criteria are as follows: (a) *usefulness,* which examines whether the application facilitates image interpretation, supports 3D visualisation, and has the potential to be used in current radiology practice; (b) UI *design*, which evaluates the app's ease of use, graphics, and layout; (c) *authority*, which examines whether the developers of the app are credible, qualified, and intellectually rigorous; (d) and AI-*usage*, which examines the extent to which AI is used (make automatic prostate segmentation, generate PI-RADS reports automatically, and use previous imaging and biopsies results).

As depicted in **Error! Reference source not found.**, each evaluation criterion was rated from 1 to 5 (1=*inadequate*, 2=*poor*, 3=*acceptable*, 4=*good*, 5=*excellent*). It can also be rated as not applicable (N/A) in case of missing information. An in-depth spreadsheet provides more details about the evaluation process is available in Table A.3 in the appendices.

**Figure 3.3**

*Results of the final review of EHR applications.*




The aforementioned applications are developed to aid radiologists in their routine tasks by assisting them in analysing MRI images, detecting lesions, and accurately estimating their volume in order to speed up the image interpretation process and eliminate errors. Remarkably, we found that all previous apps use AI to locate ROIs and deliver precise measurements, but they differ how AI is used and what it is used for, with certain apps using AI to provide automatic prostate segmentation where others using it to generate accurate reporting. In this regard, we expect that AI will play a significant role in improving radiology practice by automating repetitive routine tasks, reducing variability between radiologist reports, and even providing more accurate image interpretation.

Furthermore, another important challenge that radiology clinics continue to face is the selection of the application to be purchased, because most vendors did not provide

detailed information about their products, especially about pricing and packaging options, which are often not provided in a transparent manner.

## Section 2. CASE SCENARIOS

Remarkably, almost one-fifth of men with PCa become depressed, which can impair with treatment outcomes, worsen a patient's disease burden and raise treatment expenses (Sharpley et al., 2020). Living with PCa can be challenging to manage emotionally and physically, and it can affect patients' feelings and potentially increase their risk of suicide. This subsection describes, using a case scenario, some of the usual emotions that a patient with PCa may experience during his healing journey.

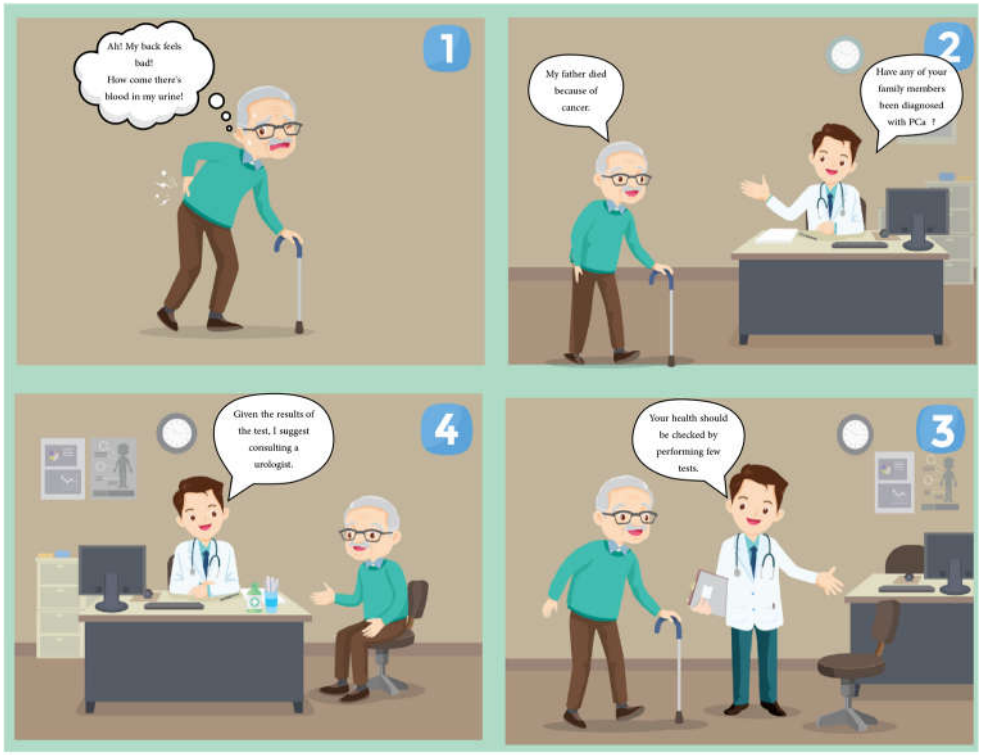
### 1.1. *Scenario 01: A patient's Life with PCa*

This case scenario is a simulated situation based on a real story, which allows to live the PCa experience through the eyes of a 65-year-old man named "Abdelhamid". As well, it explores how a certain situation might occur in the real world. Five years ago, Abdelhamid began to feel slight back pain. Unfortunately, he did as usual, as many adults of his age would do, "he thought, I'm just getting older...and grew through the pain."

Eight months later, things have worsened, and he begins to experience more severe symptoms such as difficulty urinating and the appearance of blood in his urine, prompting him to consult his primary care doctor to determine the cause of the problem.

As a part of the medical examination, the doctor asked some questions regarding the symptoms, his personal medical history as well as about cancer incidences in the family. As it turned out that his father had died because of pancreatic cancer, the doctor became preoccupied and suggested doing blood tests. The results showed that the PSA level had risen above 5, so the doctor advised Abdelhamid to see a urologist immediately to get checked for possible prostate problems.

**Figure 3.4**
*Case scenario 01: Abdelhamid is visiting his primary care doctor.*




A few weeks later, Abdelhamid visits a urologist, who examines the medical tests performed previously and performs a DRE to check if there is an abnormality in the prostate. Because the urologist discovered some abnormalities, he recommended doing a mpMRI or a prostate biopsy to check for PCa. Hearing the word "cancer", Abdelhamid felt frustrated and anxious as he began to think about his life, his family and how his future plans might be changed. That "sense of loss" had made him stop his work until he could see what would happen. Meanwhile, he started searching online about PCa, the survival rates, and asking questions about possible treatments in the forums. It was a miserable experience, as he read bad stories about men's having horrible care journeys and, this led him to be more fearful and obsessed with PCa.

It was only the beginning; The worst is yet to come. After performing the biopsy, he was confirmed to have a locally advanced PCa, in which the urologist explained his case and suggested a list of treatment options that he could made. A cancer diagnosis came as a complete shock; after returning home, Abdelhamid was embarrassed to tell his wife about the bad news, and speculation began to circulate in his mind about the coming worrying time, as he may have treatment that has adverse side effects and could limit his life for many years. Thinking about all this stuff made him having insomnia. Even when treatment is

completed, Abdelhamid still feels anxious and has difficulty moving forward and thinking about the future.

**Figure 3.5**
*Case scenario 01: Abdelhamid is visiting a urologist.*


Abdelhamid's story caused us to reflect, where several questions arose: Why are there still such horror stories? Why do patients diagnosed with PCa feel lonely, especially during difficult times? Is there a way to help PCa survivorships reintegrate into society and resume their normal lives? Indeed, some problems appear to be simple to avoid, but the impact of psychological anguish in patients with PCa, particularly when not addressed, can result in a shorter life expectancy and an increased risk of suicide (Galvão et al., 2021). Importantly, recent studies (Sharpley et al., 2020) revealed that depression rates among patients with PCa are higher than in the general male population, primarily owing to the uncertainty of treatment outcomes. Therefore, managing psychological anguish in patients with PCa should be a priority.

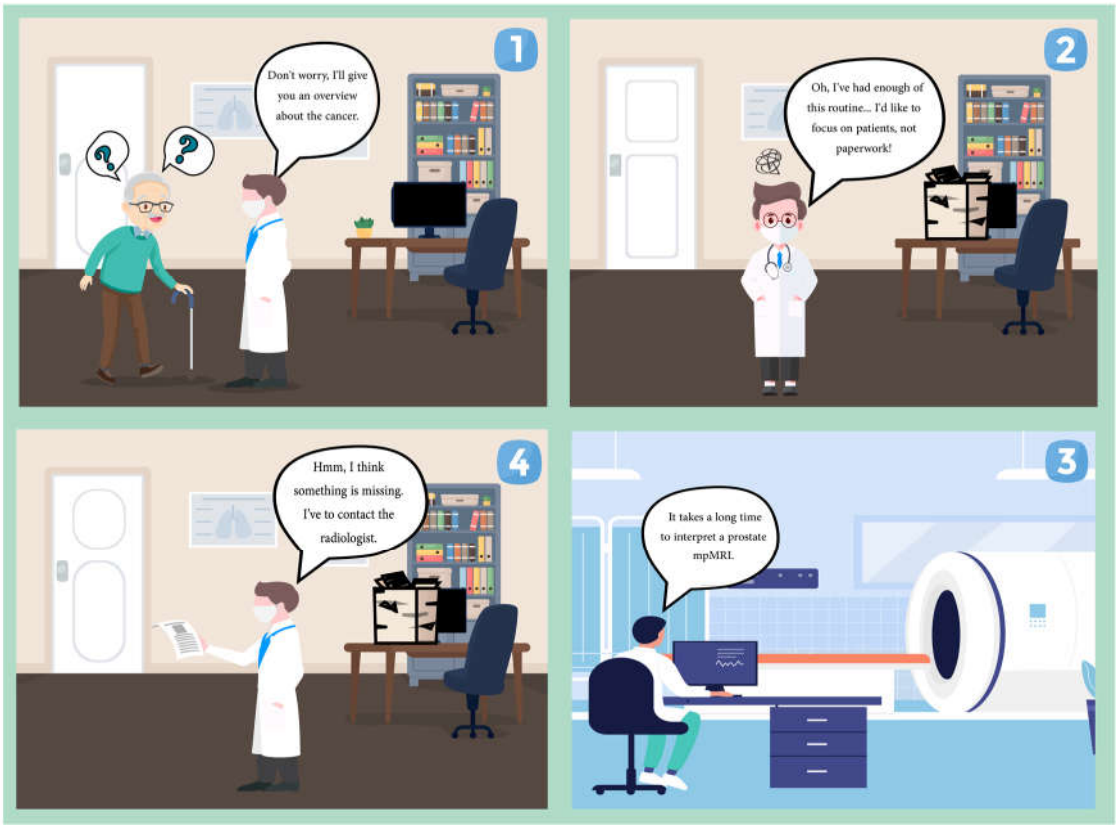
As a result, we had started going more in depth and looking why healthcare practitioners provide an unsatisfactory psychological care to their patients. Surprisingly, we discovered that they too suffer from the same problem; With a study (Shanafelt et al., 2015) conducted in USA suggested that "burnout is increasing among doctors in many specialities, and the statistics for urology are troubling." More shocking facts are revealed in the following second case scenario.

## 1.2. *Scenario 02: Caring for a Patient with PCa*

Dr Issam was the urologist who takes care of the health condition of Abdelhamid. In spite the fact that the doctor had asked Abdelhamid a series of questions regarding his personal and family medical history during the first consultation, this was insufficient due to the doctor's limited time frame, which did not allow him to ask about all the necessary information about Abdelhamid. Dr Issam, like with any other patient, gave Abdelhamid general information about PCa and how it could be treated. This routine made the doctor feel anxious by spending too many hours in telling patients about PCa, and what made the situation even worse is that and most cases, he will have to re-explain this information again because most patients will have difficulty understanding all the information due to the shock of being informed that they have a cancer. After analysing the blood test results, he asked Abdelhamid to perform a mpMRI before conducting the prostatic biopsy.

**Figure 3.6**

*Case scenario 02: The urologist investigates whether Abdelhamid has PCa.*




Three days later, the mpMRI images were interpreted by a radiologist, who detected potentially cancerous lesions. However, due to the complexity of the process, which requires attention, the radiologist forgot to indicate in his final report that the cancer had spread from the prostate to nearby organs.

Indeed, the situation is terrible. In this regard, several international organisations to conduct surveys and the results revealed that: "more than half of all health care workers worldwide are experiencing burnout that, if not addressed, could cause many to leave their fields in favour of less-stressful occupations or choose early retirement." (L. Martin & Koval, 2021)

The statistics showed also that 63% of urologists who experienced burnout pointed to an increase in the number of bureaucratic tasks as the leading contributor. Other factors include lack of respect from administrators, colleagues, and patients, as well as a lack of autonomy as a result of numerous regulations, especially during the COVID-19 pandemic.

To summarise, the two aforementioned case scenarios demonstrated that there are still numerous issues in the current PCa management workflow that affects both patients and healthcare professionals. We can enumerate these issues as follows:

- ❑ Regarding the patient, he is still facing the following challenges:
  - – Finding information about PCa that is relevant to his medical condition is difficult.
  - – Feeling lonely since most care providers ignore the impact of psychological disorders on treatment outcomes.
  - – Confused about how to choose the best treatment option and feel anxious about what changes in daily life activities should be made following treatment.
  - – Difficulty accepting the new way of life, which includes disobeying the doctor's instructions and forgetting visiting periodically, as well as missing to take medications, eating healthy, and doing physical activities.
- ❑ On the other hand, the urologist suffers from the following problems:
  - – Due to the limited available time frame, he was unable to ask all of the necessary questions in order to obtain a complete picture about the patient and so provide him with more specific pieces of advice.
  - – Tough administrative regulations and medical recommendations that changes regularly make it hard to concentrate on providing an individualised care pathway that takes into account the patient's medical condition, family history, and preferences.
- ❑ Finally, the radiologist confronts certain issues, although medical imaging is ever more part of the PCa diagnosis stage:
  - – The process of interpreting mpMRI images is too complicated and it relies on his experience, which might lead to misdiagnosis, or in certain cases, overdiagnosis.

Therefore, a standardised communication channel between health care providers is required.

## CONCLUSION

In this chapter, we conducted an analytical study of the current applications and works in our field of work, where we first presented existing applications and then indicated their pros and cons in radar charts. The evaluation was conducted objectively using specific criteria, allowing us to identify the gap to be filled more accurately and, as a result, explain the problematic through two case scenarios.

In the next chapter, we will present the proposed solution "**Proman**", explaining the methodology used to develop it and detailing the main features it offers.

# Part 2. Contribution

After studying PCa from many aspects and the possibility of applying AI in its management, we have extracted a set of problems that can be solved and actually embodied. Where we recycled a set of ideas, based on which we proposed solutions in the form of a system we called Proman, which takes care of helping patients in their pathway with PCa and also contributes to facilitating and assisting health professionals in their care of patients. Where we will present the idea of Proman and the way we followed in his embodiment and the results we reached, as this part is divided into two chapters as follows:

In the chapter "**Proman**", we presented the idea of Proman in detail, starting with the way we followed in managing the project, where we chose scrum framework, which is based on agile methodology, where we presented its various artifacts, its life cycle and its steps and the reason for choosing it. And then we presented how we applied the rules of this framework during the planning of our project. It began by writing the project's vision and defining the roles of each member of the scrum team. This was followed by the process of listing the goals that the project seeks to achieve and we presented it with use case diagrams and some user stories. This allowed us to produce a set of Sprints and determine the timing of their delivery and those responsible for completing them. Then we presented the proposed solution in the form of units that we divided in order to facilitate the understanding of the features and then we presented the technical architecture of our project represented in the hexagonal architecture and presented all the details related to its modules.

The process of creating Proman, we presented it in Chapter "**Implementation, Results, and Discussion**", where we presented the programming languages, tools and APIs that we used in implementing Proman, and then we presented the products that Proman provides in the form of software and the pricing packages of using Proman gold features. We also presented some screenshots of the patient mobile app and the urologist web app. Finally, we presented the results of the AI models that we obtained

*"There is no difference between saving lives and extending lives, because in both cases we are giving people the chance of more life."*

*– Aubrey de Grey, a computer scientist*
*July 24, 2013*

# 4

# Proman: when Technology, Innovation, and Health Care come Together

## Abstract

Choosing the most appropriate method for software development in such a complex field, as the application of IT technologies and AI to improve PCa management is a crucial step. The chosen method should save time and focus on meeting users' needs correctly more than anything else, especially since it is related to of patients' lives. All these constraints had led us to choose Agile Scrum framework, during which we started by defining the project vision and business goals. Then, a list of user stories was written and arranged within releases and sprints. More details about the selected architectural style were given.

