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Artificial Intelligence-Based Prediction of Survival Outcomes Among Men with Prostate Cancer in Nigeria Using PSA Markers

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Abstract

One of the popularly recognised health problems among the Nigerian black men is metastatic prostate cancer, it is known to have variations in treatment response as well as the survival outcomes at the onset of surgical castration. Artificial intelligence and machine learning models have been classified to provide great opportunities for improving the assessment of the prognostics and individualised planning. Therefore, the study focused on a systematic review for the evaluation of its applications in terms of prognostic models used to predict the treatment outcomes at the onset of surgical castrations among the black men in Nigeria having the disease. The focus was on a systematic review using the PubMed, Google Scholar, Scopus based on clearly defined keywords. Studies that focused on the applications of machine learning or artificial intelligence for predicting survival outcome, treatment responses, progression of the disease as well as risk stratification after surgical castration were identified, selected and critically reviewed. Furthermore, patient's data features, predictive variables and the techniques of the modellings, performance of the model were extracted and synthesised. The outcome revealed that artificial intelligence prognostic techniques, predictive performances, its clinical applications were able to identify the bases of the disease within the Nigerian contexts. Attention was given to the accuracy of the model, validation as well as the factors which influence the outcome of the treatment. Therefore, artificial intelligence models have the potentials to improve the prediction of the treatment outcome, support the personalised management of metastatic prostate cancer after surgical castration. Although, it is important to established that models validated locally and quality dataset in Nigeria are significant for reliable clinical predictions.

Keyword: Prostate cancer, Artificial intelligence, prognostics, surgical castration, Treatment response

Introduction

The large percentage of patients with advanced prostate cancer in Nigeria has led to the poor outcome in terms of survival [1]. The serum prostate specific antigen (PSA) markers are hardly deployed for early screening of the population, which serves instead as a chance diagnostic test for the cases of symptomatic diseases [2]. This correlates with the delay in treatment and reduction in the level of survival. PSA markers have several roles which include late presentation where the majority of Nigerians tend to seek for care when the case becomes symptomatic [3-5]. This gives a record of high average or median PSA level during the presentation when compared to the western population [6-7]. Also, there is gaps in screening where absence of uncoordinated national PSA screening activities, leaving detections dependent on the case of opportunistic community awareness drive [9-11]. Variation in thresholds also exist in which the clinicians frequently rely on the overall values of the PSA together with digital rectal examinations in order to determine the indications of the biopsy which sometimes misses the intermediate range cancer [12-13]. The survival outcomes are associated with some barriers or challenges which include the advancements in the disease load [14]. In this case, the majority of the cases diagnosed comes with high grade diseases where the interventions are no longer possible or effective [15-16]. Primary therapy issue is associated with the restriction to palliative predominantly and androgen deprivation therapy, thus, limiting the long-term survival rate [17]. Further to this, there are systematic delays which involve the treatment initial barriers, financial constraints and the socioeconomic inequities which elevates the poor prognosis due to an elevated PSA result. To achieve the optimal outcome of prostate cancer, high-quality care for curable diseases is required [18]. Basically, in Nigeria, different barriers usually stop the curative treatments of prostate cancer, however, the impact on care and patients' outcomes remain anecdotal [19]. [20] assessed the quality of treatment, survival outcomes and interhospital variation of the metrics among patients having clinically localised prostate cancer in Nigeria. The study was retrospective with patients having clinical stages T1-T3a and M0 prostate cancer in 3 different higher institutions in Nigeria over a 3 year period was carried out. The collected data were socio-demographics, clinical pathological behaviour, quality measures, used image, treatment and survival rate. The main endpoint was the diagnosis time to the first treatment while the secondary endpoint was from the presentations to diagnoses [21-22]. Other metrics for prostate cancer quality, all cause survival and interhospital differences in the metrics. Cox regression was used to describe the treatments, diagnostic qualities as well as other outcomes. The outcome revealed that out of 110 patients having a median age of 67 years, majority of them (61%) had high risk of diseases [23]. 31 days was recorded to be the median period from tertiary hospital presentations to the diagnostics stage. Also, 68 days was established as the median period from diagnoses to the first treatment having radical radiotherapy as 117 days and that of prostatectomy of 104 days. 18% experienced guideline concordant imaging for tumour staging while 61% of the treatment received surveillance and retentions was 42%. In three years, the all cause survival was 41% with significant variation in some quality metrics. Figure 1 depicts the procedures for treatment and management of low, intermediate and high-risk categories of prostate cancer while Figure 2 shows all time survival of

the disease [24-25]

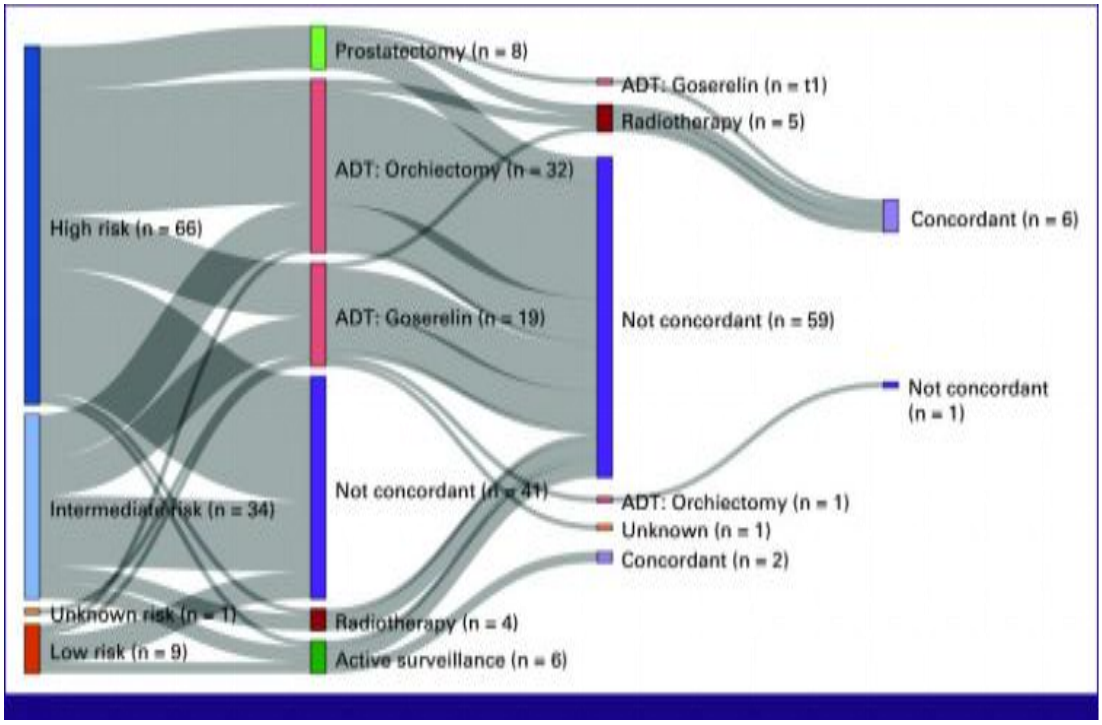


Figure 1: procedures for treatment and management of low , intermediate and high risk categories of prostate cancer [20]

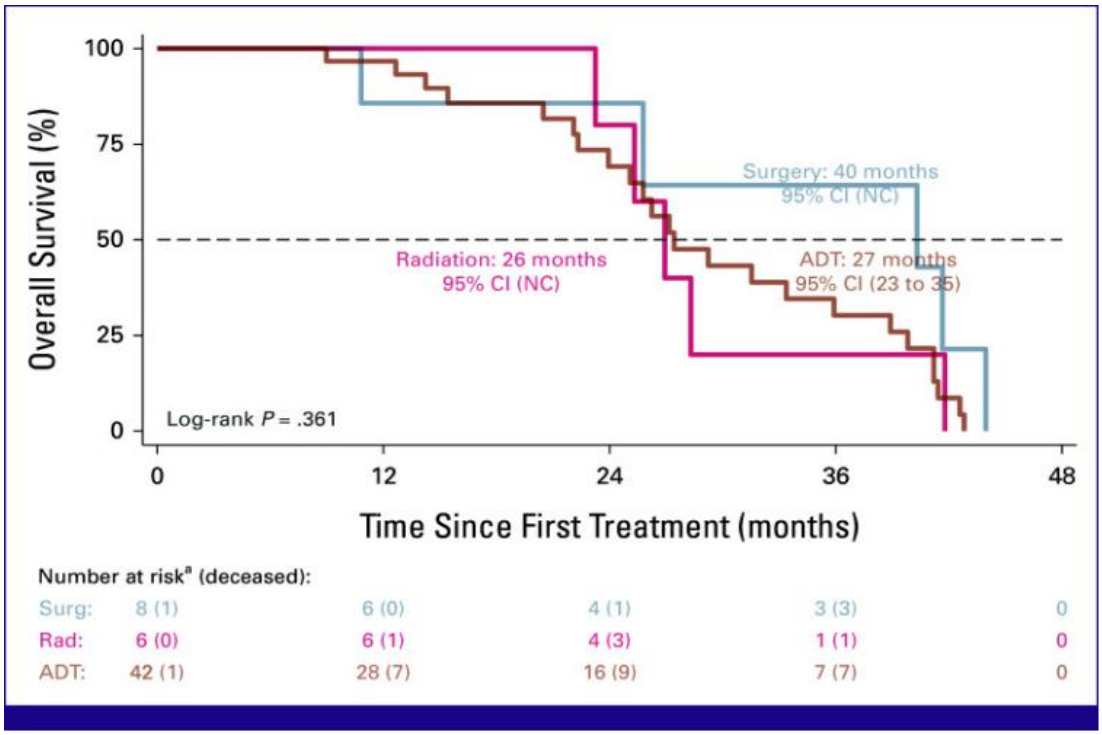


Figure 2: All time survival of prostate cancer [20]

Methodology

The study involves comprehensive research using PubMed, Google Scholar, Scopus using a precise keyword. The studies that were eligible focused on artificial intelligence and machine learning predictions of survival outcome, treatment responses, progression of disease and the stratification of risk at the onset of surgical castrations. Sufficient methodology and clinical homogeneity were considered and all sources cited were equally referenced.

Prediction of Survival Outcomes of Men with Prostate Cancer in Nigerian using Machine Learning

Several studies in Nigeria have deployed machine learning models like Random Forest, Logistics Regression and Support Vector Machine on clinical datasets for the purpose of predicting prostate cancer stages and the survival outcome. These models have established delay in presentation and high prostate specific antigens (PSA) were responsible for the prognosis of in Nigerian men. Increased concentration of PSA heavily connects to advanced stages of the disease, also, increased score of Gleason resulted in aggressive and fast-moving tumours [26]. In addition to this, ages of patients like from 65 years and above usually face increase mortality risk while family history such as genetic linkage increases the late stage odd presentation.