## Contents

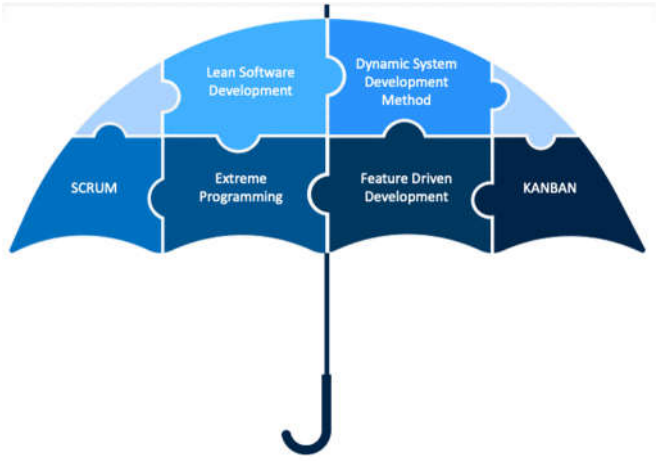
In this chapter, we will detail the "**Proman**", the proposed solution to solve problems faced by patients with PCa and their health care givers. The first section explains Agile Scrum, the software design methodology used to develop Proman. Next, the technical architectural style is presented, as well as a description of each internal module is provided.

# Section 1. SOFTWARE DESIGN

## 1. Agile Scrum

Basically, Agile is a mindset and philosophy informed by the Agile Manifesto's values and principles (Agile Alliance, 2021; *What Is Agile? What Is Scrum?*, 2021). Those values and principles guide how to produce and respond to change, as well as how to deal with uncertainty. As shown in the **Error! Reference source not found.**, *Agile software development* refers to "an umbrella term for a set of frameworks and practices based on the values and principles expressed in the Manifesto" (Agile Alliance, 2021).

**Figure 4.1**
*Agile Umbrella: Frameworks and Practices*.




*From Agile Umbrella, by SketchBubble, 2021, (https://www.sketchbubble.com/en/presentation-agile-umbrella.html).*

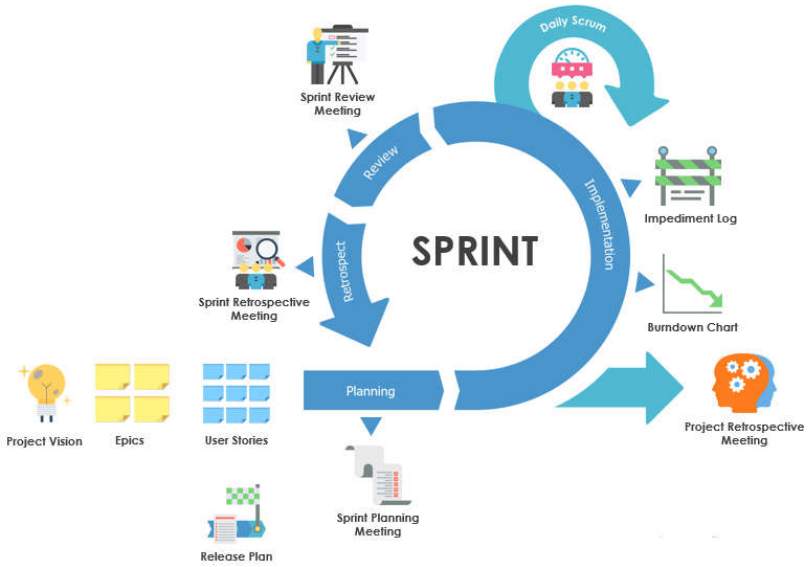
In contrast to the classic waterfall methodology, *Scrum* is not a standardized process in which developers methodically follow a series of sequential steps that are guaranteed to produce a high-quality product that delights customers (Schwaber & Sutherland, 2020, p. 13). Instead, Scrum is a framework used in software development based on an iterative and incremental processes. In other words, Agile is the mindset and Scrum is the framework that describes a process for implementing the agile philosophy (*What Is Agile? What Is Scrum?*, 2021).

## 1.1. *Scrum Lifecycle*

A Scrum process is distinguished from other agile processes by specific practices, which are themselves embodied in specific *roles*, *activities*, *artifacts*, and their *associated rules*. The lifecycle is a succession of sequential steps and iterative stages that should be performed during the realisation of each Scrum project (Sergeev, 2020). Besides, a Scrum project's work is broken into chunks called *sprints*. The project develops from one sprint to the next until the final product is ready. Each sprint cycle is subdivided into four successive stages that must be completed from start to finish.

**Figure 4.2**

*An overview of the Scrum framework lifecycle.*




*Adapted From What is Agile? What is Scrum?, Visual Paradigm, 2021, (https://www.visual-paradigm.com/scrum/what-is-agile-and-scrum/).*

The product owner has a vision of the software he wants to build, and because the vision can be extensive, it is divided into a set of features represented in the so-called *product backlog*. A sprint begins with *sprint planning*, encompasses the development work (referred to as *implementation*), during which the team meets every day to discuss its progress (*daily Scrum*). The sprint concludes with the team reviewing their efforts and conducting a retrospective to identify what went well or what needs to be improved for the next sprint.

## 1.2. *Motivation*

To ensure the success of any IT project, it is critical to plan it and choose a software design method; In our situation, we were presented with a range of possibilities from which to choose. Therefore, after considering various factors, including the scale of the project, the

nature of team members, and the limited time frame for completion, we decided to adopt the Agile Scrum framework. It is worth noting that the decision has resulted in several benefits, including:

- **Adaptation:** This feature gave us more control over the project, allowing us to prioritise product's features, to expect changes, and to adjust the product in response to changes that occurred. After finishing each sprint, we were able to receive feedbacks from users, which allows us to see the product from a broader perspective than we would have otherwise.
- **Focus on the business value:** This is one of the key benefits that has helped us deliver numerous functionalities and validate those important faster. In addition, we were able to ensure that the user felt comfortable with the project's completion and its development. As Scrum encourages the participation of all stakeholders in the process by consulting them in the organisation of priorities in the product backlog.
- **Transparency:** To be honest, at the beginning of the project, we were doubtful about the purpose of this Scrum value. But as the project grew in size, we realised that the fact that each team member has the access to all information important to the software development had increased the sense of responsibility within the team and motivate everyone to observe and understand what is going on.

# 2. Project planning

## 2.1. *Defining the Project Vision*

During the COVID-19 pandemic, healthcare providers had lived tough periods as they were first-line who confronted the pandemic. Regrettably, the pandemic continues negatively affecting health practitioners not only within emergency services but also those working in other specialities including urology and oncology. A situation had motivated us to think about creating a start-up that offers computer-assisted software to help care providers provide a good care for patients.

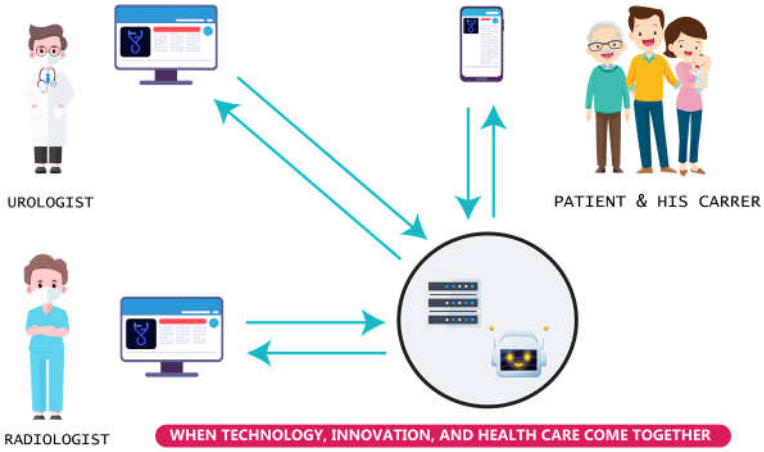
Since AI is gradually transforming our daily lives, we ask ourselves "*why not use AI for PCa management?* "This is where the idea of "**Proman**" emerges. This label denotes "*Prostate Management*" because we used a patient-centred care strategy in which the solution concentrates on certain stages of the PCa care pathway, namely diagnosis, treatment, and follow-up. We believed that AI-based technologies can provide solutions that benefit all stakeholders in PCa management, including patients, urologists, and radiologists. In other

words, "*it is the solution that brings together the right technology, innovative ideas, and health care providers in order to improve the well-being of patients with PCa* ".

Proman strives to improve the overall health care provided for African patients with PCa in general, and Algerian PCa patients in particular. We offer our service (i.e., final deliverables) to a variety of customers including radiology laboratories, urology-specialised centres, and public hospitals. Proman consists of three applications, one of which is a mobile application that a patient or his career could use, and the other two are web applications designed for urologists and radiologists, as shown in **Error! Reference source not found.**.

**Figure 4.3**

*Presenting final delivrables of the proposed system "Proman".*




On the one hand, we would like to promote medical literacy among patients and their carers by providing medically-checked, concise, and personalised information about PCa based on the patient's profile and current health status. We also endeavour to provide everything the patient needs to live with PCa (e.g., assistance in choosing a good treatment option, a healthy diet, medication intake reminders) and to enhance his relationship with care providers via frequent communication without bothering them.

On the other hand, since the urologist plays such a crucial role in making the patient's journey less stressful, we are eager to improve the work of urologists by helping them make decisions about diagnosis plans and the suitable treatment option to choose. Besides, we aim to apply AI to assist radiologists in interpreting prostate mpMRI images and writing comprehensible radiology reports, which will reduce misunderstanding and increase revenue for radiology centres.

## 2.2. *Establishing Scrum Roles*

After identifying the project vision, it was crucial that each team member be assigned to a Scrum role and clearly understand his responsibilities. The Scrum roles were as follows:

- **Product owner:** assigned to Mr *Leghelimi*, who leads the commercial outlook and identify business goals that must be accomplished for the project to succeed.
- **Scrum master:** who is responsible for ensuring that the team has they need to complete their tasks. The role was assigned to our supervisors as it is considered a challenging role that demands good communication skills to bridge the gap between the customer and the development team,
- **Development team members:** are in charge of the software development. We were members of the development team.

There is another role not part of the Scrum framework, but is still critically important to agile projects is **stakeholders**, who are anyone (an individual or an organisation) with an interest in the project, who frequently interacts with the scrum team to provide them with inputs. In the development of Proman, patients, general practitioners, urologists, and radiologists are those involved.

## 2.3. *Identifying Product Requirements*

Scrum and sequential product development seem to have very differnt approaches toward requirements. In sequential product development, requirements are nonnegotiable, detailed earlier, and meant to stand alone (Rubin, 2012, p. 79). In contrast, in Scrum, the details of a requirement are negotiated through constant interactions that occur during development. They can be adjusted to meet *business goals*. For example, if a team is running out of time or money, they can eliminate low-value requirements.

### 2.3.1. Identifying Goals

In an agile methodology, the most important artifact obtained is the tested and working code (Gallud & Fardoun, 2018). All the other agile artifacts are simply secondary tools for developers to use in order to control the agile process. Regarding documentation and Unified Modelling Language (UML) diagrams, it is highly recommended to use the following diagrams:

- *Use case diagram* to summarise the desired system, in which the stakeholders who will use the system are modelled as *actors*, and the ways in which the system will be used to achieve these goals are modelled as *use cases* (*What Is Agile? What Is Scrum?*, 2021).

- *Class diagram* enables the development team to discuss the best design for implementing the required functionality (Gallud & Fardoun, 2018).
- *Deployment diagram* as it provides the development team with a high-level view of the solution's components (Gallud & Fardoun, 2018).

Due to the fact that the Scrum framework focuses on the interaction of end user with the system, we will only present the use case diagram of Proman. Please keep in mind that some use cases are not mentioned here after because the diagram is used only for demonstration purposes. Furthermore, the diagram had been divided into two packages, the first shown in Figure 4.4 illustrates the business goals to be achieved by the patient, and the second shown in Figure 4.5 illustrates those concerning healthcare professionals.

Patients are the one whom the system comes to serve, directly or indirectly. The solution must provide the patient with the following:

- Access to an easy-to-read overview of his medical records to help him better understand his overall care pathway.
- Obtain personalised recommendations on treatment options, diet and physical activities, and supportive care.
- Stay informed by receiving notifications that remind him to take medications, follow the urologist's advice, and properly prepare for upcoming visits.
- Meet with health care providers via online consultations, sharing his experience, and viewing cancer survivors' stories.

The urologist is another essential actor required for the proper operation of Proman, and improving his performance will benefit patients by providing a more personalised care pathway. The solution must provide the following to the urologist:

- Provides a detailed view of the patient's medical record by incorporating all results from the various examinations, and using insightful graphs to illustrate disease evolution.
- Provides an accurate PCa diagnosis while reducing overdiagnosis.
- Selects the suitable treatment that takes into consideration the patient's preferences, current status, life expectancy, and eventual side effects (i.e., estimating its risk).
- Automates repetitive routine tasks, for instance giving instructions before exams and surgery, provide information about PCa, explain the steps of the chosen care pathway, describing treatment options and their side effects.
- Allows him to remotely monitor patients and stay up to date on all changes to the recommended PCa care workflow and new research findings.

- Facilitating communication with other staff members, allowing for the exchange of medical reports.

**Figure 4.4**
*The Use Case Diagram of Proman: Package "Patient".*

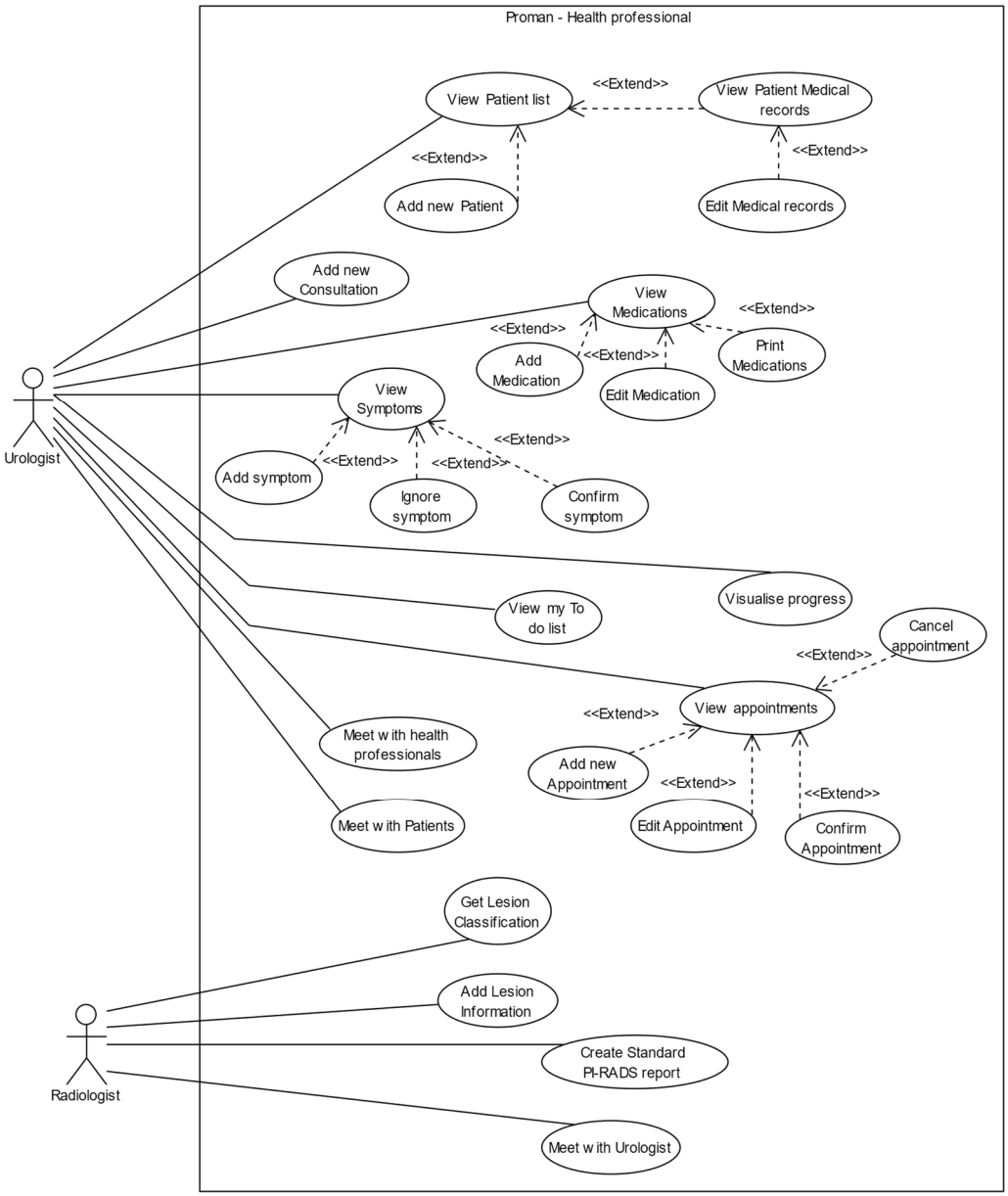

Since mpMRI is increasingly recommended as a first-line diagnosis procedure to be done prior to biopsy, assisting radiologists in doing this task accurately is important. Therefore, the solution must allow radiologists to:

- Interprets mpMRI and detects ROIs to provide accurate PI-RADS scoring and tumour grading.