Random forest emerges frequently as the top performing algorithm for structured data within the clinical cohorts in Nigeria. Also, the prediction accuracy of the local framework helps to achieve high sensitivity and AUC-ROC scores, thus, making the identification of patients at risk for stage 3 and stage 4. However, the adaptation of the industry is key as new projects will focus on lightweight data tools compared to expensive MRI infrastructure which rural clinics do not have [27-28]. In a study by Christian and Ejiro [29], despite the advancements in early-stage cancer detection and screening structure present in delta state, there are still issues inadequate knowledge and late stage diagnosis. Based on this, the study deployed 4 different machine learning classifiers such as decision tree, logistic regression, random forest and support vector machines to obtain the records of the patients from 6 healthcare centres in across Delta State. The focus was to identify the clinical risk factors that are associated with developed stage diagnoses and building of predictive structure with the capacity to differentiate early stage from late stage disease. The study focused on the collation of secondary data from sixty cases of confirmed prostate cancer which was diagnosed between January 2015 to December 2023 using the three centres and three hospitals.

Training of the model was carried out using 80% of the dataset while the evaluation was done on the 20% remaining with the aid of accuracy, specificity, sensitivity and AUC-ROC. The outcome revealed that about 68.3% of the cases were either in stages 3 or 4 during diagnoses. The average age at presentation was 64.2 years and three-quarter of the patients experienced PSA levels that was more than 10 ng/m. The strongest predictors of the advanced stage were PSA levels being OR=5.82, Gleason score about 8-10 (OR=4.37), age 65 years (OR=3.14) while the family history (OR=2.41). it was established that random forest performed better than the other three models having about 91.3% accuracy, 89.6% sensitivity, 92.8% specificity while AUC-ROC was 0.94. therefore, machine learning at supervised levels would predict prostate cancer effectively using the collated clinical data. The outcome established that it is possible to have early detection policies and clinical triage within the studied region.

Several efforts have existed in prostate cancer survival outcome using machine learning algorithm. Based on this, [30] investigated some prognostic algorithm related to biochemical free survival, castration resistance survival, complication free survival, metastases free survival and the overall survival. How the outcome of the study could be transmitted into clinical practices were fully discussed.

Figure 3 depicts the various machine learning algorithm deployed into the evaluation of the overall survival outcome.

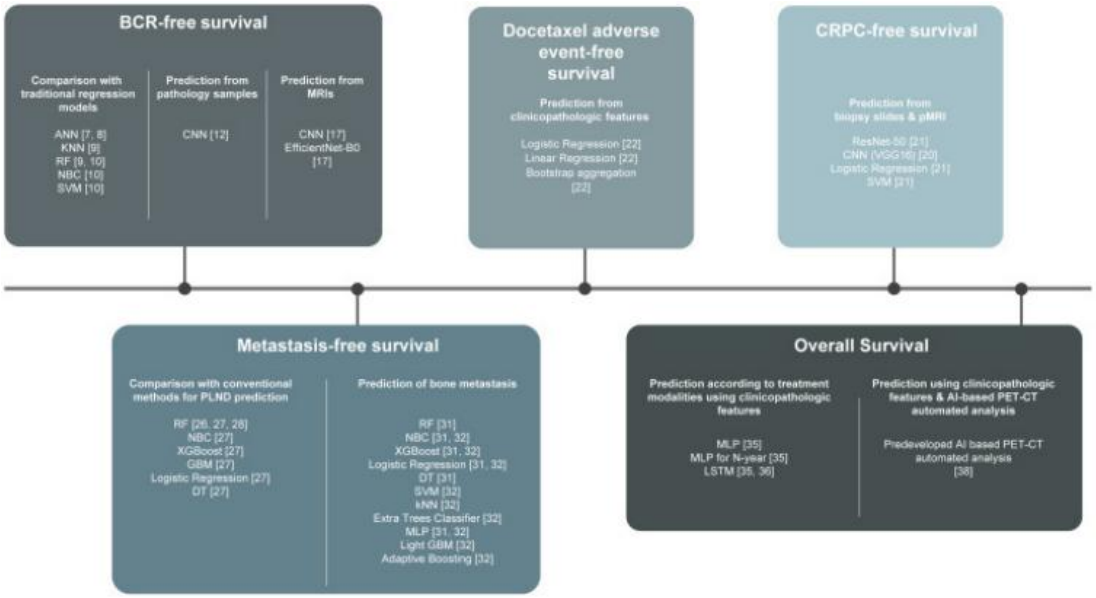


Figure 3: machine learning algorithm deployed into the evaluation of the overall survival outcome [30]

The outcome of the established that prediction of the prostate cancer can be done through various aspect with each having important clinical applications. The coming of artificial intelligence has enabled the development of recent prediction models that are superior to the traditional statistical based method. The advancement in machine learning techniques together with the growth of artificial intelligence-based methods is quite significant in the treatment and survival outcome of prostate cancer, which is linked to the increasing number of studies in that area. When it comes to the survival outcome, artificial intelligence can be deployed in pathology, radiology and electronic health records.

Huo et al. [31] reported that non specific clinical biomarkers have been established to help in the identification of prognostic risks in cancer patients. But, the potentials of prognostics biomarkers for the prediction of survival in patients having metastatic castration resistant prostate cancer still have room for improvement. Thus, the study carried out the prediction of three year metastatic castration resistant prostate cancer survival among patients through the analyses of clinical and demographic characteristics. Out of 664 patients, about 41 clinical and demographic factors were determined. Class weighted XGBoost algorithm was deployed in addressing the imbalance in the class as well as improving the accuracy of the prediction outcome. 0.73 accuracy by the model, AUC of about 0.74 with a recall precision and F1 value of 0.84. this indicates a good potential to differentiate patients who survived less than three years or more than three years. The findings suggested that PSA with other non specific biomarkers are important predictors of survival in metastatic castration resistant prostate cancer patients which can be used successfully in machine learning algorithm to predict metastatic castration resistant prostate cancer patients.

According to a study by [31], machine learning methods having potential to provide close accuracy of survival estimates of afflicted patients having adenocarcinoma which is the most complex case of prostatic cancer. Investigation using ensemble techniques combined to provide predictions of overall survival in terms of the disease. Figure 4 depicts the overall survival prediction of prostate

Adenocarcinoma using ensemble techniques. It was established that out of all the ensemble techniques used in assessing the overall survival predictions, Gradient Boosting technique outperformed the other models. Figure 5 shows the ensemble techniques.

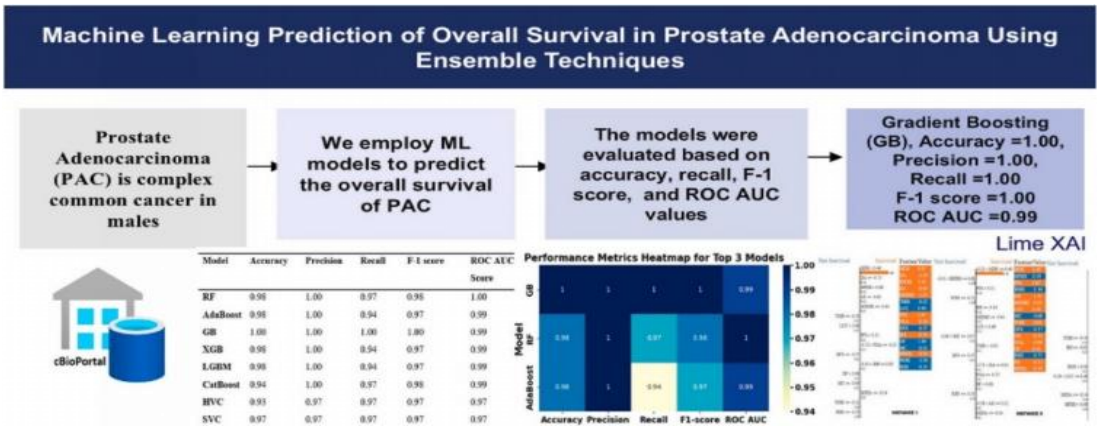


Figure 4: Overall survival prediction of prostate Adenocarcinoma using Ensemble Techniques [32]

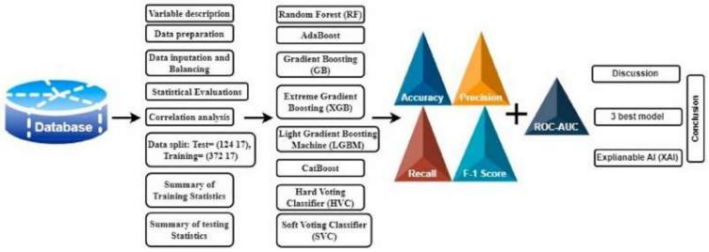


Figure 5: Dataset and Ensemble Techniques [32]

Importantly, early diagnosis could provide a high chance for adequate treatment. Thus, the study is quite significant for prediction of the overall survival rate of patients with prostate cancer. It was mentioned that serious barrier exists for different illness, medical conditions as well as constraints with the traditional diagnostic markers. Thus, the reality of this matter necessitates the use of machine learning techniques. Figure 6 depicts the dataset distribution from the various health institutions.

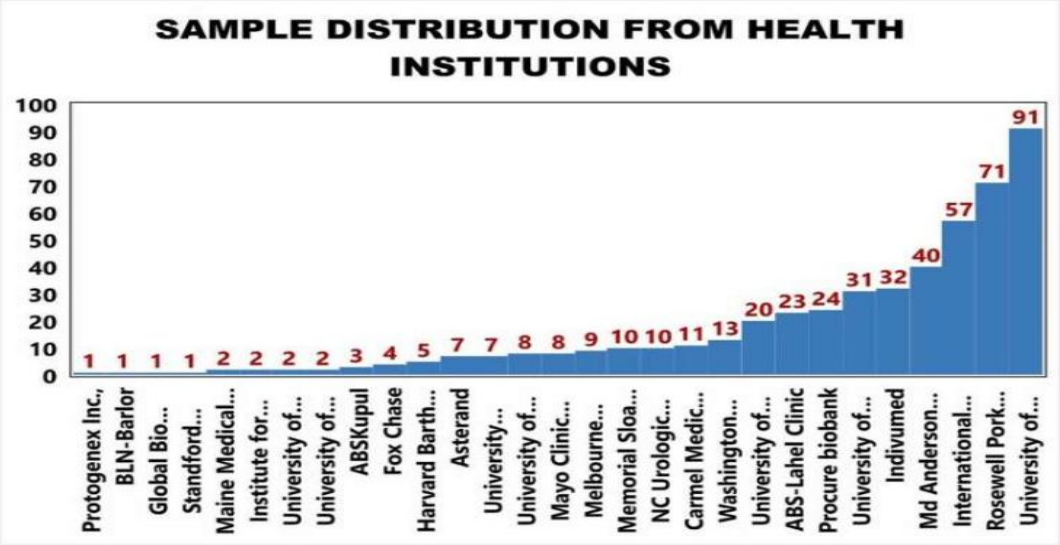


Figure 6: Samples according to health institutions [32]

Predictiction of Treatment Responses and Disease Progression after Surgical castration using Artificial Intelligence

Artificial intelligence usually deploys machine learning and deep learning algorithms for the analyses of patient data, scans and laboratory results. These models have the ability to predict the patient responds to surgical castration as well as how the progression of prostate cancer can be assessed while in the castration resistant stage. According toa a study by Ejaz et al. [33] metastatic castration resistant prostate cancer has been a clinical problem regardless of advancements in therapy. Thus, the study examined the significance of artificial intelligence, deep learning and machine learning in tackling the therapeutic resistances present in the disease. The artificial intelligence techniques dwell on the integration of dataset which comprise of genomics, proteomics and clinical features to reveal the molecular mechanism, predict treatment response as well as identifying biomarker of the resistance. The approach make provision for personalised treatment solutions designed for every individual patient history. However, the heterogeneity of data and that of regulatory concerns remain the barriers that hinders the artificial intelligence translations into the clinical practice. Through the synthesis of the available studies, progress was examined, its limitations and subsequent potentials in tackling the resistance in the disease was studied. Figure 7 depicts the common approach of therapeutic resistance in metastatic castration resistance prostate cancer. Also, artificial intelligence has the capacity to change the environment of this disease treatment through the revolution aspect of the patient care. Figure 8 depicts the different areas of application of this tool in targeting the disease. Its algorithm has the capacity to analyse data such as imaging results, genomic profile, patient data as well as the treatment history to predict the responses of the individual to the various modalities for treatment. The identification of the behaviour of individuals will help the clinicians to create customised treatment plans that optimises the therapeutic benefits as well as reducing the adverse effects.