- Build a comprehensive and well-structured PCa radiology report that includes all mandatory steps to ensure better communication with the urologist.

**Figure 4.5**

*The Use Case Diagram of Proman: Package "Health Professional".*




## 2.3.2. Writing User Stories

Although there are some similarities between user stories and use cases, in that each describes one way to use the system, is centred around a goal, and is written from the perspective of a user using natural language of the business; user stories are a convenient format for expressing the desired business value for product features because they are

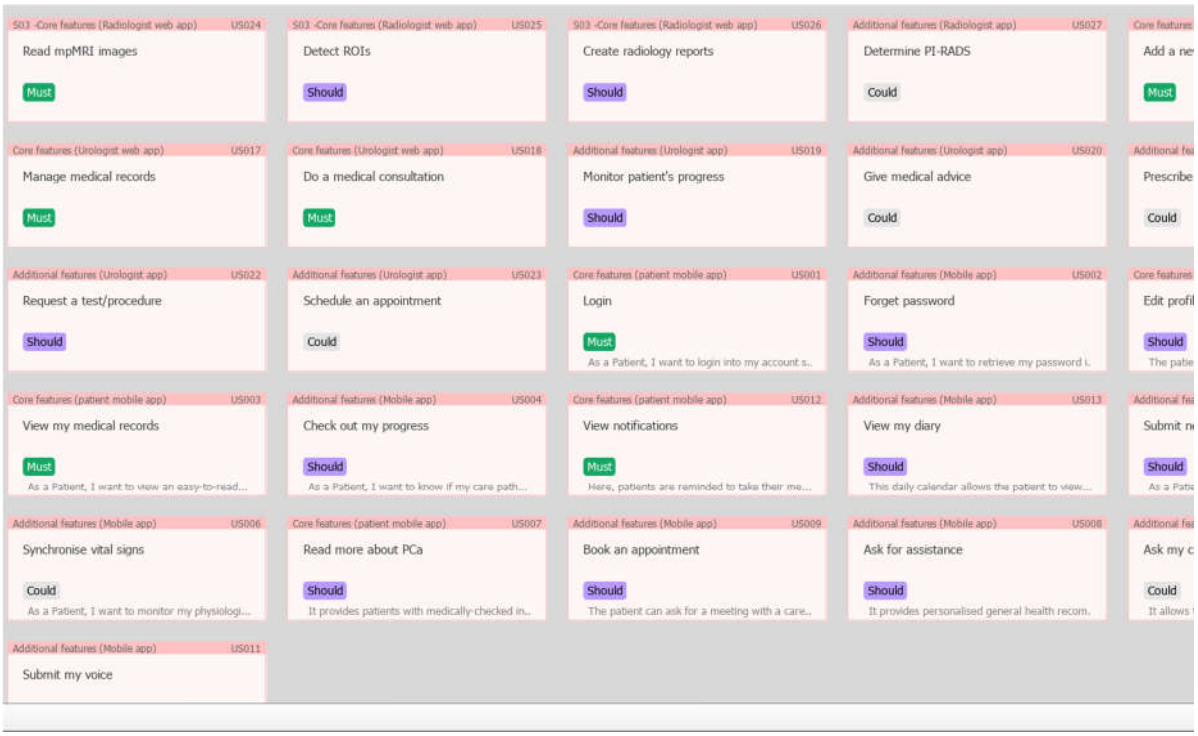
crafted in a way that makes them understandable to both business people and technical people (*User Story vs Use Case for Agile Software Development*, n.d.).

All user stories as expressed by the stakeholders are arranged into a map as shown in the Figure 4.6. Each user story has the following parts:

- **Title:** a recognisable name for the user story.
- **As a:** type of user.
- **I want to:** take this action.
- **So that:** I get this benefit.
- **Acceptance criteria:** which expresses to the team on what is expected from the user story.

For instance, the user story entitled "**As a** patient, **I want to** view an easy-to-read brief about my care pathway **so that** I can understand in which step am I in and to look for all medical records."

**Figure 4.6**
*A User Story Map that Captures the stakeholders' Stories.*




## 2.4. *Release and Sprint Planning*

The creation of the release plan was conducted based on three steps. First, we had defined the project deliverables to be produced. The results were three different applications (one mobile app and two web apps). Next, we had determined a target release date based on

the team's speed and capabilities. At the end, we arranged used stories into releases. The Table 4.1 presents our release plan, in which for each release, we gave a title, a description of the deliverable, and the planned date of software release.

**Table 4.1**

*List of Releases of Proman.*

| Release | Description | Planned Release Date |
|---|---|---|
| *Release 1.0* | Implementing the Android application of the patient that includes all main functions. | 15th April |
| *Release 1.1* | Completion of the mobile application of the patient that includes also optional functions. | 1st June |
| *Release 2.0* | The release should support the major features of the web-based application offered to the urologist. | 24th May |
| *Release 2.1* | Completion of the web application of the urologist that includes also optional functions. | 25th June |
| *Release 3* | The release should support all features of the web-based application offered to the radiologist. | 05th June |

On March 15th, we hold a *sprint planning meeting* to establish a sprint plan and confirm the tasks to be completed in the first sprint. After reviewing user stories, we created the first sprint entitled "*S01: Core features (patient mobile app)*", which was assigned to Mr Leghelimi and includes five user stories. The goal of the sprint was to provide essential functions to the patient including signup and login, edit profile, view medical record, receive notifications, and read about PCa. The complete list of sprints is detailed in Table 4.2.

**Table 4.2**

*List of Planned sprints.*

| Sprint | User Stories | Owner | Start Date | Finish Date |
|---|---|---|---|---|
| *S01- Core features (patient mobile app)* | – Login<br>– View my medical records<br>– Edit profile<br>– View notifications<br>– Read more about PCa | Mr Leghlimi | 23th March | 15th April |
| *S02- Core features (urologist web app)* | – Manage medical records<br>– Add a new patient<br>– Do a medical consultation | Mr Lechekhab | 10th April | 24th May |
| *S03- Core features (radiologist web app)* | – Read mpMRI<br>– Detect ROIs<br>– Create radiology reports | Mr Leghlimi | 20th April | 15th May |
| *S04- Additional features (mobile app)* | – Forget password<br>– View my diary<br>– Check my progress<br>– Synchronise vital signs<br>– Submit new symptoms<br>– Ask my care provider<br>– Ask for assistance<br>– Submit my voice<br>– Book an appointment | Mr Leghlimi | 17th May | 1st June |
| *S05- Core features (radiologist web app)* | – Determine PI-RADS score | Mr Leghlimi | 20th May | 5th June |
| *S06- Core features (urologist web app)* | – Monitor patient's progress<br>– Request a test/procedure<br>– Schedule an appointment<br>– Give medical advice<br>– Prescribe medication | Mr Lechekhab | 1st June | 25th June |

The meeting had allowed us to have the overall development schedule and clearly determine the milestones. During one week, in a daily basis we started working on designing the software architecture. More details about the chosen architectural style are provided in the next section.

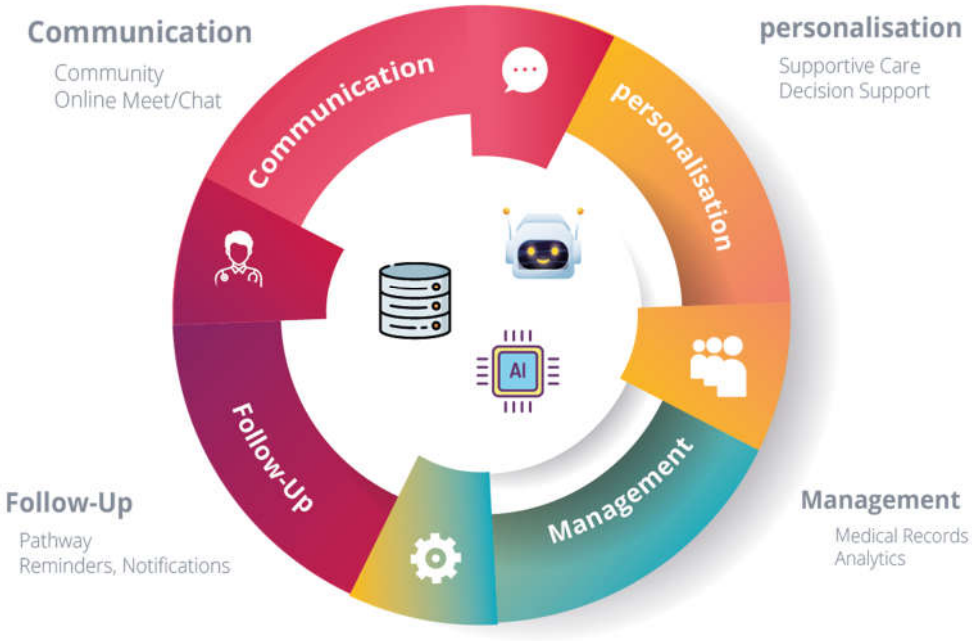
# Section 2. PROPOSED SOLUTION

## 1. Overview

After identifying requirements and detailing the different user stories, the Proman's features could be arranged into logical groups (i.e., in Agile Scrum, these groups are called *themes*). This step had allowed us to work with stakeholders to understand more the desired usage flow. The features were grouped based on business capabilities into four themes as follows:

- **Follow-up:** it includes all the functions needed to effectively monitor the patient's condition. Other functions are also available to patients, such as access to their medical records and assistance in understanding the steps of the care pathway**.**
- **Personalisation:** is where AI come into play; it provides decision-making support for health professionals in the form of diagnostic and treatment plans for urologists and automated interpretation for radiologists. Furthermore, it helps patients to decide which treatment plans to pursue as well as the diet to follow.
- **Management:** because the doctor receives data about patient records from a variety of sources, organising them is critical so that he can find what he needs quickly. It contains features that filter irrelevant data, improving clinical outcomes as clinicians have to focus only on relevant information related to their current situation. The doctor also needs to analyse his work and provide information on the progress of health care to achieve better effective care coordination, and to improve patient safety and quality of care.
- **Communication:** It provides continuous communication between the stakeholders. Above all, it ensures communication between the patient and the health care providers, whether to ask questions through messages or to book an online consultation via video meeting in cases where he is unable to make in-person consultation. It also allows health care professionals exchange information between each other via online meetings and to ask for assistance.

**Figure 4.7**
*Presenting the main features of Proman.*




# 2. Technical Architecture

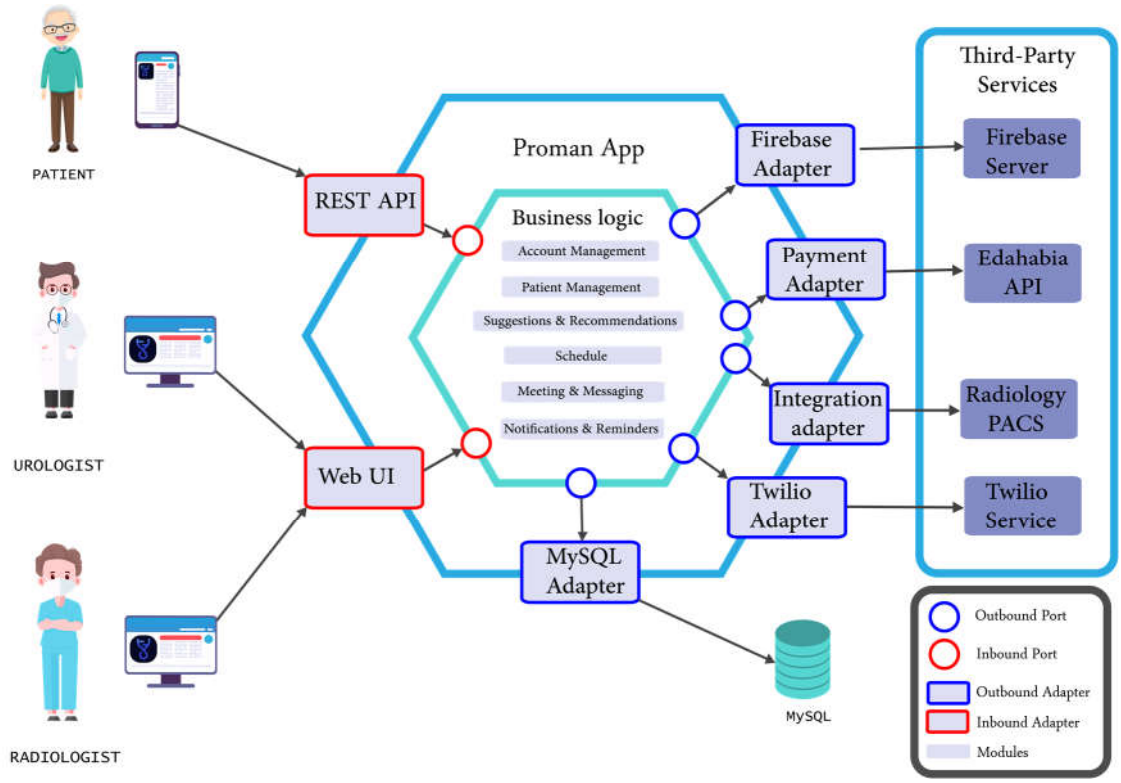
## 2.1. *Hexagonal Architecture*

Hexagonal Architectural is an architecture pattern that aids in the solution of difficulties associated with application maintenance in traditional architecture (*What Is Hexagonal Architecture*, 2021). It is based on the idea that the application is at the heart of the system, which is completely consistent with the values of Agile Scrum. As shown in the Figure 4.8, Proman is divided into three parts: user-side, business logic, and server side.

The user part in our case consists of three actors, which are the patient, the doctor and the radiologist. The patient uses a mobile application for access, this is done through REST API which in turn allows access to the Business Logic through the port.

The business logic consists of a number of modules, each of which is linked to the server via outbound adapter and ports. The server side consist of third-party services and a database, such as Firebase to get real time notifications, *Edahabia* API for payment, *Twilio* for online meeting, and MySQL for database.