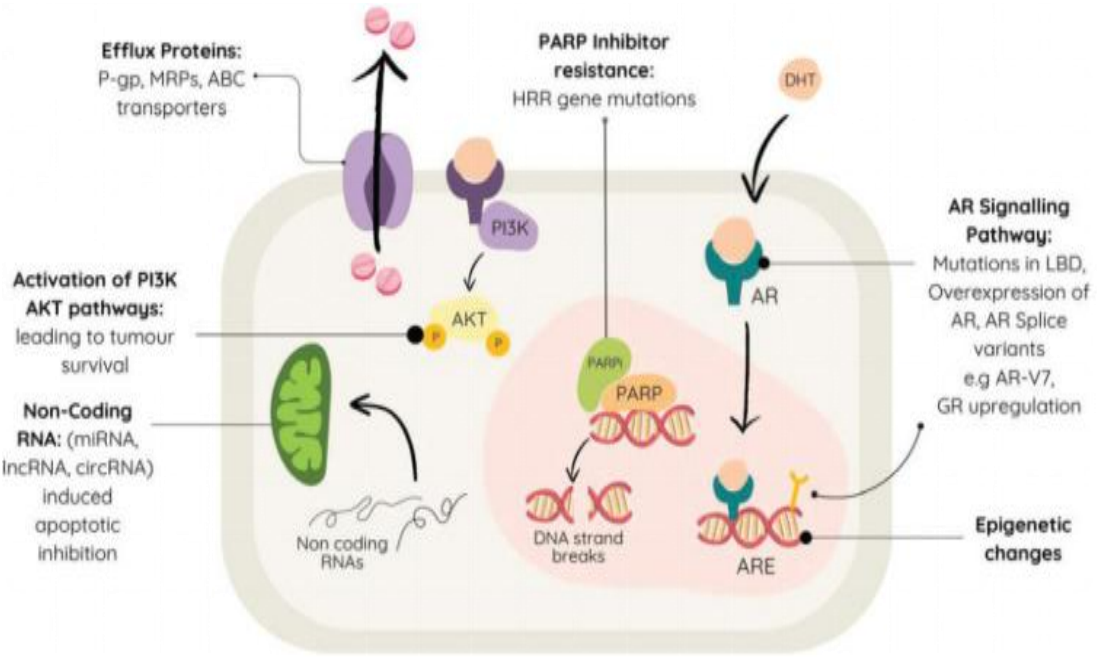


Figure 7: common approach of therapeutic resistance in metastatic castration resistance prostate cancer [33]

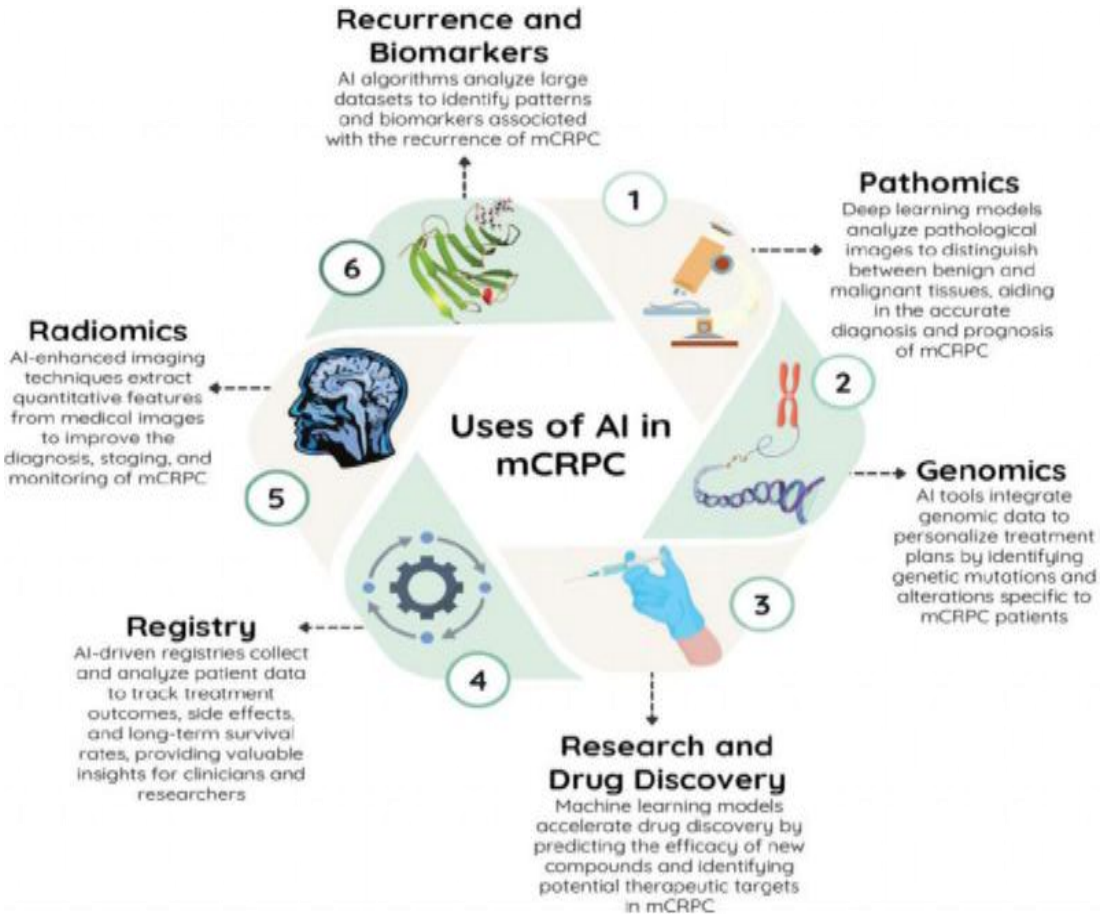


Figure 8: different areas of application of this tool in targeting the disease [33]

The assessment of surgical skill has been done through manual method usually done by human which is a process that are usually affected by the inefficiencies in time as well as the presence of bias. Artificial intelligence has sophisticated solutions this problem. Through the training of dataset such as the surgical videos and the kinematics of the surgical tools, artificial intelligence pioneers a transformative solution to the assessment of surgical skills. Therefore, the integration of the artificial intelligence solutions with metrics that are quantifiable in terms of surgery helps to get a good assessment of surgical ability [34].

It was reported that kinematic metrics obtained from surgical robots of about seventy-eight prostatectomy cases using parameters like length of path, velocity of the instrument to classify the radical prostatectomy. Artificial intelligence improved skill evaluation systems demonstrated the potential to predict accurately the experiences of the surgeon in terms of the level of correlation with postoperative metrics like the period like hospital stay duration and the longer time of recovery with the inclusion of urinary continence [35-36].

Artificial intelligence Risk Stratification models development for the analyses of Prostate Cancer Patients at the onset of Surgical Castration

These types of models help to combine clinical variables, laboratory marker, digital pathology through machine learning algorithms to predict the progression of treatment responses, survival outcome at the

onset of surgical castrations. Predictive factors and models were explored for the progression of prostate cancer bones metastasis to castration-resistance, 286 clinical datasets of patients diagnosed with the disease was used. This was treated initially using endocrine therapy and progresses to the main issue which resulted in data collation. Through adequate comparison of the variation in factors between the groups having fast and slow event of castration resistant prostate cancer, the comparison was carried out using Kaplan-Meier and multivariate regression model [37]. Furthermore, the multivariate risk proportional model was deployed to assess the effect of the candidate factor on the progression time to castration-resistant prostate cancer and deduced a predictive model. The model accuracy was validated using receiver operating characteristic (ROC) curves and decision curve analyses (DCA). Figure 9 depicts the model structure and criteria for evaluation.

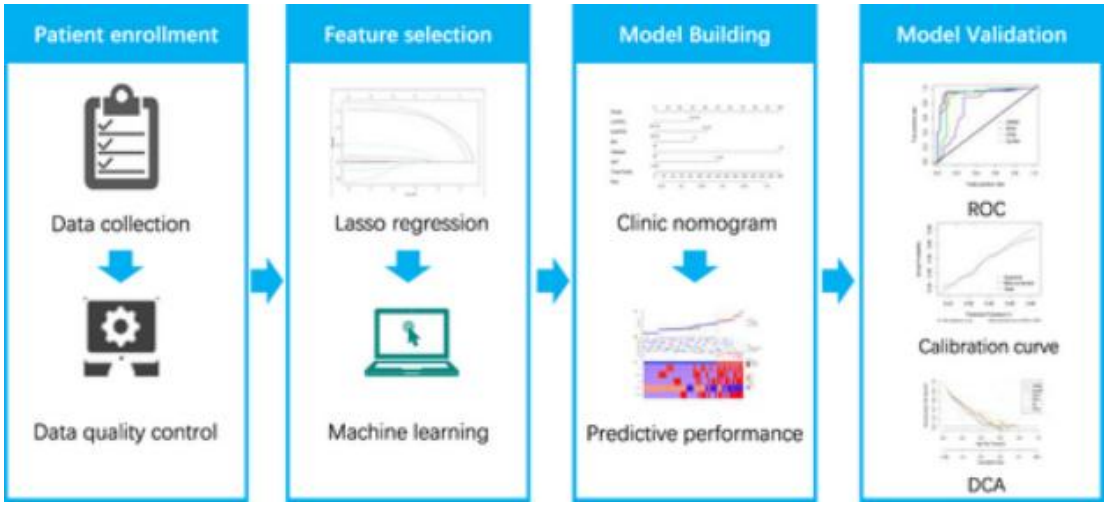


Figure 9: Model structure and criteria for evaluation [37]

Figure 10 (A-B) shows the receiver operating characteristic plots of four different machine learning model where (A) and (B) represents the training set and validation set respectively. In the same vein, Figure 11 shows the machine learning algorithm nomogram, calibration curves as well as the frequency histogram of the prediction.