**Figure 4.8**
*The Architecture of Proman.*




## 2.2. *Modules*

As we mentioned earlier here, we will explain in detail the modules and all the features that Proman offer. It is divided into 6 modules as follows

### 2.2.1. Account Management

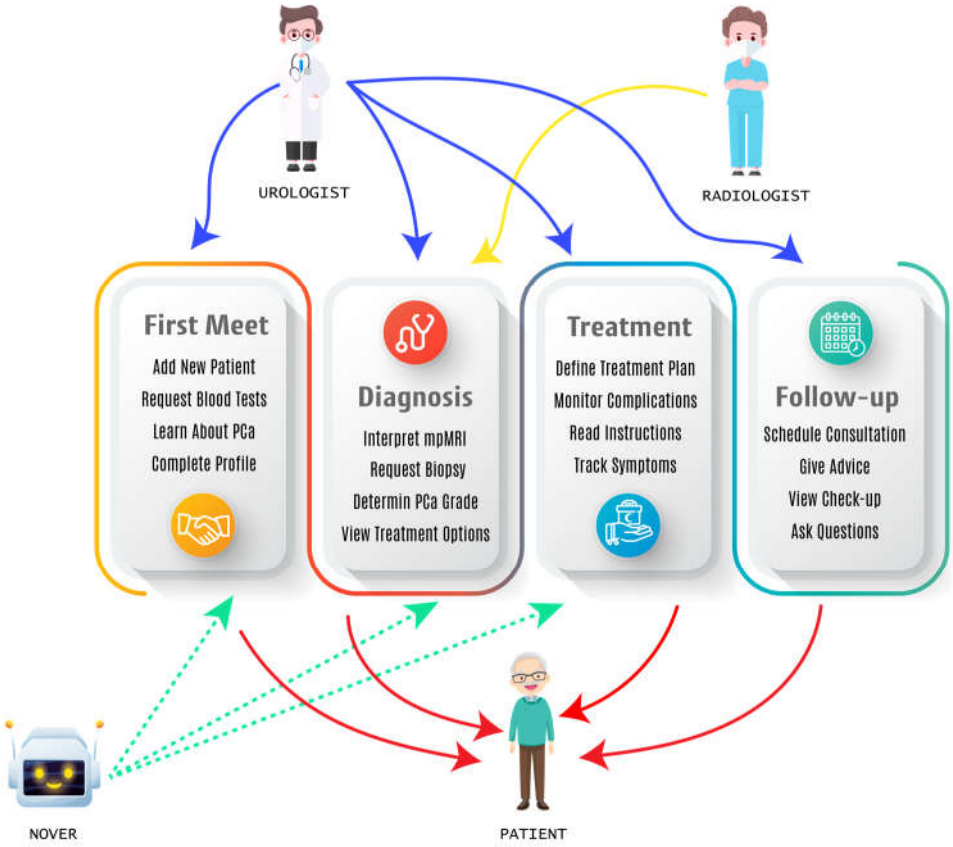
Given that Proman will provide its services to a variety of actors, it is crucial to add an account management module that ensure the authentication of different users. The module provides the following features:

- Give access to urologists and radiologists to their accounts.
- Allows the patient to use and benefit from the features of the application, and without it, he will be unable to access his account.

### 2.2.2. Patient Management

This module combines many characteristics related to all actors, where some are shared by all and others are unique to only one of them.

**Figure 4.9**
*The Pathway Management Module.*




Among the common features, we mention pathway management, which we will explain below:

### 2.2.3. Pathway Management

This feature benefits all actors by providing many services in the pathway of PCa, as it gives the urologist with a clear pathway that allows him to manage the cancer in an organised and accurate manner. To ensure the best possible delivery of the feature, it has been divided according to the corresponded step of the care pathway as follows:

- For **First Meeting:** where it allows to add a new patient with some information about him, in addition to that, as well as give his patient information to access his account through the mobile application, and it also allows him to request a set of analyses from his patient and schedule his upcoming appointments, here the *Nover* chatbot intervenes in order to alert the urologist we will discuss it in detail in the next model.

- For **diagnosis,** it provides the ability to request analyses and mpMRI images - this feature provides the radiologist the ability of create intermediate PI-RADS reports that are easy to understand by the urologist. The feature also provides biopsy preparation through an interactive interface that shows the regions of the prostate, which allows the urologist to determine the places from which he should take biopsies and enter the relevant results.
- With regard to **treatment,** this feature provides the urologist with treatment plans in a logical order that expresses the extent to which the treatment plan is compatible with the patient's condition and allows him to confirm it to be presented to the patient.
- As for the last division of the pathway, which is the **follow-up** of the patient, it allows the urologist to organise periodic appointments for his patient and provide him with advice.

### 2.2.4. Questions, Progress, and Edit Profile

The 'Questions' feature allows the patient to ask direct questions to his doctor or view the most frequently asked questions about PCa. Progress allows the patient to monitor his vital signs in addition to the PSA test by displaying them in an easy-to-understand format that helps him and his urologist understand the progression of his condition. The patient must complete his profile information in order to make full use of all features. The following figure depicts these characteristics:

**Figure 4.10**
*The Relationship between the patient and his urologist.*

### 2.2.5. Suggestions & Recommendations

This module includes features designed to assist patients in obtaining correct and accurate directions, as well as to assist health professionals in making decisions. It enables patients to be given daily instructions on what to do, as well as to be supported with treatment plans tailored to his condition, the diet to be followed, and the necessary psychological care. In terms of health care professionals, it includes features that allow the urologist and radiologist to make decisions. Following that, we will categorise and explain each feature in detail based on the actors:

#### *Decision Support with Nover AI Chatbot*

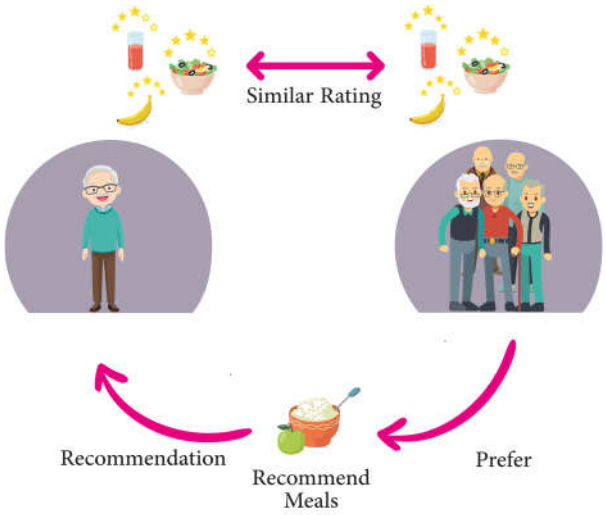
This feature is represented in a real time interactive smart chatbot – Nover - that alerts the urologist and reminds him of his full path with PCa while using the application, as it relies in its alerts on a set of data and rules that we have created based on the recommendations adopted by the health authorities. Nover's primary goal is to reduce problems of overdiagnosis and overtreatment, as well as oversight. The rules that were followed in its creation are explained in decision trees in Figure B.1.

#### *Meal recommendation*

This feature aims to improve the patient's diet by organising daily meals and giving him recommendations for foods that suit him based on his profile, diseases he suffers from, and evaluations of previous patients with similar characteristics. As the number of users increases, so do the recommendations, which improves the patient's diet. where we call our recommendation system to suggest meals to the patient after filtering foods and ignoring those that conflict with one of his diseases. The diagram below depicts how our recommender system works.

To do so, we collected the data for this study from a group of PCa patients by giving them a variety of foods and evaluating them. We gave them a set of 25 dishes and received 20 patient reviews. We gathered this information using social media as a source. Whereas the goal of gathering this data was to conduct an analytical study of the meals as well as to start our recommendation system with correct and logical data. The pseudo-code below explains how our recommendation system works.

**Figure 4.11**
*Proman uses Collaborative Filtering to Recommend Meals.*




**Algorithm 1**

*User-User Meals Collaborative Filtering Recommender System*

**Input:**

Meals: Group of meals

User: User profile information

Bias: Used to avoid the cold start when a patient has no preferences at the beginning

N: Number of meals to recommend

Output: Scores for each Meals

```
1:  Meals Filtering based on User (age, Diseases, Interference with current medications).
2:  for all Meals' which User has no preferences do
3:      for all Meals which Users has preferences do
4:        Calculate similarity between Meals' and Meals + Bias
5:      end
6:   end
7:   score (Meals)
8:   return (N Meals)
```

### *Personalised Information & Psychological Care*

The first feature is to provide the patient with customised information based on the stage he is in, and this revised and reliable information is displayed based on his profile. The second is represented by telling him about the experiences of cancer survivors and how he can save himself. And keeping him up to date by presenting all new information about the disease, including promising treatment methods that have proven effective.

### *Prostate Lesion Classification*

The dataset used in this study were extracted from Kaggle, where they were cleaned and enhanced with new data, as they have already been used in other AI techniques, but after studying their data, we noticed that the use of Deep Neural Network can give very good results.

**Algorithm 2**

*Deep neural network for Lesion Classification*

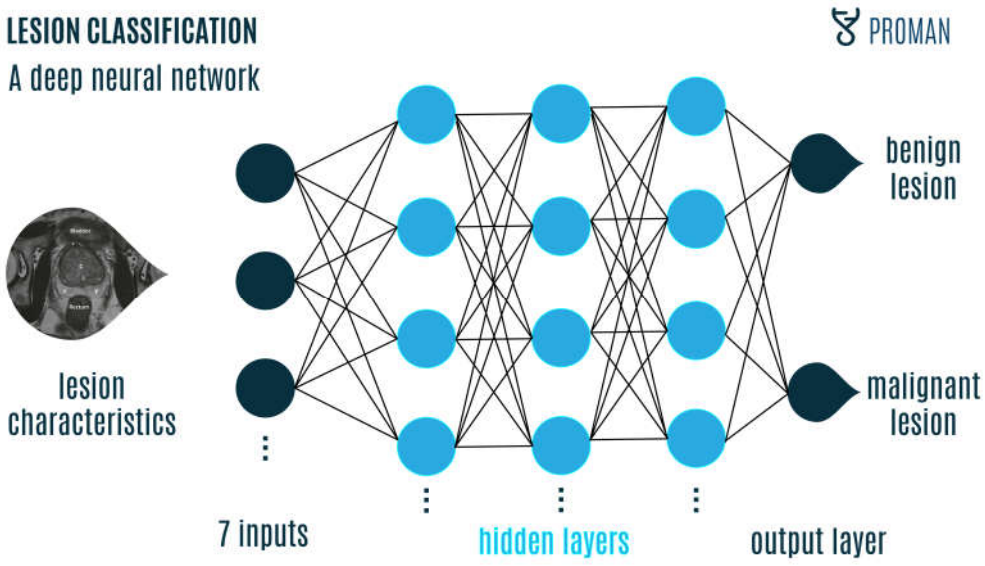
**Input:** Lesion characteristic: radius, texture, perimeter, area, smoothness, compactness, symmetry, fractal dimension

**Output:** Lesion Class, Benign or Malignant

1: Data Collecting and Data Cleaning
2: Data Visualisation
3: Training data 75%, Test data 25%
4: Apply a classifier with 3 hidden layers and 150 neurones for each layer.
5: return (lesion type)

The Figure 4.12 shows the architecture of the deep neural network used and its properties:

**Figure 4.12**
*The Deep Neural Network for Lesion Classification.*




## 2.2.6. Schedule, Meeting & Messaging, Notifications & Reminders

These modules have in common that they are related to time as we have compiled them on that basis. The following figure shows the advantages that the patient and the urologist benefit from.

**Figure 4.13**
*Proman's Features of Schedule, Meeting, and Reminders.*


### *Schedule*

This module provides a set of features, which is to organize the patient's diary and manage his appointments with the health professional.

### *Meeting & Messaging*

This module aims to provide the possibility for patients to communicate with the health professionals by creating an online meeting and providing the possibility of

communication via messages and live chat, as well as providing communication between the urologist and the radiologist and the possibility of exchanging patient files.

### *Notifications & Reminders*

This model provides the feature of reminding and alerting the patient regarding the use of the application, or those related to his medication or appointments with the health professional and all the activities in his diary.

## CONCLUSION

In this chapter, we presented the idea of Proman, the method of management that we followed in our project and all the features provided by the system, as this allows us to present our project and all its details.

In the next chapter, which is the implementation unit, we will display the method that we will follow in the embodiment of the project and also the results we have reached.

*"Although we have enough healthcare support, often it doesn't reach the poor and needy. In this scenario, technology is the best solution."*

*– N. R. Narayana Murthy, a businessman*

# 5

# Implementation, Results and Discussions

## Abstract

As the founder of Linux Linus Torvalds says "Talk is cheap. Show me the code." This quote indicates that speaking by mouth about what the solutions offer is easy, but the most important thing is the code, that is, its actual embodiment, and from this point of view, we have created the Proman system so as not to leave it ink on paper. where, in this part, we presented the methods we followed in creating the system, and this includes the programming languages we used, the technologies and frameworks, as well as the final product that we obtained, this includes plans to subscribe in the application and the technical conditions necessary to use Proman. We also referred to some of the important source codes and the design pattern used in writing it. Finally, we presented the final results through some UIs related to the mobile application and the urologist application, where we gave some results of the AI model as well.

## Contents

After the project idea was presented in the previous chapter and in order to materialise the idea and confirm the applicability of it, we created the Proman system in order to facilitate the management of PCa and use it as a means to collect data on this worrisome cancer. This chapter contains all the steps we followed in the process of implementation.

Where in the first part we presented the programming languages and technologies that we used to create the system with the tools that helped in that, and from that we provided information about the last product that we obtained, including the features that it offers, both free and paid. Then we provided the minimum requirements so that the patient can use the mobile application, and the conditions that must be met on the server in order to host the site and the database. In the last part, we showed some of the software codes for our system, as well as some screenshots from the patient application and the urologist application and some tests of the AI models that we have implemented.

# Section 1. TECHNICAL INFORMATION

## 1. Development Ecosystem

Like any other project in the field of computer science, in order to start in the realisation of the project, the technologies must be chosen in a logical and thoughtful way. At Proman, we have created a study of the current technologies, programming languages, and available frameworks that comply with our goals. With the large number of these technologies and programming languages, we focused on choosing criteria that suit the users of the application and the sensitivity of their situation, where the application must meet the following conditions: speed, accuracy, and ease of use. these criteria were compared with the available technologies and we chose the best ones. We focused more on native technologies as they do not require much time to load.

### 1.1. *Programming languages and Frameworks*

In the following figures we will give a brief explanation of the programming languages and frameworks that we used in developing the system and that helped us in our work, as choosing them was not easy in light of the presence of many of them and their convergence in features, as we focused on the most effective and fast programming languages in order to provide the best user experience.


**ReactJS** is a declarative, fast, and versatile JavaScript library for creating user interfaces.
It allows the user to build complicated user interfaces out of "components," which are small, independent pieces of code.


**Node.js (Node)** is an open-source server-side execution platform for JavaScript programming. it is commonly used for real-time applications and is ideal for designing apps that require a persistent connection from the browser to the server.


**PHP** is scripting language that is used to create dynamic Web pages. It is commonly used to extract data out of a database on the Web server and present it on the Web page." PHP is supported by all Web servers and widely used with the MySQL database.

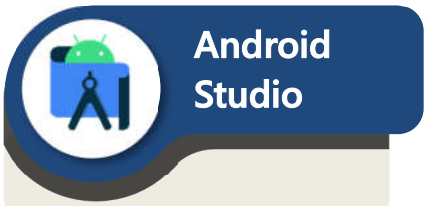

**Python** is an interpreted, object-oriented with dynamic semantics. Its high-level built-in data structures, make it very attractive for Rapid Application Development, Python supports modules and packages, which encourages program modularity and code reuse.


**Java** is an object-oriented programming language designed for having lesser implementation dependencies. It is considered as one of the fast, secure, and reliable, it can be considered both a compiled and an interpreted language because its source code is first compiled into a binary byte-code.

## 1.2. *Development Tools*

Below is a brief introduction about the methods we used in developing the system, which helped us to speed up the development process and improve the quality of code.


**Postman** is a collaboration platform for API development. Postman's features simplify each step of building an API and streamline collaboration. (Postman) We used the program to test the HTTP requests and view Json Responses in order to test the codes for fetching data from the database.




**Android Studio** is the official (IDE) for Android app development, based on IntelliJ IDEA . On top of IntelliJ's, it offers more features that enhance the productivity (Android Developer, 2021). it helped us in development by providing automatic code completion for java codes and for xml too.

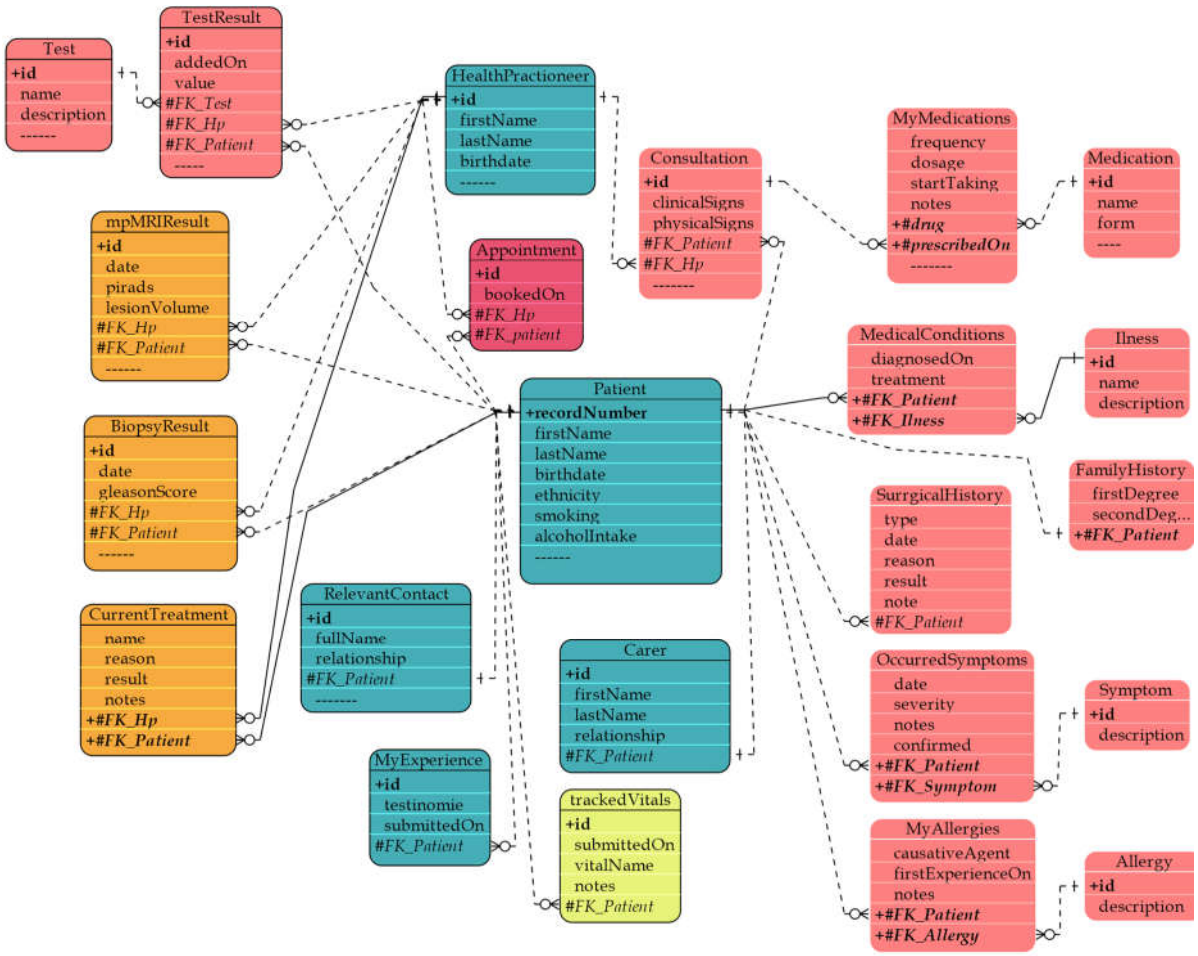

**VS Code** is a powerful source code editor, characterized by its speed and advantages that help programming, and supports many programming languages such as JavaScript, Java, Python (code.visualstudio.com). We used it to write JavaScript and PHP code


**PyCharm** is a Python IDE with complete set of tools for Python development. In addition, the IDE provides capabilities for professional Web development using the Django framework (www.componentsource.com). it Help us speed up the process of writing codes for training and test.

## 1.3. *Database*

Among the important things in the development of systems is the database, where it is concerned with storing data, and any defect in it can lead to data loss or corruption. As we had many choices regarding SGBD, we chose MySQL due to its high efficiency in Transactions, speed, ease of maintenance and high efficiency in dealing with applications. Where we created 26 tables which we will show part of them as follows:

**Figure 5.1**
*The Entity-Relationship Model of our MySQL database.*




It's worth noting that for the "notification & messaging" module, we used FCM from Firebase to send real-time notifications, as well as Twilio for online meetings. Whereas, we were unable to obtain the “Edahabia API” because it is expensive and often “Algérie Poste” takes a long time to respond to booking requests.

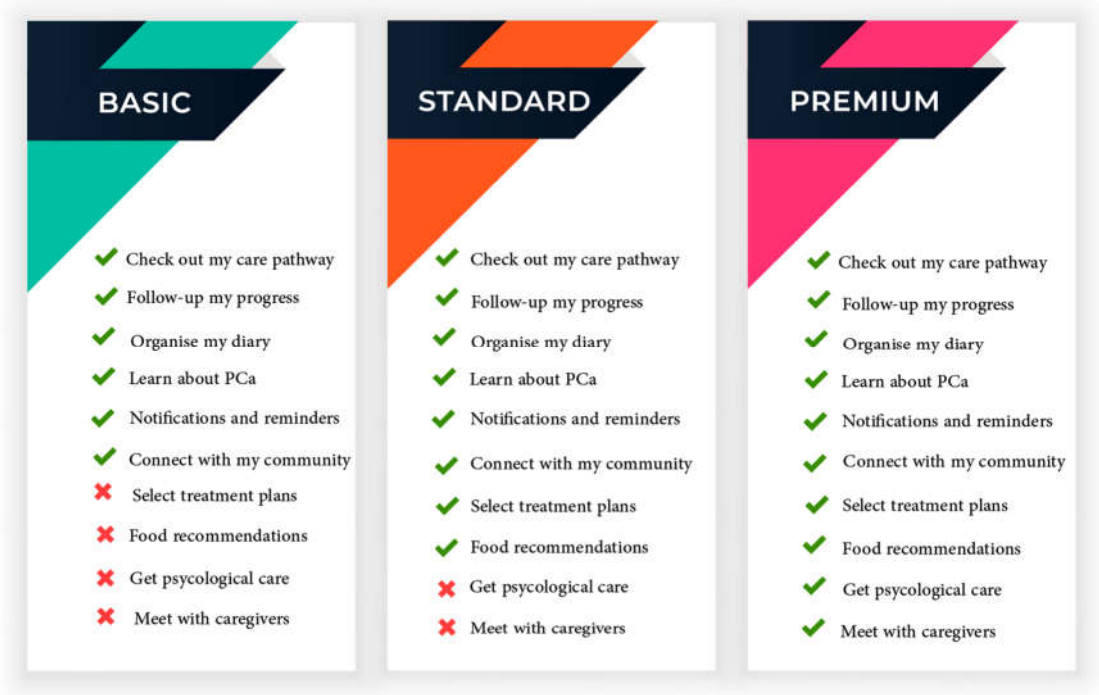
## 2. Final Products

Proman consists of three applications, a mobile application for the patient, and two web applications, one for the urologist and the other for the radiologist. As these applications serve each other by means of some associated features.

### 2.1. *Pricing packages*

Proman's philosophy is to provide the basic service free of charge in order to ensure that most problems faced by patients are solved as a human aspect. For some of the advanced features and those related to patient support, they are paid in order to ensure the continuity of the project and help other patients.

**Figure 5.2**
*Pricing Packages offered for patients.*

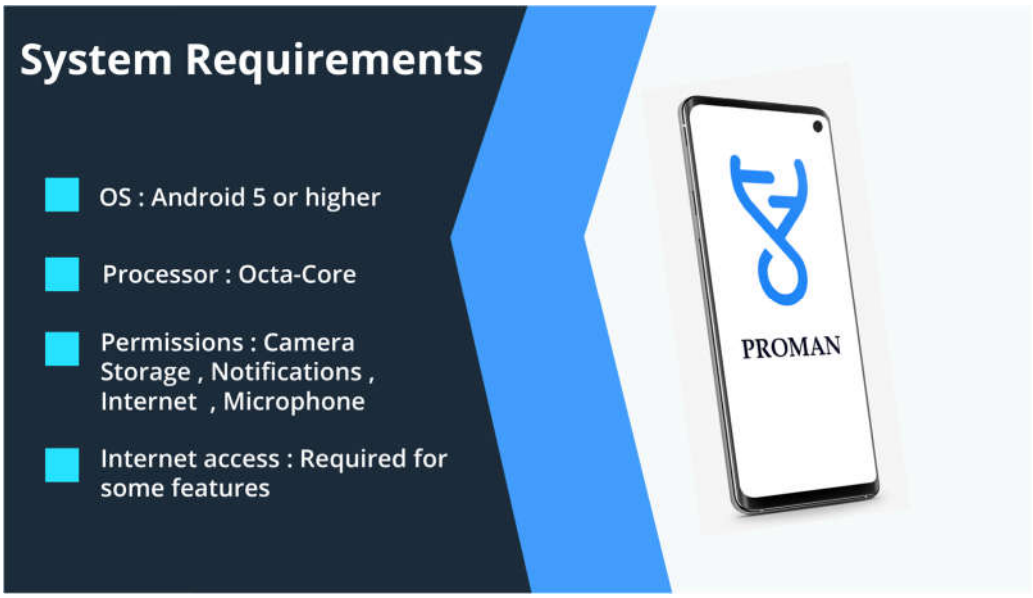



### 2.2. *Required hardware*

#### 2.2.1. Mobile app

The following figure shows the minimal requirements that must be available in the user mobile in order to use it:

**Figure 5.3**
*Minimal System Requirements for the Mobile Application.*




t is recommended to have a high-quality Internet in order to use the connected features such as communication and video consultations.

### 2.2.2. Hosting to the Web

In order to ensure system speed and efficiency, the following conditions must be met in the hosting server:

- 100 GB storage (preferred SSD)
- 4 GB RAM
- CPU - 2 Core
- VPS (that allows us to use NodeJS + PHP)
- PHP v 7.4.x
- MySQL v
- Node JS v14.16.x
- Express JS v4.17.x
- SSH Access
- Apache web server

After conducting a search for hosting servers, we chose one of the paid servers, and it is *GoDaddy*, as it provides the previous conditions and more, which will allow a high efficiency of the system.

# Section 2. SYSTEM PRESENTATION

In this part we are going to give an excerpt about the code and techniques used in the design pattern in order to give a mini documentation about this project. Then we will show the user interfaces of the developed applications.

## 1. Design pattern and exchange methods:

We will explain the design pattern that we used in the process of writing code, represented by MVC, and show some examples from our project, and we will explain the method of linking the front end and the back end in the project.

### 1.1. *MVC*

We developed the applications by following the MVC design pattern. This enabled us to organise our code by separating data access from View and Logic, this helped us to reuse it quickly and easily and allowing easy understanding of the code and the possibility of developing it from other people.

### 1.2. *Axios*

Axios is a Node promise-based HTTP client .it allows sending asynchronous HTTP requests to REST APIs which make fetching or saving data simple, and It may be used with either simple JavaScript code or a library like Vue or React. Axios is better than Fetch APIs because it allows Automatic JSON data transformation, Request and response interception, Streamlined error handling, Protection against XSRF, Support for older browsers, etc.

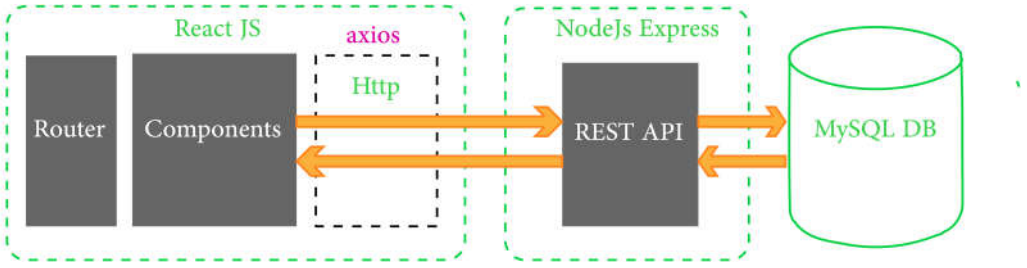
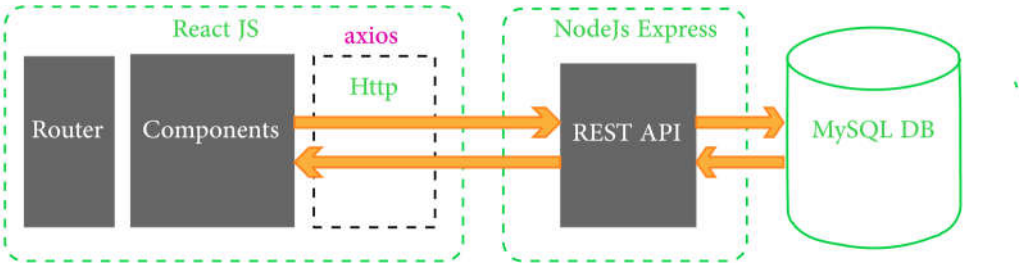



**Figure 2.26. — Axios library**

Ddd

**Figure 5.4**
*The Architecture of the Axios Library.*




## 2. Source code

We are going to show some of the code that we wrote for the development of the web application, this is for the way we used to write the code in order to show how the about the code is look like. Where the following figure shows the code of how to add and delete symptoms in the front-end part of the web app using axios and ReactJS:

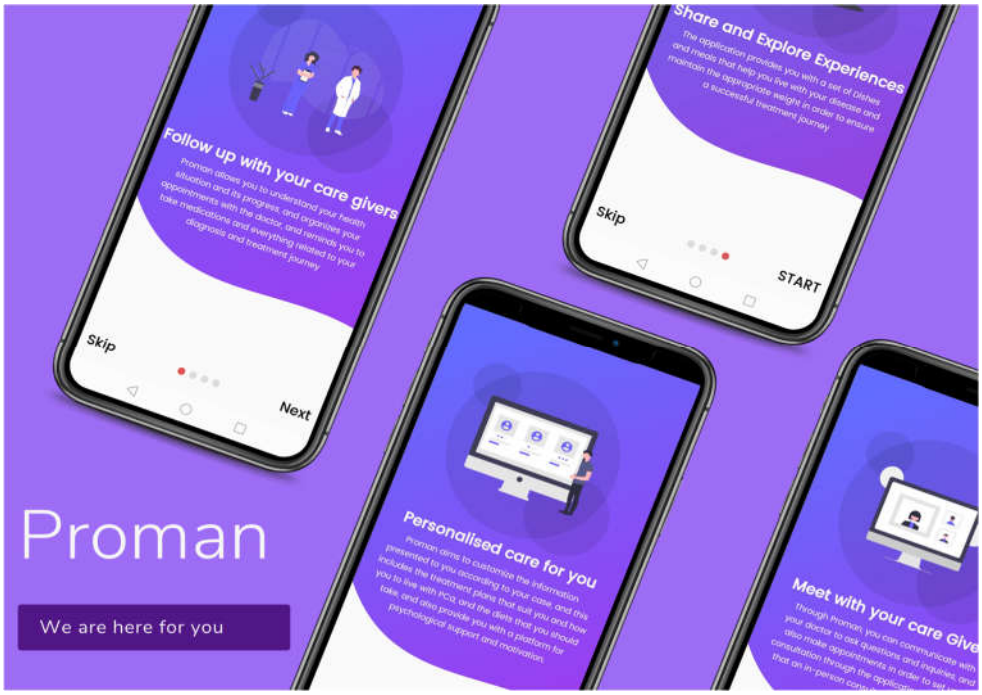
```
HandleSubmite = (event) => {

const desi = {p_id:this.props.id,sy_id:this.state.sy_name,date:this.state.sy_date,severity:this.state.severity,note:this.state.sy_note}
axios.post("/AddSymptome",desi).then(response => {
    console.log(desi)
  axios.get(`/getSymptome/${this.props.id}`).then(response => {

    this.setState({sym:response.data})

  })
  this.notify("br")

}).catch(err => {


    });

}
componentDidMount() {
    axios.get(`/getSymptome/${this.props.id}`).then(response => {

        this.setState({sym:response.data})

    })
}

RemoveHandler (iv) {
  axios.delete('/deletSymptome/',{ params: { id:this.props.id ,ic:iv} }).then(response => {

    axios.get(`/getSymptome/${this.props.id}`).then(response => {

        this.setState({sym:response.data})

    })

  })
```

The following figure shows the code of how to add and delete symptoms in the back-end part of the web app using axios and ExpressJS.