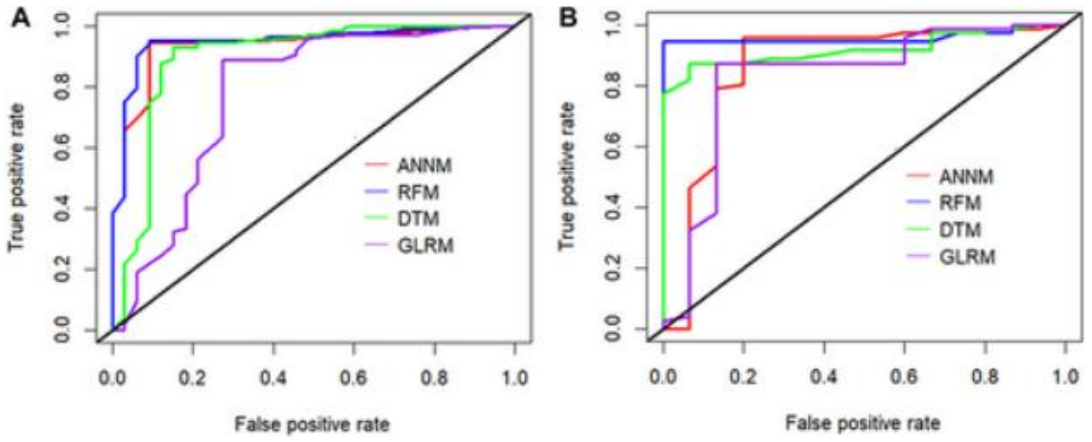


Figure 10: ROC curves of the algorithms [37]

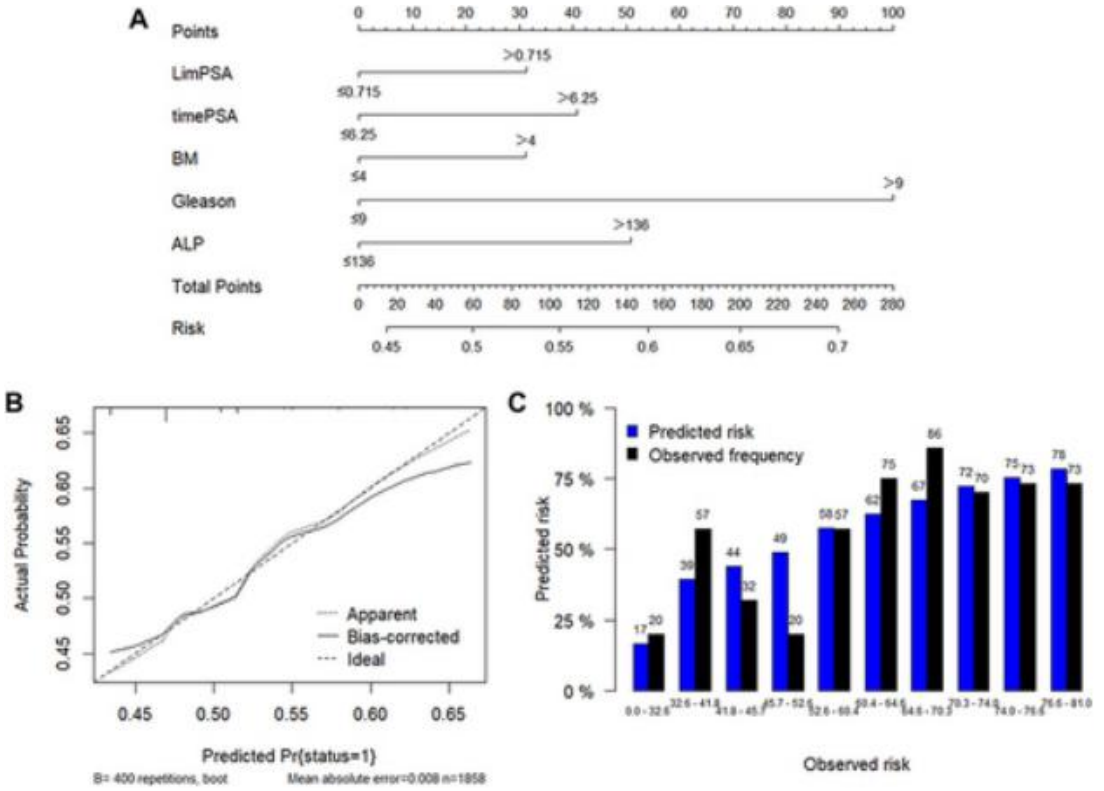


Figure 11: clinic nomogram based on the algorithms of the machine learning [37]

In terms of the validation of the model performance, the prediction model was analysed based on the machine learning algorithm into the decision curve analyses. The outcome revealed performance of RFM was good in both the training and validation dataset as depicted by Figure 12. Also, the visual in the patient risk stratification plots shows that RFM separated the possibility of patients developing the cancer Figure 13. This has a good insight for clinical diagnosis and treatment. From Figure 13, it was observed that the stratification in two categories which were low risk and high risk according to the nomogram obtained from the machine learning with A denoting the risk score, B being survival time and C is the prediction parameter.

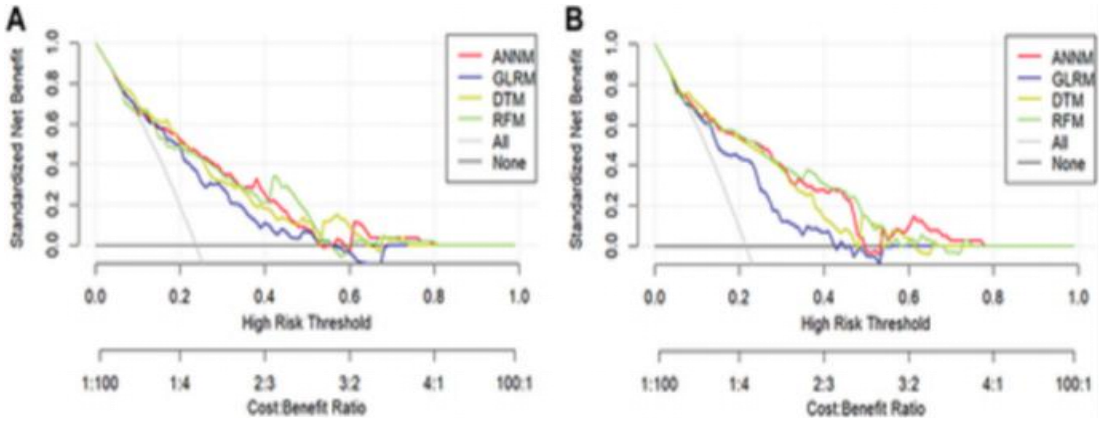


Figure 12: Decision curve analyses of the algorithms [37]