# 3. User Interfaces

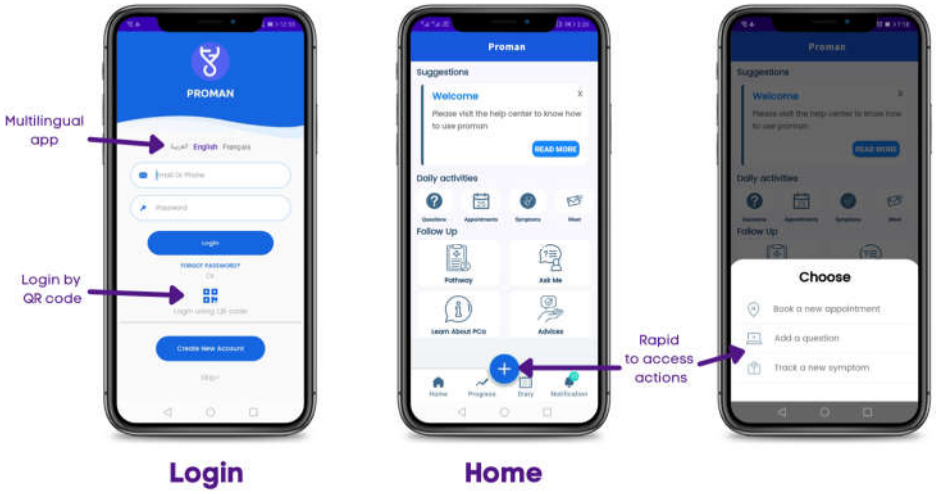
## 3.1. UIs for patient app

In order to give the patient a brief look at what the application provides for you, we have created the onboarding screens to summarise the features that he will find in the application.



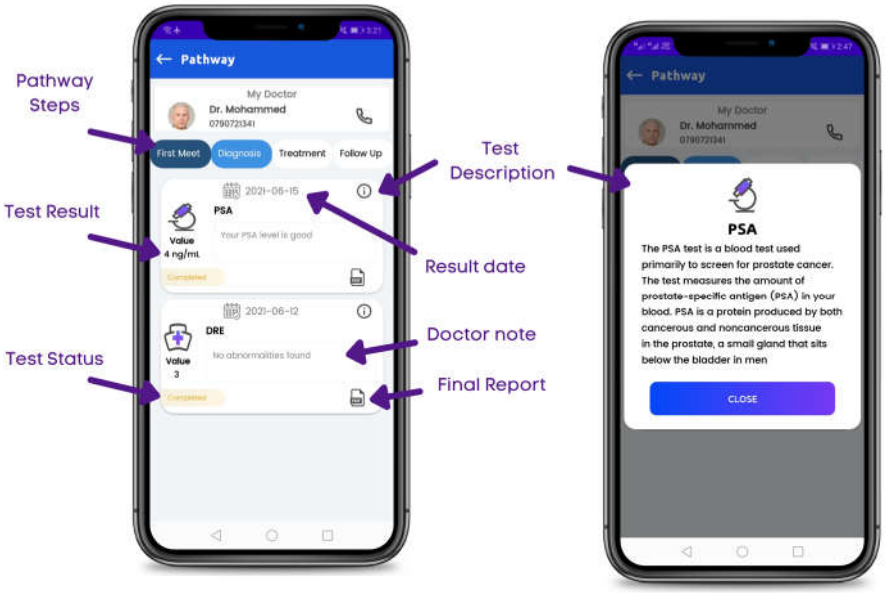

### Login and Home

Where the user can access his account either through the login information or through scan the given QR code. After a successful login, he can access the main page, which allows him to use all the features of the application. the following figure shows screenshots of the login and the home page.

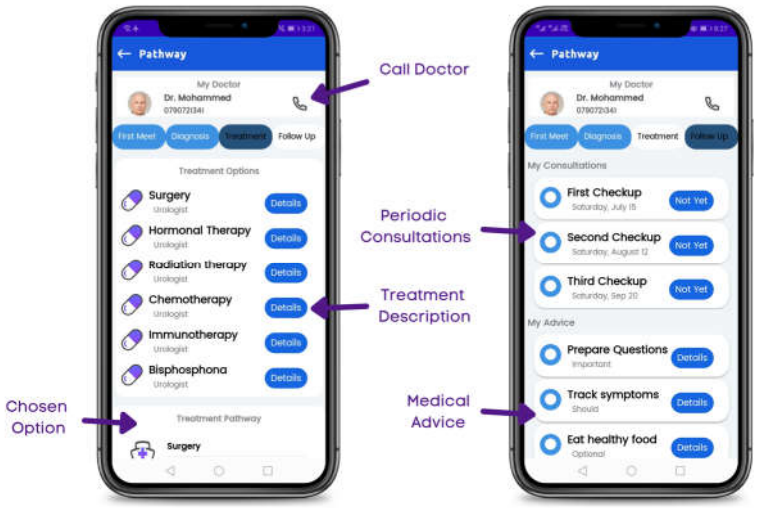


## Pathway Overview

The next figure shows the screenshots that display how the patient can view the analyses requested by the doctor, information about them and their expiry date in order to remind him, as well as their results and the doctor's note about them, in addition to the final report about these analyses, and this includes the step of the first meeting and diagnosis.

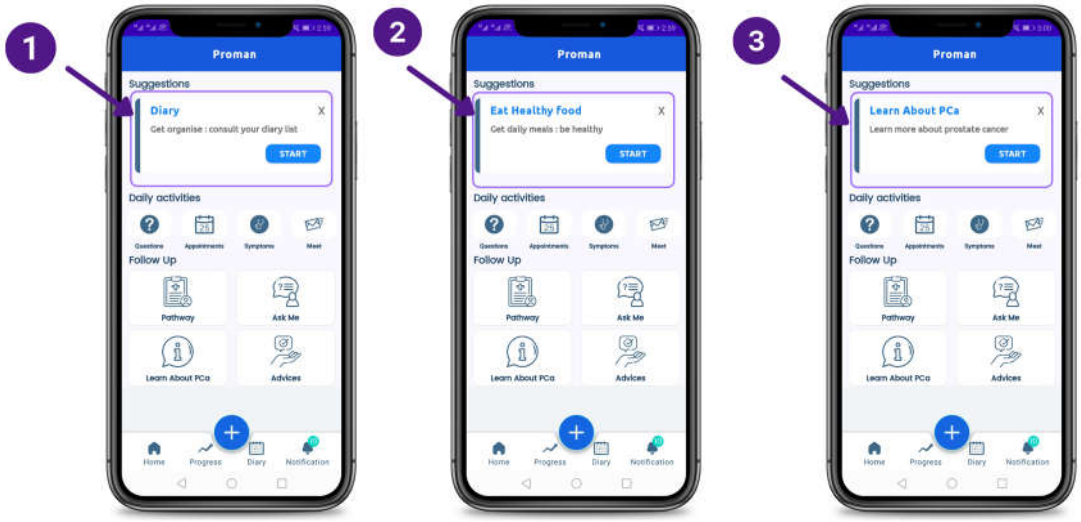



With regard to treatment and follow-up, the following screenshots show how the application displays the treatment methods chosen by his urologist in order to know and see them. As for follow-up, his periodic appointments with the doctor are presented as well as the advice that was provided by his urologist.



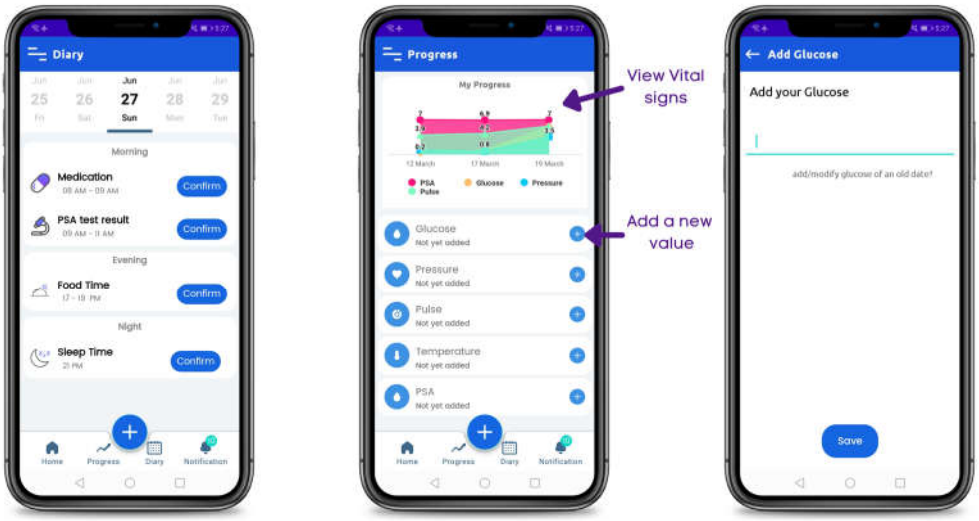
### Daily Suggestions

This part allows the patient to get suggestions for the optimal use of the application as it urges him to use the features, including giving an overview of the application and urging him to complete his profile and others as shown in the following figure.




## Diary And Progress

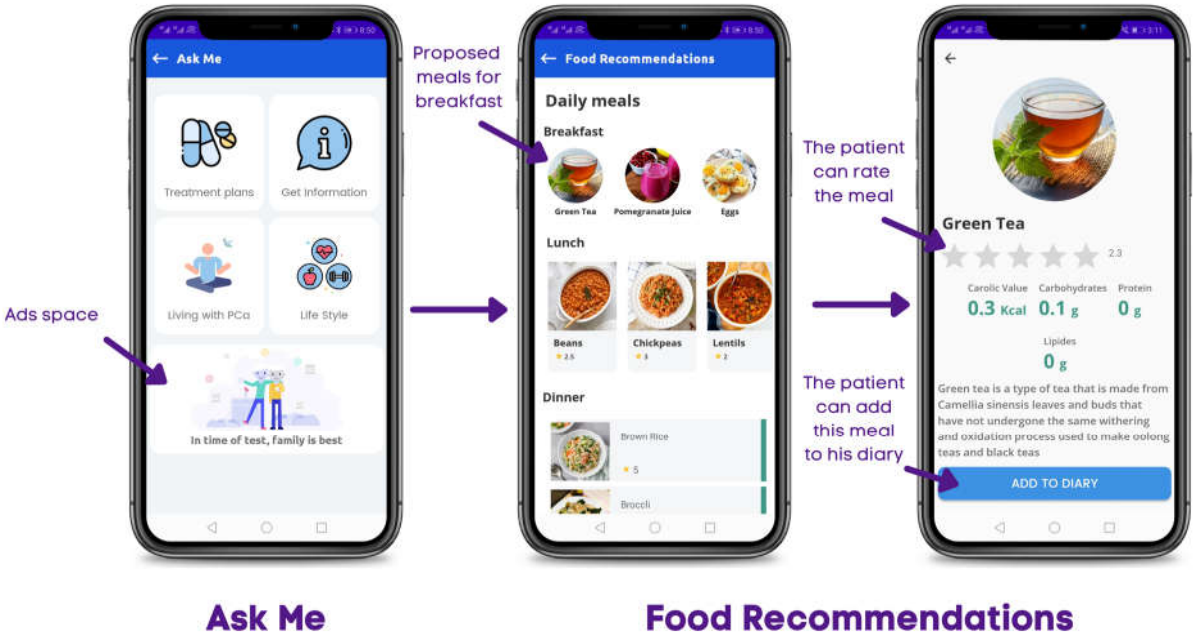
Diary allows the patient to view and confirm his daily activities. It organises his diary and helps him organise his time. in progress the patient can add his vital signs that allows him to follow the development of them by displaying it in interactive data that accurately shows the development of the case.



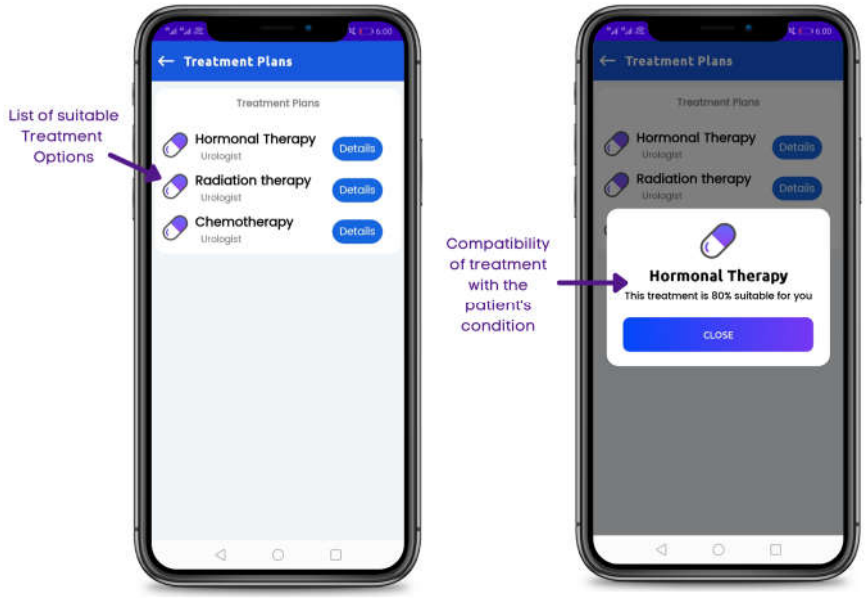

**Diary** **Progress**

## Ask Me: Food Recommendation and Treatment options

This feature allows the patient to organise his life and choose right decisions, as the first is to give him a set of meals divided into 3, where we suggest a customised diet according to his case as shown in the following figure:

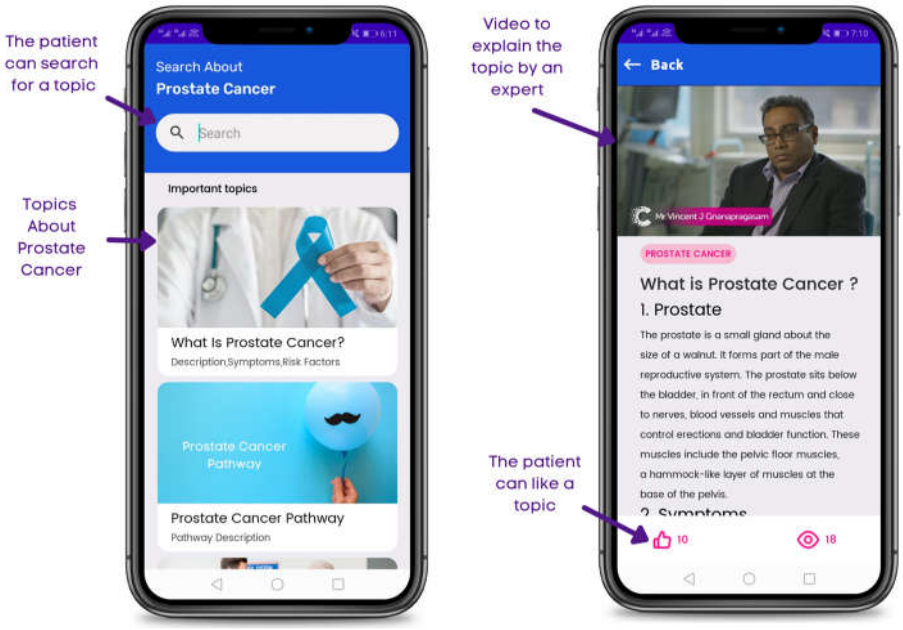



Treatment options feature is represented in giving the patient a set of treatment options customised for him and that suit him based on other people who have succeeded with them and who share some characteristics with him.

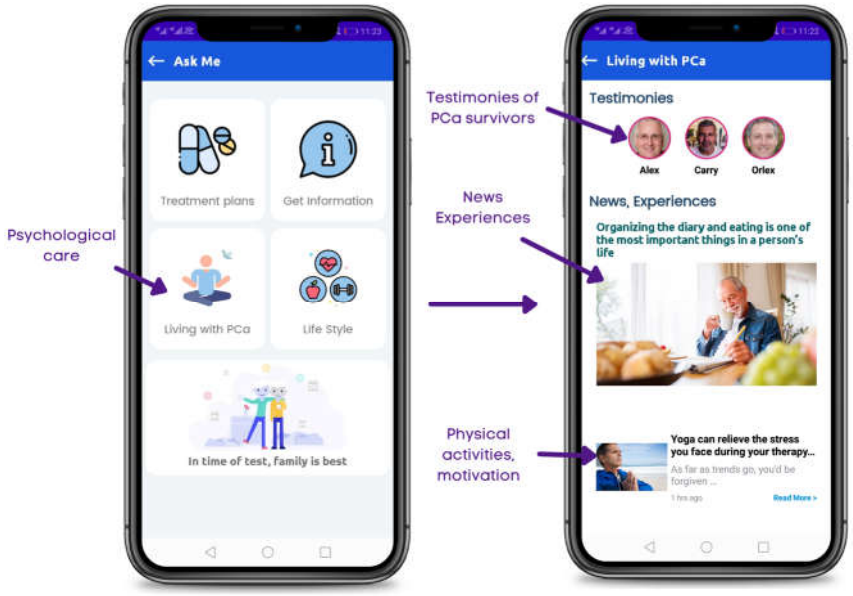


## Personalised Information and Psychological Care

This feature allows the patient to be given a set of revised and reliable information about his disease, according to the stage to which he is required and also according to his profile. The following figure shows how this feature is provided to the patient:



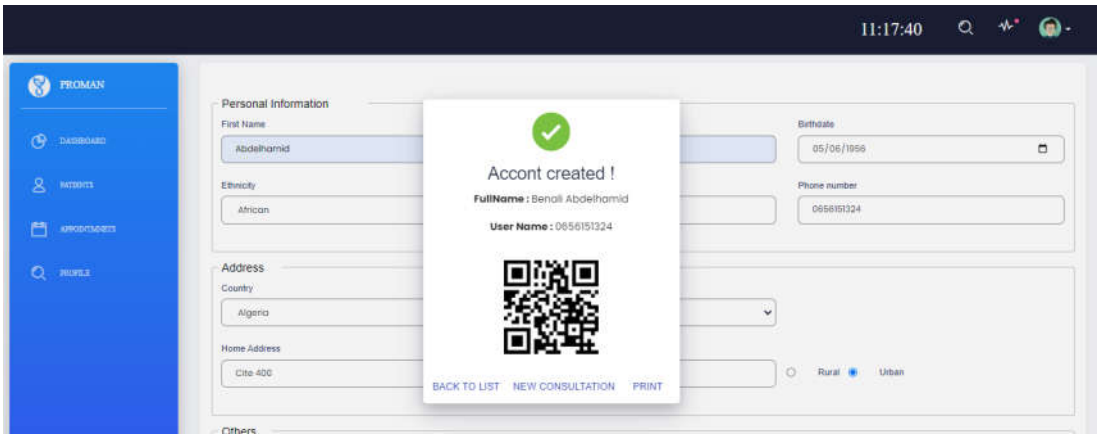

Psychological care feature gives the patient a set of previous experiences of people who faced the cancer and got rid of it, so that incentives, promising treatment methods and news about the cancer are presented.



## 3.2. *UIs for Urologist app*

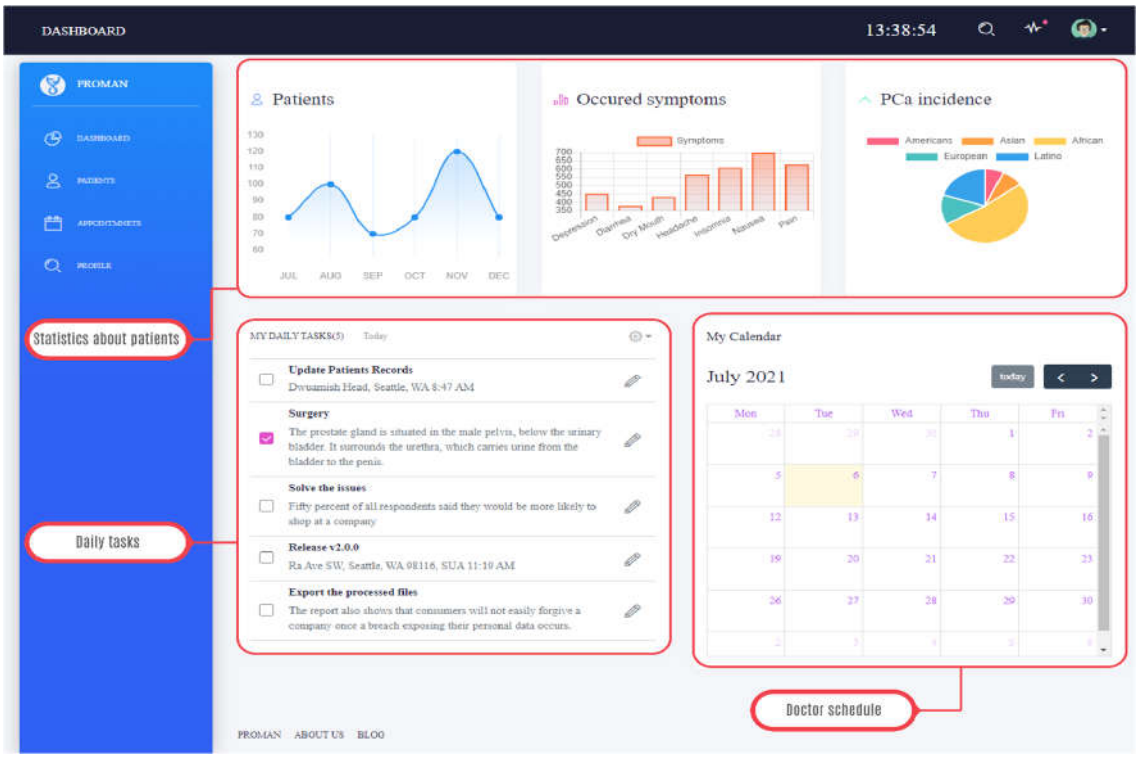
### ADD NEW PATIENT

This UI allows the urologist to add a new patient, as it provides him with the ability to enter information serially and allows him to give the patient a QR code in order to access his account in the mobile application as well as print his medical file.



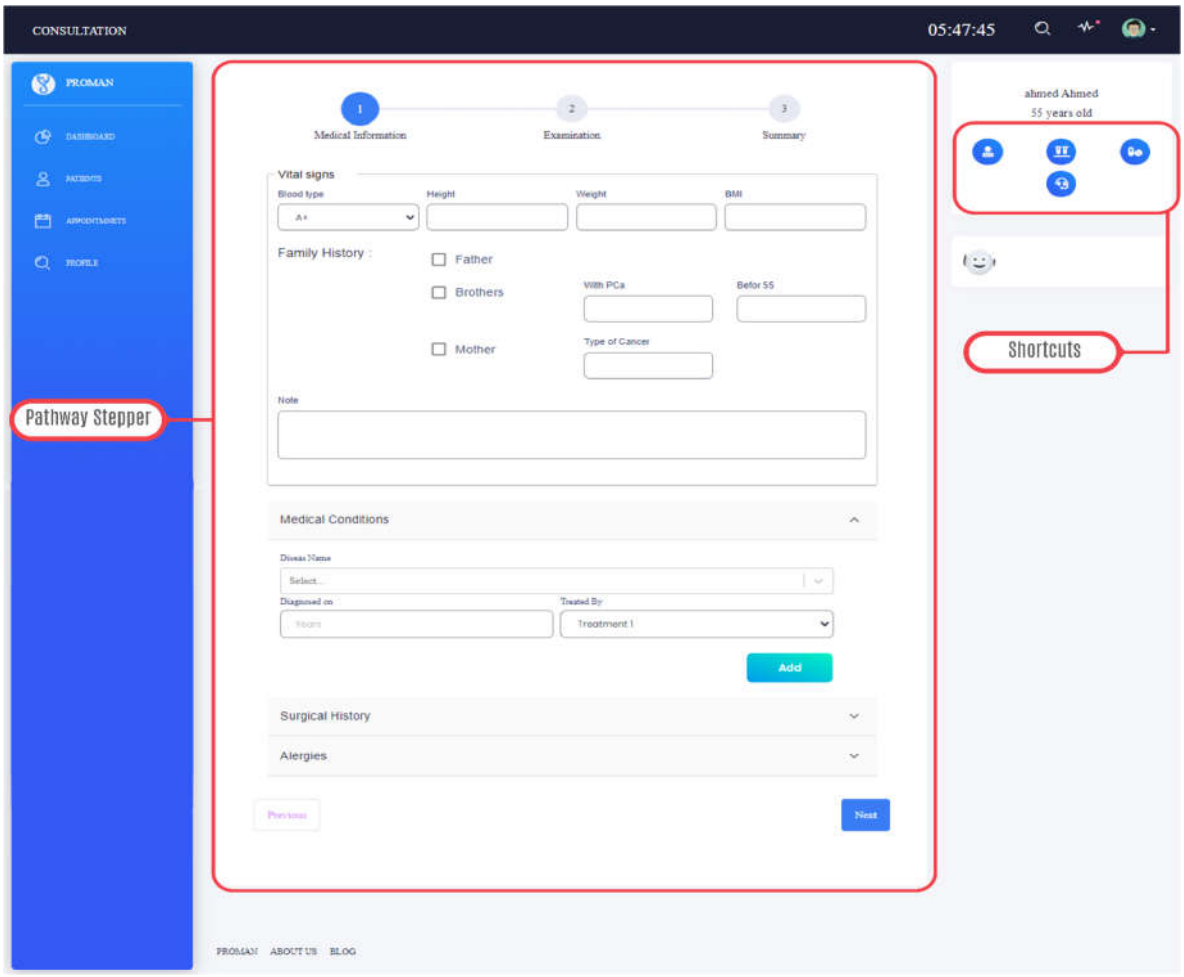

### DASHBOARD

The following figure shows the urologist's dashboard, allowing him to visualise charts containing data about the number of patients he cares for, and also showing him the symptoms and their rates of appearance in order to know what are the common symptoms. It also allows the urologist to know what activities he has to do today and on all days.



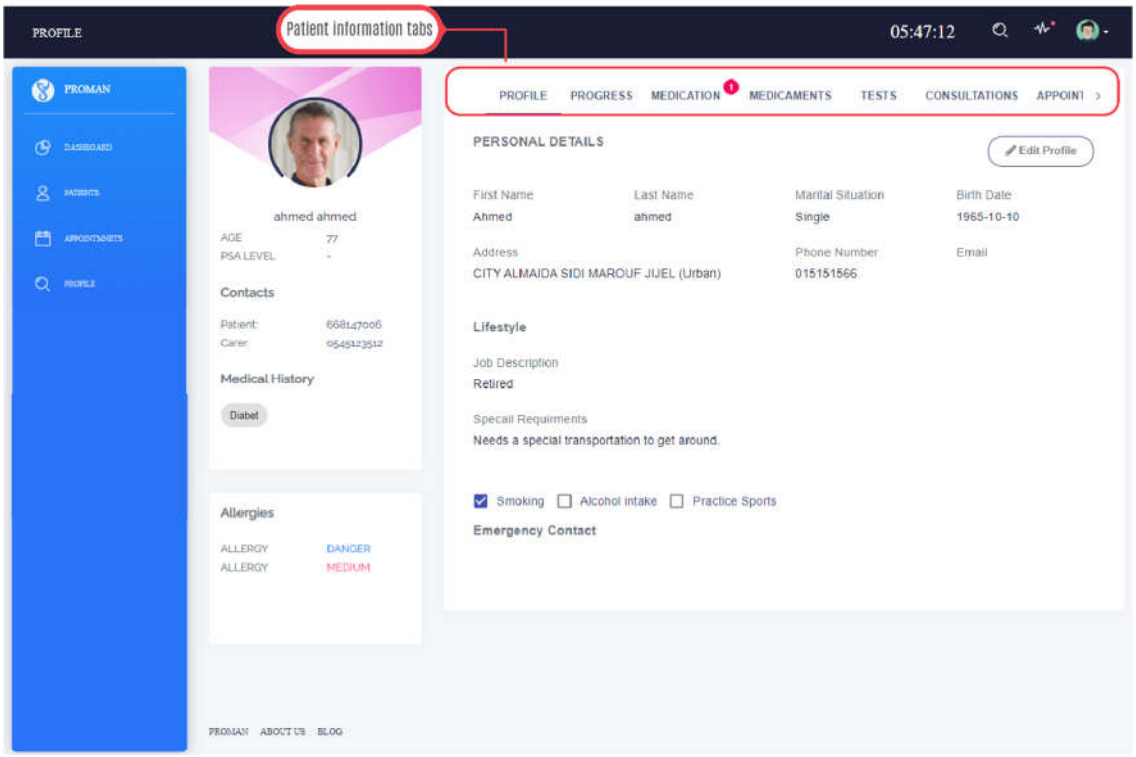

## Pathway

This UI allows the urologist to manage the prostate cancer pathway by facilitating this follow-up and ordering tests and examinations through easy and consistent interfaces via the pathway stepper feature that allows the order of steps and also allows him to access other information about the patient via shortcuts such as information Previous consultations as well as confirmation of new symptoms and reading of incoming messages.