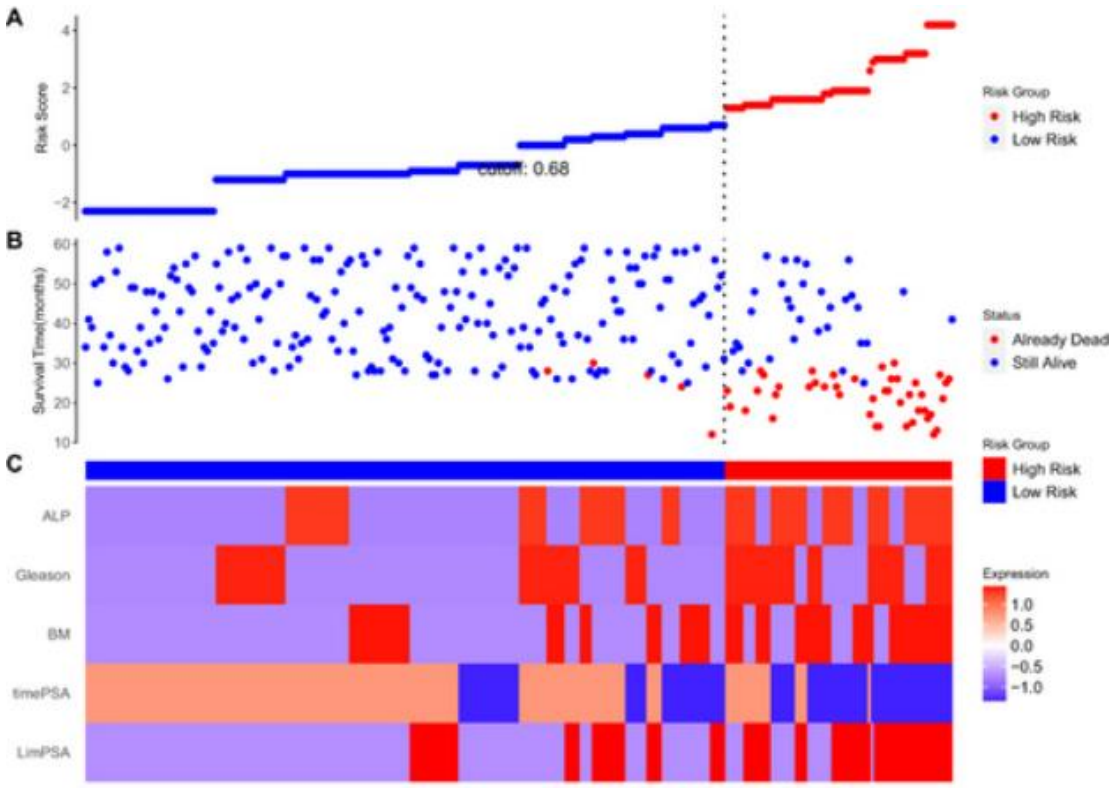


Figure 13: Classification of Prostate cancer patients [37]

Summary of findings

To develop a machine learning algorithm with precision, several techniques must be considered which include; enhancement of the qualities in terms of data preparation, selection of optimal algorithm which will be in compliant with the objectives of the study, optimise the hyperparameter, refine the model architecture, address overfitting and underfitting cases and improvement in the computational capacities. In the application of machine learning based algorithms in real life, it is significant to tackle biases and inequality especially the ones coming from the algorithm trained on heterogenous prostate cancer populations. External confirmation in different countries, ethnicities and medical centres can improve reliability and generalisability of the models which facilitates their inclusions in clinical instructions and the routine practices. Thus, getting this need collaboration with industries like health insurance providers and start-ups coming with innovation, hence supporting the global spread of these advanced tools. The superior performance of gradient boosting implies that it is an ensemble model which have the potential to predict the prostate adenocarcinoma due to its ability to identify all the positive cases, minimise the negative ones as well as its clinical integration. Furthermore, the performance revealed its ability to differentiate positive and negative scenarios for the disease showing high level of accuracy in the prediction of the disease presence. The potentials of artificial intelligence in diverse disciplines shows how the system can change the field in terms of speed and accuracy of diagnoses, helping for adequate intervention to prevent the development of the disease. Artificial intelligence provides potential to discover great agents and predict therapeutic solutions of drugs. It can be used to decide the best therapeutic solutions for the patient and provides different opportunities for the integration of genomic data for personalised treatments. Artificial intelligence potentials goes more

in the direction of the analyses of the surgical footage via vision recognition technology which helps the accurate identification of some surgical manoeuvres like passing of needles, suturing and the knot tying as well as in classifying the expertise of the surgeon. It also has the capacity to analyse the colour and texture given a dataset of twenty surgical videos for the recognition of anatomical structures in the case of pelvic lymph node dissections and uses regression analyses to correlate these features.

Conclusion

In summary, the demonstrates the predictive models for survival outcomes in patients with prostate cancer which helps in the understanding of early warning signals, risk stratification using machine learning algorithms. Also, the variables selected which include the PSA, the number of biomarkers will help to assess the actual risk of progression of metastatic castration resistant prostate cancer in patients, thus, helping to reduce expenses for patients. Interestingly, using the artificial intelligence algorithms like XGBoosting and random forest helps in optimal prediction, risk diagnosis of the disease as well as making the personalised diagnosis and treatment recommendation to improve the prognosis of patients.

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