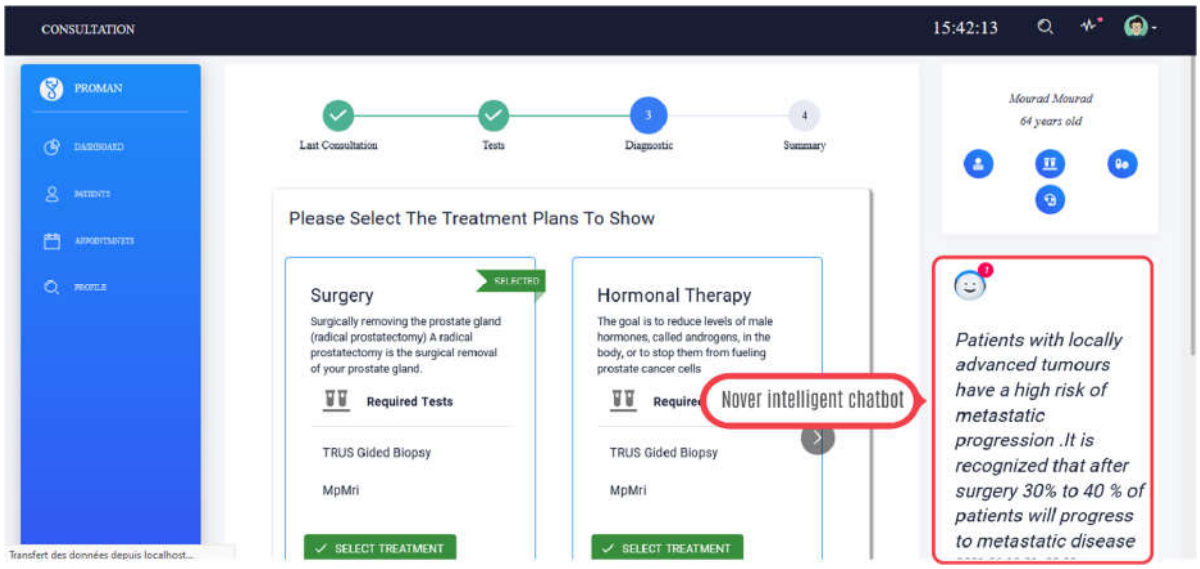

## Profile

This UI allows the urologist to add and update information about his patient, including personal information and information about his pathway with PCa, including test results, examinations, treatment plans and the development of his condition.




## Nover Chatbot

This smart and interactive Chatbot allows to follow the activities of the urologist during all steps of the pathway and to alert him of the most important points that concern his decisions, from decisions about the analyses that should be given to the patient to the diagnostic and treatment plans that he should choose for his patients.




The results we obtained related to the classification of Lesion to benign or malignant, showed impressive results, showing an effectiveness of 0.92, despite the lack of data that has been worked on. Where compared to the previous work, which scored about 0.86, it is considered a promising solution, especially with its support with new data. As for the

recommendation system, it showed its effectiveness after trying it on a number of patients around 15 patients, as it is developing more and more with the increase in the number of users, which increases its effectiveness in giving useful and appropriate meals.

With regard to Nover our AI chatBot, the rules on which it is based are respect the international recommendations of health organizations and have been confirmed by the urologist for their effectiveness.

## CONCLUSION

In this chapter, we presented all matters related to the development of the Proman system from the beginning to its use, where we started from introducing the programming languages, tools and frameworks that we used in its development and database tables, and then presented information about our final products related to the application The patient and the urologist, where we offered the prices of services and the conditions necessary for the use of these applications.

Finally, we provided mini-documents on how to write the codes and also presented some of the codes in order to explain the way it works and make it easier to understand. The user interfaces of the urologist web application and the patient mobile application were presented and explained and then we presented some results That's what we got for.

*"I imagine a world in which AI is going to make us work more productively, live longer, and have cleaner energy."*

*– Fei-Fei Li, a professor of Computer Science at Stanford University*

# 6

# Conclusions and Perspectives

## Contents

In fact, it is often the very last part to be completed along with the abstract.

## 1. Contributions

For both the patient and the health professional, the pathway of PCa is large and vast with many loopholes. Where many software has been created in order to solve these problems.

The study that we conducted allowed us to develop the Proman system directed to patients with PCa and health professionals. A mobile application for the patient and two web applications, one for the urologist and the other for the radiologist. In the mobile application, we developed everything related to facilitating the patient's life, and we focused especially on organising his life and support his decisions. As for the application of urologists and radiologists, we have developed features related to helping them make decisions and facilitating and speeding up the process of care.

## 2. Potential Limits

On our way to developing Proman, we encountered many obstacles, which are the difficulty of contacting healthcare professionals due to the COVID-19 pandemic. Where it was not possible for us to collect data from radiological imaging services, due to illness and also due to the lack of a ready-made dataset for use, and also its format requires a large time in order to convert it into images capable of analysis.

## 3. Future Work

We aspire to develop Proman more to include the large parts of the radiologist, and by that we mean those that help him in segmenting and interpreting prostate mpMRI images, where we have already set out in the process, but we are waiting to get the dataset of images in order to start the development process, which is based on convolutional neural networks and image processing.

## 4. Recommendations and Perspectives

The studied field is a very vast field, and the applications of artificial intelligence in it are numerous, but there are many things that have not been studied or embodied, especially those related to analysis of mpMRI images, which is the link of opportunities in early detection of the disease.

Proman aspires to be the first startup company specialized in the application of artificial intelligence for the management of prostate cancer in Africa. As the first step we

have prepared the administrative files related to obtaining “Innovative project label”, and we will start the process with it in the near future.

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# Appendices

*"Health informatics is about bringing data and new technologies to efforts to improve human health."*

*– Kishor Vaidya, Health Informatics for the Curious: Why Study Health Informatics*

# A

# Results of the final review

## Contents

## 1. Evaluation of Patients' Mobile Apps

**Table A.1 —** Results of the evaluation of patients' mobile apps using MARS system and other app-specific criteria.

| App name | *Cancer.net mobile* | *ChemoWave: cancer health app* | *My prostate cancer coach* | *Owise -Prostate cancer support* |
|---|---|---|---|---|
| **Engagement** | **2.2** | **2.8** | **1.8** | **3.8** |
| Entertainment | 1 | 2 | 1 | 2 |
| Interest | 2 | 3 | 2 | 4 |
| Customisation | 2 | 3 | 1 | 4 |
| Interactivity | 3 | 3 | 2 | 5 |
| Target group | 3 | 3 | 3 | 4 |
| **Aesthetics** | **1.67** | **3** | **2** | **4.33** |
| Layout | 2 | 3 | 2 | 5 |
| Graphics | 1 | 3 | 2 | 4 |
| Visual appeal | 2 | 3 | 2 | 4 |
| **Functionality** | **3** | **3.25** | **3.5** | **3.75** |
| Performance | 4 | 4 | 4 | 2 |
| Ease of use | 3 | 3 | 4 | 4 |
| Navigation | 1 | 3 | 3 | 4 |
| Gestural design | 4 | 3 | 3 | 5 |
| **Information** [a] | **3.43** | **3** | **2.57** | **3.14** |
| Accuracy | 4 | 4 | 3 | 4 |
| Goals | 2 | 3 | 2 | 4 |
| Quality | 4 | N/A | 2 | 3 |
| Quantity | 4 | N/A | 2 | 1 |
| Visual information | 3 | N/A | 3 | 4 |
| Credibility | 4 | 3 | 3 | 4 |
| Evidence base | 3 | 2 | 3 | 2 |

| | | | | |
|---|---|---|---|---|
| **Follow-up** [b] | **0** | **1** | **0.33** | **1.33** |
| Pathway | N/A | 3 | 1 | 4 |
| Instant messaging | N/A | N/A | N/A | N/A |
| Online meeting | N/A | N/A | N/A | N/A |
| **AI-usage** [b] | **0** | **1.33** | **1** | **1.33** |
| Treatment options | N/A | 2 | 3 | 4 |
| Lifestyle | N/A | 2 | N/A | N/A |
| Supportive care | N/A | N/A | N/A | N/A |
| **Overall** | **1.72** | **2.4** | **1.87** | **2.95** |

[a] Evaluation criteria rated as "N/A" are excluded from the mean score calculation.

[b] "N/A" values refer to "0" and are included in the mean score calculation.

## 2. Evaluation of EHR software

**Table A.2 —** Results of the evaluation of EHR software.

| **App name** | *NextGen health care* | *Praxis* | *NueMD* | *AthenaOne* | *Intelligent medical software* | *UroChartEHR* |
|---|---|---|---|---|---|---|
| **UI design** | **2.5** | **2.25** | **2.5** | **3.25** | **1.5** | **3.25** |
| Ease of use | 2 | 3 | 3 | 3 | 2 | 3 |
| Graphics | 3 | 2 | 2 | 3 | 1 | 3 |
| Layout | 3 | 3 | 3 | 4 | 2 | 4 |
| Responsive | 2 | 1 | 2 | 3 | 1 | 3 |
| **Usefulness** | **2.2** | **2** | **3.4** | **3** | **3.2** | **3.2** |
| Schedule | 3 | 3 | 3 | 2 | 3 | 3 |
| E-prescription | 2 | 3 | 4 | 4 | 3 | 4 |
| Lab results | 1 | 2 | 3 | 2 | 3 | 2 |
| Medical billing | 2 | 1 | 3 | 3 | 3 | 3 |
| Patient portal | 3 | 1 | 4 | 4 | 4 | 4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Authority** [a] | **2.33** | **3** | **3** | **3** | **3** | **3.5** |
| Accuracy | 3 | 4 | 3 | 3 | 3 | 4 |
| Credibility | 3 | 3 | 3 | 3 | 3 | 3 |
| Cost | 1 | 2 | 3 | N/A | 3 | N/A |
| **Follow-up** [b] | **2.67** | **1.33** | **1.67** | **2.67** | **1.33** | **4** |
| Symptom monitoring | 3 | 2 | 3 | 1 | 1 | 4 |
| Instant messaging | 2 | 2 | 2 | 3 | N/A | 4 |
| Online meeting | 3 | N/A | N/A | 4 | 3 | 4 |
| **AI-usage** [b] | **0.67** | **3** | **2** | **2.33** | **1.67** | **1.33** |
| Personalised care pathway | 1 | 3 | 2 | 2 | 2 | 2 |
| Decision-aid | N/A | 2 | 1 | 2 | 3 | 2 |
| Reporting | 1 | 4 | 3 | 3 | N/A | N/A |
| **Overall** | **2.07** | **2.32** | **2.51** | **2.85** | **2.14** | **3.06** |

[a] Evaluation criteria rated as "N/A" are excluded from the mean score calculation.

[b] "N/A" values refer to "0" and are included in the mean score calculation.

## 3. Evaluation of radiologists' applications

**Table A.3 —** Results of the evaluation of applications developed for radiologists.

| **App name** | *DynaCAD prostate* | *ProFuse MRI software* | *Ezra prostate AI* | *Quantib prostate* |
|---|---|---|---|---|
| **UI design** | **1.67** | **2** | **4.34** | **3.67** |
| Ease of use | 1 | 2 | 4 | 3 |
| Layout | 2 | 3 | 5 | 4 |
| Graphics | 2 | 1 | 4 | 4 |
| **Usefulness** | **2.67** | **3.33** | **3.33** | **4.33** |
| Image interpretation | 2 | 3 | 4 | 5 |
| 3D visualisation | 3 | 4 | 5 | 4 |

| | | | | |
|---|---|---|---|---|
| PI-RADS Reporting | 3 | 3 | 1 | 4 |
| **Authority** [a] | **3** | **3** | **3.67** | **4** |
| Accuracy | 3 | 3 | 4 | 4 |
| Credibility | 3 | 3 | 4 | 4 |
| Cost | N/A | N/A | 3 | N/A |
| **AI-usage** [b] | **3** | **2.75** | **1.75** | **2.5** |
| Image pre-processing | 3 | N/A | N/A | N/A |
| Automatic lesion detection | 3 | 4 | 4 | 4 |
| Automatic segmentation | 4 | 4 | 3 | 4 |
| Personalised MRI pathway | 2 | 3 | N/A | 2 |
| **Overall** | **2.58** | **2.77** | **3.27** | **3.63** |

[a] Evaluation criteria rated as "N/A" are excluded from the mean score calculation.

[b] "N/A" values refer to "0" and are included in the mean score calculation.

*"Health care is yet to be transformed by technology."*

*– Joshua Kushner, a businessman*

# B

# Medical Recommendations

## Contents

## 1. Grade Groups

**Table B.1 —** ISUP 2016 Grade Groups (Canadian Cancer Society, 2021).

| Grade Group | Gleason score | Grade | Description |
|---|---|---|---|
| *1* | 3+3=6<br>or less than 6 | Low | The cancer cells are well-differentiated, which means that they resemble normal prostate cells in appearance, behaviour, and arrangement. The glands in the prostate are visible. The cancer is growing very slowly and often does not need treatment. |
| *2* | 3+4=7 | Low-Intermediate | The cancer cells are moderately differentiated, which means they differ from normal cells but are not as abnormal as poorly differentiated or undifferentiated cells. Cancer may grow very slowly and sometimes does not need treatment. |
| *3* | 4+3=7 | High-Intermediate | The cancer cells are moderately differentiated, and cancer is growing at a moderate rate and usually needs to be treated. |
| *4* | 4+4=8<br>3+5=8<br>or 5+3=8 | High | The cancer cells are poorly differentiated. They have a very different appearance, behaviour, and arrangement than normal prostate cells. The glands in the prostate are not visible or are not visible well. The cancer is overgrowing and is more likely to spread. |
| *5* | 9 or 10<br>4+5=9<br>5+4=9<br>or 5+5=10 | Very High | The cancer cells are undifferentiated, which means they are very abnormal. They have a very different appearance, behaviour, and arrangement than normal prostate cells. The glands in the prostate are not visible or are not visible well. The cancer is proliferating and is more likely to spread. It has a poor prognosis. |

## 2. Clinical practices: Early detection, diagnosis, and treatment

### Figure B.1

*Decision Tree for PCa Diagnosis.*

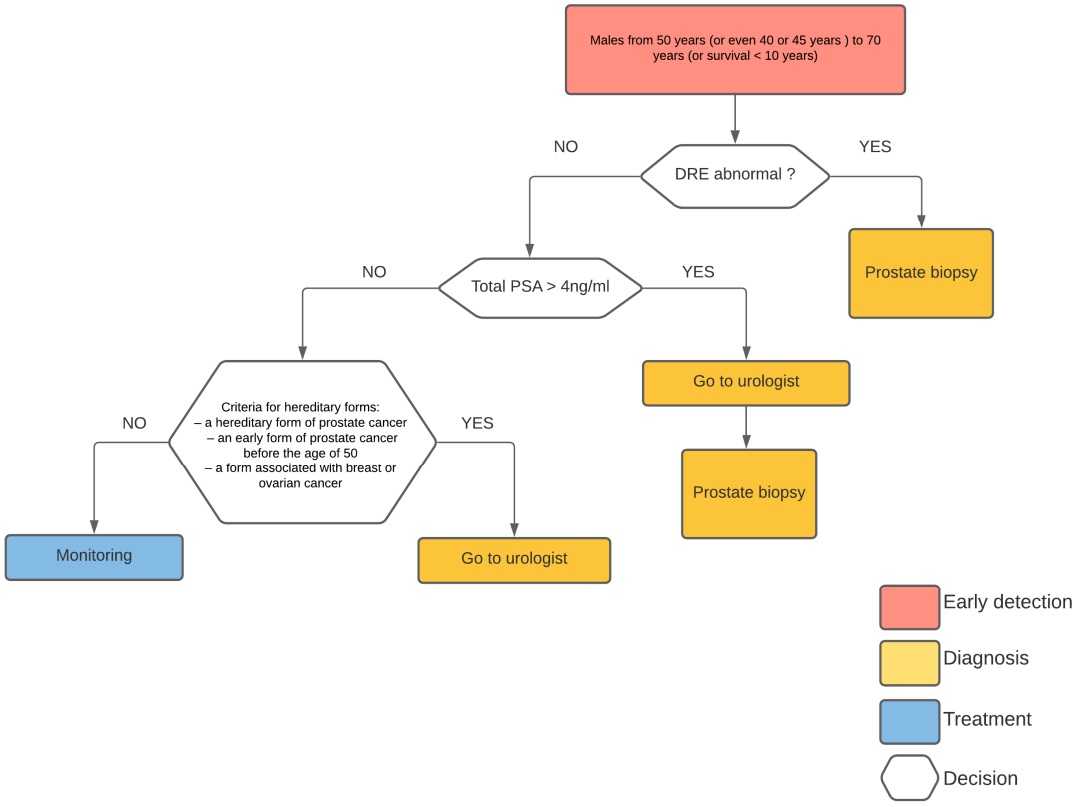

**Figure B.2**
*Decision tree for treatment selection*